DOCUMENT RESUME

ED 448 682 IR 020 418

AUTHOR Thomas, David A., Ed.

TITLE M/SET 99: International Conference on Mathematics/Science Education & Technology Proceedings (San Antonio, Texas, March 1-4, 1999).

INSTITUTION Association for the Advancement of Computing in Education, Charlottesville, VA.

ISBN ISBN-1-880094-34-7

PUB DATE 1999-00-00

NOTE 594p.

AVAILABLE FROM Association for the Advancement of Computing in Education (AACE), P.O. Box 2966, Charlottesville, VA 22902; Web site: http://www.aace.org ($35 AACE member; $40 nonmember); CD-ROM format only.

PUB TYPE Collected Works - Proceedings (021)

EDRS PRICE MF03/PC24 Plus Postage.

DESCRIPTORS Computer Uses in Education; Distance Education; *Educational Technology; Elementary Secondary Education; Higher Education; *Information Technology; Internet; *Mathematics Education; *Science Education

IDENTIFIERS Technology Integration; *Technology Utilization

ABSTRACT

The International Conference on Mathematics/Science Education and Technology (M/SET) is an annual conference focusing on current research, theory, issues, classroom applications, developments, and trends related to the use of information technologies in mathematics, science, and computer science education. The M/SET 99 Program Committee accepted 111 papers from 21 nations addressing these topics across a wide range of educational levels and settings. This proceedings is organized in the following sections: Business/Corporate Sessions; Computer Science; General Papers; Invited Speakers; Mathematics; Panels; Poster/Demonstration Abstracts; Roundtable; and Science. Most papers contain references. (MES)

INTERNATIONAL CONFERENCE ON M/SET 99

MATHEMATICS/SCIENCE EDUCATION & TECHNOLOGY

Proceedings of M/SET 99–

March 1-4, 1999

San Antonio, Texas

Editor

David A. Thomas

AACE Association for the Advancement of Computing in Education

published by

Association for the Advancement of Computing in Education (AACE)
P.O. Box 2966
Charlottesville, VA 22902 USA
http://www.aace.org/

Printed in the USA

ISBN 1-880094-34-7

Preface

The International Conference on Mathematics/Science Education and Technology (M/SET 99) is an annual conference focused on current research, theory, issues, classroom applications, developments, and trends related to the use of information technologies in mathematics, science, and computer science education. The M/SET 99 Program Committee accepted 111 papers from 21 nations addressing these topics across a wide range of educational levels and settings. These Proceedings of the International Conference on Mathematics/Science Education and Technology provide a basis for on-going reflection and discussion of M/SET 99 conference themes and issues. The following thoughts are offered as a catalyst for such dialogues.

From primary school to graduate school, information technologies play an increasingly important role in mathematics and science education. The significance of information technologies in professional practice is now recognized by the National Council of Teachers of Mathematics (NCTM) and the National Science Teachers Association (NSTA). The National Council for Accreditation of Teacher Education (NCATE), the National Science Foundation (NSF), and the US Department of Education advocate training in the use of these technologies in teacher education programs. Winning the support of these organizations has not been easy. Information technologies have never been in the mainstream of such organizations. The credibility that we enjoy today has been earned on the basis of years of hard work by researchers, teachers, and technologists unafraid to "go against the flow."

At M/SET 99, information technologies in mathematics and science education are the mainstream. We are the people who have developed, validated, and disseminated many of the most significant advances in mathematics and science education over the last 20 years. Let's take time to meet one another, to learn from one another, to celebrate our common interests and achievements, and to share our dreams for the future.

While high-level policy statements are useful in some contexts, common beliefs about the nature of mathematics and science education often work against a general adoption of information technologies at the local level. Overcoming resistance to the use of information technologies will require more than research findings and policy statements. It will require effective demonstrations at the local level of the power and value of these technologies in the lives of teachers, students and adult learners. As researchers, teachers, technologists, and leaders, we have a stake in the outcomes of those demonstrations. Without our direct involvement, who will represent our interests? Do we really want to leave this to NCTM and NSTA? M/SET and its sponsoring organization, the Association for the Advancement of Computing in Education (AACE), can speak directly to our interests while collaborating with other organizations. We have earned a "place at the table." Let's occupy it and deliver a clear and consistent message.

In the emerging global community, information technologies will transform education, the economy, politics, and popular culture and empower those who have the knowledge and skills to use them productively. Schools, libraries, communities, and universities have been asked to create and support information technology infrastructures and professional development environments that provide

- Teachers access to computer and Internet technologies appropriate to their professional assignments and the training necessary to use these technologies to enhance their teaching and professional development;
- Students access to computer and Internet technologies appropriate to their grade levels, academic needs, and interests and the training to use these technologies to enhance their education and long term career opportunities; and
- Adult learners access to computer and Internet technologies used in the delivery of information services and distance education courses and the training to use these technologies to their enhance life-long-learning and long term career opportunities.

To help lay a foundation for a continuing dialogue, three keynote speakers have been invited to provide perspectives on different aspects of the challenges we all face.

- **Nora Sabelli, National Science Foundation, USA**
  "Education Research on Cognition, Content, Practice, Systemic Change:
  What Constitutes an Appropriate Research Balance?"
- **Robby Robson, Oregon State Univ., USA**
  "Putting Pedagogy On-line"
- **Elliot Soloway, Univ. of Michigan & Cathie Norris, Univ. of North Texas, USA**
  "From NetDay to NextDay: Are We Up to That Challenge?"

In addition to the M/SET 99 keynote speakers, thanks are offered to the Program Committee, listed below, for their service and to all the authors for submitting and presenting their work.

Robert Biddle, Victoria Univ. of Wellington, New Zealand
Lisa Bievenue, NCSA, Univ. of Illinois USA
Francois-Marie Blondel, Institut National de Recherche Pedagogique, France
Ed Dubinsky, JCMST & Georgia State Univ., USA
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Raul Zaritsky, NCSA, Univ. of Illinois, USA

The International Conference on Mathematics/Science Education and Technology (M/SET 99) is sponsored by the *Journal of Computers in Mathematics and Science Teaching* (JCMST), organized by AACE, and hosted by the University of Houston and the University of Texas-San Antonio; March 1-4, 1999, at the San Antonio Convention Center, San Antonio, Texas.

David A. Thomas, Program Chair
International Conference on Mathematics/Science Education & Technology
Dept. of Mathematical Sciences, Montana State Univ., USA
dave@math.montana.edu

Program Chair

David A. Thomas, Montana State Univ., USA

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Janice Woodrow, Univ. of British Columbia, Canada
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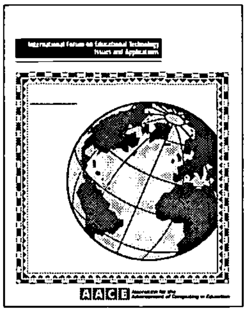
International Forum on Educational Technology Issues & Applications

(ETR) ISSN# 1065-6901



AACE's member journal is the focal point for AACE members to exchange information between disciplines, educational levels, and information technologies. It's purpose is to stimulate the growth of ideas and practical solutions which can contribute toward the improvement of education through information technology. All AACE Professional and Student Members receive *ETR* as a benefit of membership.

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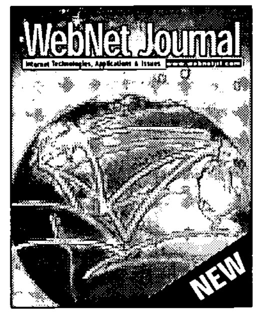
Internet Technologies, Applications & Issues

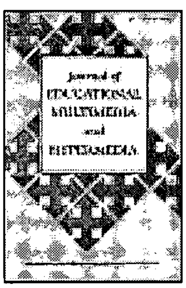
ISSN# 1522-192X *Quarterly*



Focused on WWW, Internet, and Intranet-based technologies, applications, research, and issues, the *WebNet Journal* is intended to be an innovative collaboration between the top academic and corporate laboratory researchers, developers, and end-users. Columnists offer how-to articles and expert commentary on the latest developments.

Journal of Educational Multimedia and Hypermedia

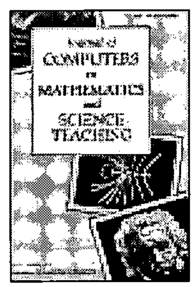
(JEMH) ISSN# 1055-8896 *Quarterly*



Designed to provide a multidisciplinary forum to present and discuss research, development and applications of multimedia and hypermedia in education. The main goal of the *Journal* is to contribute to the advancement of the theory and practice of learning and teaching using these powerful and promising technological tools that allow the integration of images, sound, text, and data.

Journal of Computers in Mathematics & Science Teaching

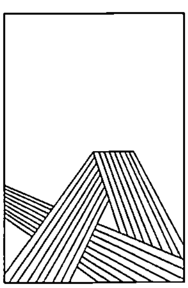
(JCMST) ISSN# 0731-9258 *Quarterly*



JCMST is the only periodical devoted specifically to using information technology in the teaching of mathematics and science. The *Journal* offers an in-depth forum for the interchange of information in the fields of science, mathematics, and computer science.

Journal of Interactive Learning Research

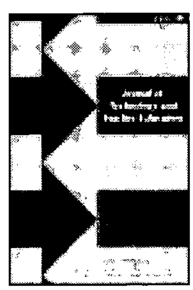
(JILR) ISSN# 1093-023X *Quarterly*



The *Journals'* published papers relate to the underlying theory, design, implementation, effectiveness, and impact on education and training of the following interactive learning environments: authoring systems, CALL, assessment systems, CBT, computer-mediated communications, collaborative learning, distributed learning environments, performance support systems, multimedia systems, simulations and games, intelligent agents on the Internet, intelligent tutoring systems, microworlds, virtual reality based learning systems.

Journal of Technology and Teacher Education

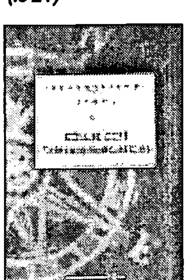
(JTATE) ISSN# 1059-7069 *Quarterly*



A forum for the exchange of knowledge about the use of information technology in teacher education. *Journal* content covers preservice and inservice teacher education, graduate programs in areas such as curriculum and instruction, educational administration, staff development, instructional technology, and educational computing.

International Journal of Educational Telecommunications

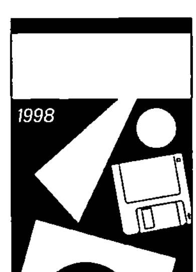
(IJET) ISSN# 1077-9124 *Quarterly*



IJET serves as a forum to facilitate the international exchange of information on the current theory, research, development, and practice of telecommunications in education and training. This journal is designed for researchers, developers, and practitioners in schools, colleges, and universities; administrators, policy decision-makers, professional trainers, adult educators, and other specialists in education, industry, and government.

Information Technology in Childhood Education Annual

(ITCE) ISSN# 1043-1055



A primary information source and forum to report the research on and applications of using information technology in the education of children—early childhood, preschool, and elementary. The annual is a valuable resource for all educators who use computers with children.

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- ❑ *Educational Technology Review (ETR)* **$40**

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BUSINESS / CORPORATE SESSIONS

Multimedia Computer-Based Training in Accelerator Physics

Richard R. Silbar, Andrew A. Browman, William C. Mead, and Robert A. Williams,
WhistleSoft, Inc., 168 Dos Brazos, Los Alamos, NM 87544; e-mail: silbar@whistlesoft.com[1]

Introduction

Four years ago WhistleSoft, Inc., began developing a computer-based multimedia tutorial for charged-particle beam dynamics under a Small Business Innovative Research grant from the U.S. Department of Energy. The DOE chose to support such an activity because of the importance of industrial and medical particle accelerators in the national economy. For example, about 50% of all cancer patients undergo radiotherapy of one sort or another, with the radiation often produced by electron linacs.

We originally designed the *Accelerators and Beams* tutorials for the academic market, and that is presently where most of our sales are. However, we have always had the idea in mind that we could later customize its separate modules for laboratory and/or industrial usage. This would extend the use of these modules to a non-traditional student audience, such as the technicians and operators employed at large accelerator facilities.

We are therefore targeting a broad audience – from lower undergraduates and technicians up to graduate students and professionals in science and engineering. Most of our work so far, however, has been at an elementary level, for end users who have taken, say, an algebra- or calculus-based introductory physics course.

The modules comprising *Accelerators and Beams* integrate interactive On-Screen Laboratories™ with hypertext, line drawings, photographs, two- and three-dimensional animations, progressive disclosure on the screen (at the student's choice of pace), and video and sound. These multimedia techniques enhance the student's rate of learning and length of retention of the material. The modules run essentially equivalently on both Macintosh and Windows platforms.

This paper reports our progress on this ambitious project and gives you a flavor of the look and feel of the presently available and upcoming modules.

Tutorial Content

If one completes all the contemplated modules, the combined content would be roughly equivalent to a one or two hour semester course at a university. An important feature is the ability of the student to choose to work at his or her comfort level with respect to the mathematical detail. We indicate these levels – "Introductory," "Intermediate," and "Advanced" – by a color-coded background. An alternative labeling could just as well be "Technician," "Junior Engineer," and "Physicist."

The presentation therefore ranges accordingly from one that is mostly descriptive with graphics to one, which is mathematical and abstract. The difficulty of the material obviously increases as one gets into the later modules, but one of our goals is to always have something accessible at the introductory level.

Our publisher, Physics Academic Software (see http://www.aip.org/pas), released our first module, *Vectors,* late in 1997. The *Forces* module began shipping in August of this year. *Motion in Electromagnetic Fields* became available for purchase in January 1999. A fourth module, *Dipole Magnets*, has been accepted for publication and will be available later this year. These four modules have all won honorable mentions in the 1996, 1997 and 1998 *Computers in Physics* annual educational software contests. Modules in preparation are *Quadrupoles*, *Matrix Transport*, and *Properties of Particle Beams*.

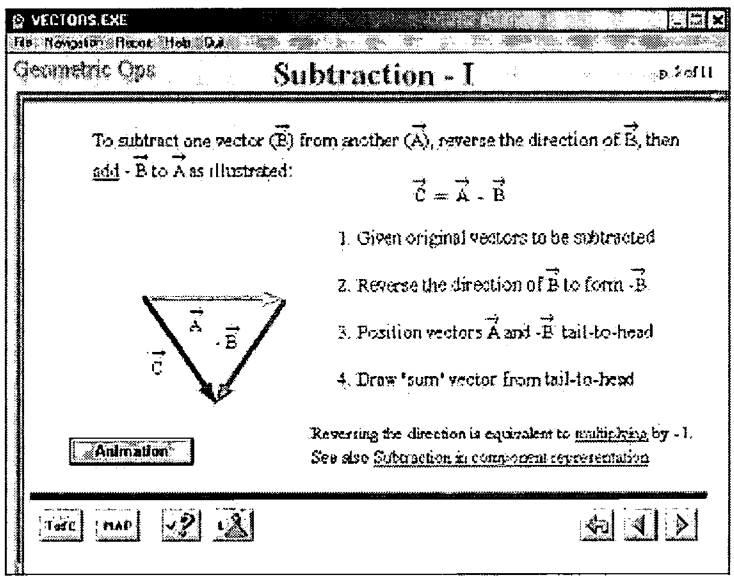
[1] See also our web pages at http://www.whistlesoft.com/~silbar/.

Vectors

This module, which is roughly like a mathematical appendix to our more accelerator-oriented modules, was our "test vehicle" in which we worked out many of the user interface issues that constitute our "Style Guide," which now serves as a template for creating a new module. The content of *Vectors* is divided into five sections:

1. Fundamentals and Definitions
2. Historical Vignettes (Cayley and Gibbs)
3. Examples of Vectors Use in Physics
4. Vector Operations in the Geometrical Representation
5. Vector Operations in the Component Representation

A representative page from Section 4 looks like this:



Note the Animation button, which goes through the steps of how the vector **C** = **B** - **A** is constructed. The buttons at the lower left take the student to a Table of Contents, a Concept Map (from which one can also navigate), a set of multiple-choice self-test Questions, and an On-Screen Laboratory.™ In this laboratory the student is presented two randomly chosen vectors, **A** and **B**. She must then, by dragging, stretching and rotating arrows on the screen representing them, form the difference, **C** = **B** - **A**. For the corresponding page on vector subtraction in Section 5 (Components), its Laboratory invokes an integrated built-in calculator for working out the components of **C** = **B** - **A** from the given **A** and **B** components.

To summarize and to indicate the size of the *Vectors* module, it has 51 Content Pages, 20 self-test Question Pages, 57 Answer Pages, and 14 On-Screen Laboratories.™

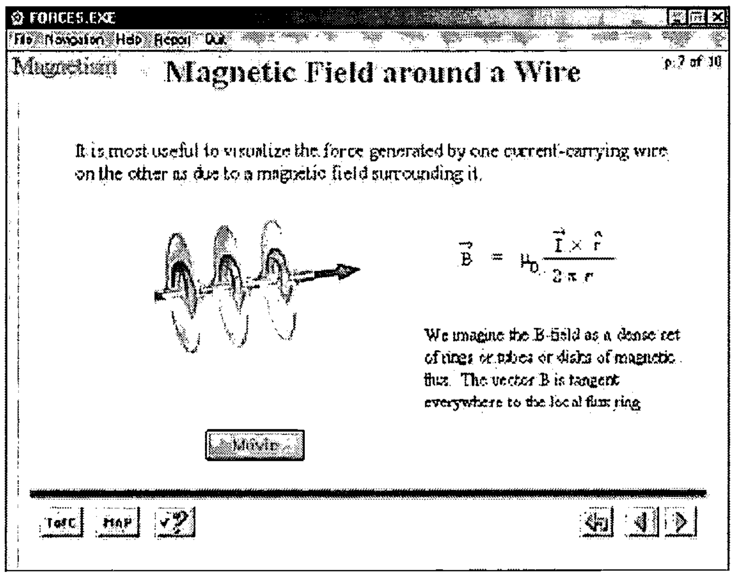
Forces

In this module we review the concepts of forces and motion, with special emphasis on electromagnetism. (This is the fundamental force of importance for accelerator physics.) The sub-topics covered in this module are:

1. Fundamental Quantities
2. History; and a Tour of the Four Fundamental Forces

3. Forces and Motion
4. Electrostatic Forces
5. Electromagnetic Forces

An important feature of this module is the use of three-dimensional animations, since the electromagnetic forces are often hard to visualize in two dimensions. Our animations often involve "moving camera" points of view. Here is a page from Section 5 showing the movie of how the magnetic field builds up as electric charges start moving through the section of wire conductor.



In *Forces* we used sound only sparingly. Buttons click when pressed and there are short sound effects associated with actions on the screen, but there are no narrative sound files. This was partly inspired by a desire to keep this module small enough to be deliverable on floppy diskettes rather than CD-ROMS.

The *Forces* module is somewhat larger than *Vectors*, having 78 Content Pages, 39 Question Pages, 52 Answer Pages, and 3 On-Screen Laboratories.™

Motion In Electromagnetic Fields

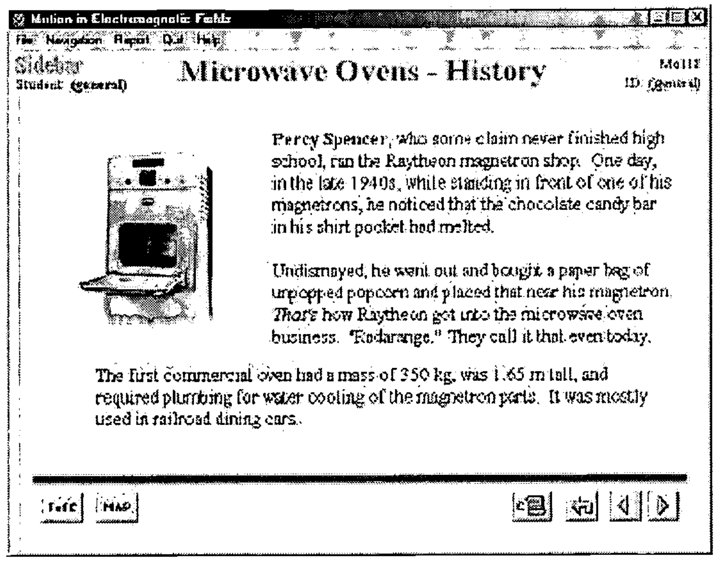
The *Motion in Electromagnetic Fields* module also covers five subtopics:

1. Circular Motion in Uniform Magnetic Fields
2. Magnetic Rigidity; Spectrometers
3. Wien Filter
4. Cyclotron
5. Magnetron

Section 4 on cyclotrons uses three-dimensional "exploded" drawings, animations, and video clips of a modern medical cyclotron. There are also some intermediate level pages that go into the relativistic limitations on the classical cyclotron and ways physicists have learned to work around those limitations.

The magnetron, Section 5, is a complicated crossed-field device, but we were able to get the idea of its operation across in surprisingly elementary terms. Some of the simulations in this section integrate the differential equation of motion for the electrons in the crossed fields, drawing the complicated electron orbits

"in real time." Intermediate-level pages cover the derivation of the equation of motion and its numerical solution. Here is a page giving an amusing historical sidelight on microwave ovens (which are powered, of course, by magnetrons.



We like including such historical vignettes in our tutorials, and feedback from our student testers indicates that they do also.

The *Motion* module has 63 Content Pages, 17 Question Pages, 23 Answer Pages, and 6 On-Screen Laboratories.™ Motion will be distributed on a hybrid CD-ROM.

Dipole Magnets

This module on bending magnets (which also have focusing properties) covers the following topics:

1. Uniform bending magnets
2. Non-uniform bends
3. Fringe fields
4. The Kerst-Serber equation.

The fourth section, unlike the first three, is at an intermediate level, requiring some calculus and knowledge of Maxwell's equations. By the time the student has finished this module, he or she will understand the operation of the double-focusing spectrometer, even the peculiar bend angle of $\pi\sqrt{2}$ radians. The page on the double-focusing spectrometer uses a 2D animation, with the motion of the charged particle moving through the spectrometer being shown simultaneously in side and head-on views:

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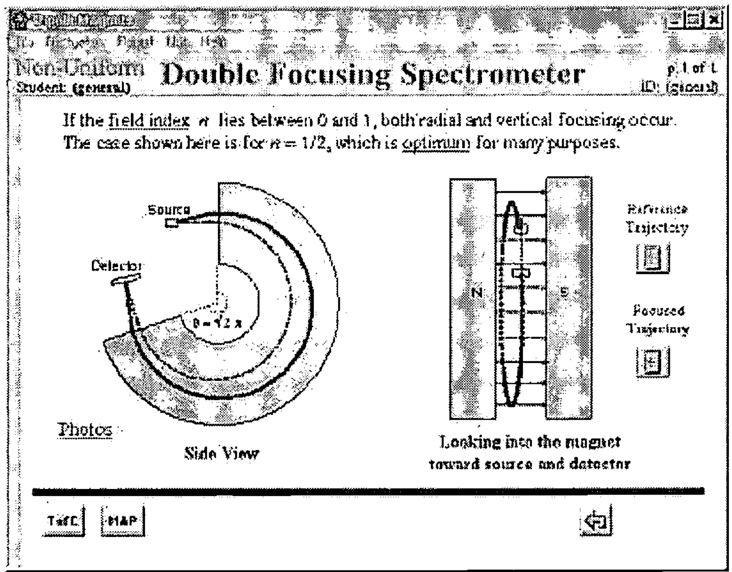
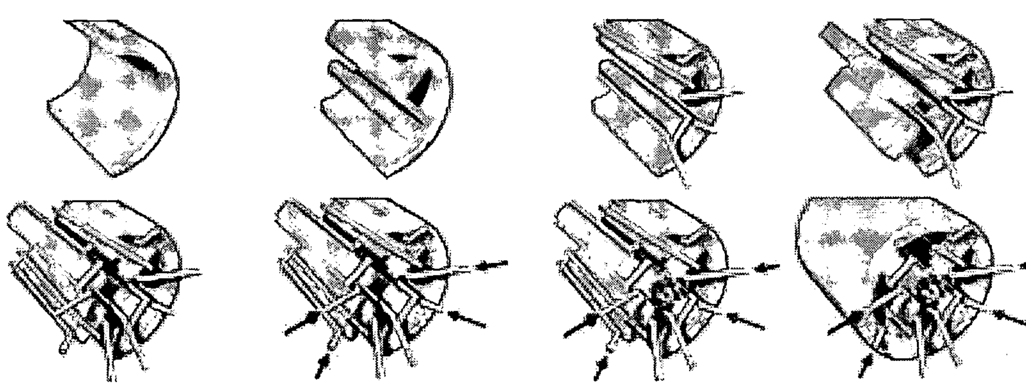


First, note that the color of the background bars has changed from blue to beige. This indicates a topic at an intermediate level. (Topics at an advanced level – of which we have very few (so far) – have rose-colored background bars.) The screen snap shown here is what the student sees after having first pressed the Reference Trajectory movie icon, then the Focused Trajectory icon. The particle paths are traced out from Source to Target in about a second. This, like all of our animations, can be repeated as often as the student wishes.

Dipole Magnets consists of 40 Content Pages, 16 Question Pages, 25 Answer Pages, and 2 Laboratory Pages.

Modules in Development

We expect to complete, by the end of this project next June, several other modules. Prototypes for these already exist. Our next module will be entitled *Quadrupoles*, which are the magnetic elements most used for focusing charged-particle beams. The following picture is a montage of 3D drawings showing how one builds up and activates a quadrupole magnet.



In the tutorial itself these will form a series of eight pages, together with commentary about what the pieces are and how they operate. This module will also cover aspects of higher-multipole magnets.

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Another module in progress is on *Matrix Transport* through magnetic elements. An alternative title might be *Particle Trajectories*. This module will integrate much of the student's experiences with the Dipoles and Quadrupoles modules, so that he or she will come to an understanding of how beam line systems or accelerator sections work.

A third module in progress, *Properties of Particle Beams*, goes into the definition of beam size, phase space, beam envelopes, and space charge effects. It has the most advanced materials of the modules that we have built so far. One unique feature about the *Beams* module is that we have made extensive use of sound for narrations accompanying the content pages. We have also implemented it with jump-outs to (and returns from) a Glossary of beam dynamics terms.

Lessons Learned

We began this project as scientists knowing something about beam optics and accelerators but rather little about multimedia techniques. At first we felt somewhat cramped by the small amount of "real estate" on the screen; we were basically trying to write a textbook to be read on a screen, which we soon learned was not such a great idea. It took us some time to realize that the computer should be used for the things that the computer does better than other media. In the process, however, we were also pleasantly surprised to find that we could find ways of presenting in simple terms what we thought were complicated concepts.

In this regard, we feel that the two-and three-dimensional animations we have learned to make are especially useful for computer-based training in a technical subject like accelerator physics. That was not one of the things we anticipated when we began this project.

Acknowledgments

Colleagues also involved in the development of these *Accelerators and Beams* modules are, or have been, Charles Brownrigg, Richard Cooper, Matthew Goldman, Kris Kern, Cathy Malloy, and Patrick McGee. We authored the tutorial prototypes and modules discussed in this paper using Macromedia's Authorware software package. Graphical content was prepared using software such as Macromedia's Extreme 3D and FreeHand, Adobe's Photoshop and Premiere, and Hyperionics' HyperSnap.

The WhistleSoft development team has had the benefit of many useful suggestions from a large number (over 100) of user testers and reviewers of our prototype modules. We also thank Prof. John S. Risley, editor of Physics Academic Software, for his advice and criticism of our software modules. The Department of Energy's Division of High Energy and Nuclear Physics has supported this project under its SBIR program.

COMPUTER SCIENCE PAPERS

The Technology that Computer Science Education Overlooked

Shriram Krishnamurthi Matthias Felleisen Kathi Fisler
Department of Computer Science
Rice University
Houston, TX, USA
Contact: shriram@cs.rice.edu

Abstract: Computer science educators have overlooked a significant and influential technology that can be harnessed to teach their subject. This is the combination of the programming language and programming environment. They use languages whose properties befuddle students, and environments which hinder students due to their complexity. Rice University's TeachScheme! Project instead uses the programming language Scheme, and the programming environment DrScheme, which circumvent these problems. As a result, students learn the principles of programming better and sooner; they elevate their understanding of algebra; and they learn how to apply programming to disciplines other than computer science.

1 Introduction: Technologies in Computer Science Education

A technology exploits scientific or technical knowledge to solve problems in a particular domain. One particularly interesting domain is computer science education, where the potential for technological aid is immense. Many computer science educators are particularly interested in designing curricula suitable for introductory computer science students. These curricula are important since they form a student's first impression of the field, which often determines whether or not the student will remain in the discipline. The debates in this area typically focus on the questions of what curricular material to cover and which programming languages to use. They typically do not discuss technology since the issues are viewed as outside the usual realm of technology.

In this proposal, we posit that one of the most important technologies employed in computer science education is the choice of programming language and programming environment. We will first explain why this combination of topics constitutes an important technology, then present our ideal choice of technology in this area, and finally discuss how our preferred combination clarifies the connection between computer science and other disciplines.

2 Programming Languages and Environments Are Technologies

The principal problem in introductory computer science education is the *teaching of the principles of computation*. A technology in this domain would help students attack this problem in an effective and efficient manner.

Though computation is independent of programming, the most widely-used and the most effective method to teach it is through programming. Clearly, teaching programming requires a programming language. A language would be useless, however, if students could not write and evaluate programs. Hence, it also requires a programming environment. The features of a programming environment, however, depend heavily on the characteristics

of the language it supports; therefore, the two must be considered in unison. The resulting combination is an application of computer science knowledge to create a tool that addresses the above needs, ie, a technology.

This technology is especially important for several reasons.

1. It is one of the first technologies that students encounter in the field; thus, it dictates their perception of the area and often convinces them to pursue the field or to drop it altogether.

2. It dictates how much material students cover and how much of the principles they assimilate, thereby having a notable trickle-down effect in subsequent classes.

3. It governs the set of problems that classes can cover, thereby determining a course's ability to show the relationship between computer science and other disciplines.

3 The Present and the Future

3.1 The State of Affairs

Many schools and colleges currently use the C++ language (Stroustrup 1991) in their introductory programming course, and use one of the many textual or graphical compilers and programming environments available for C++. Unfortunately, C++ is a poor choice of introductory language for several, now widely-acknowledged reasons. The most important ones are:

1. *The language is unsafe.* This means erroneous programs do not halt with an error, but instead continue computing with incorrect (and often *meaningless*) data. As a result, even when a program terminates, its output may be wholly meaningless—and there is no way for the programmer to know whether or not it is.

2. *The language is not portable.* Students cannot write programs on one machine and expect it to behave identically on another. This problem arises, for example, when students wish to solve homework exercises or practice their skills at home on hardware that differs from that at school. The problem is amplified when teachers want to provide students with code libraries (especially graphical ones) to make problems more interesting, since they must implement the libraries on all the platforms that the students use.

3. *The language does not support automatic memory management.* Managing allocated memory by hand is both difficult and error-prone. In addition, it introduces numerous extraneous details that have nothing to do with the principles of computation. For this reason, many other languages manage memory automatically for the programmer, but C++ does not.

In short, C++ is unsuitable for a modern introductory curriculum in computer science.

Furthermore, the existing environments for C++ are ill-suited for beginning programmers. They are designed for professional programmers, who typically use many of the advanced features of the language. Consequently, the environments inadvertently expose students to the whole language from the very first day. The problem usually manifests itself when students make minor notational mistakes. The compiler often attempts to parse a faulty phrase as an advanced language construct, producing incomprehensible and utterly frustrating error messages. Unfortunately, such environments therefore subject students to the highly subtle interaction of the various subsets of C++.

Consider the following example. The program fragment in (Fig. 1) defines three variables, representing the bounds and iteration variable for a loop. Unfortunately, the student has used the (extremely reasonable) variable name `new`. In C++, `new` is a keyword which is used to create instances of objects, which the student is not likely to encounter for another semester. Yet, because the programming environment exposes the student to the entire

```
...
int old, new, i;

scanf ("%d %d", &old, &new);
for (i = old; i <= new; i++)
  printf ("%d\n", i);
```

Figure 1: C/C++ Program Fragment

```
example.cc: In function 'int main()':
example.cc:5: parse error before 'new'
example.cc:7: parse error before ')'
example.cc:8: 'i' undeclared (first use this function)
example.cc:8: (Each undeclared identifier is reported only once
example.cc:8: for each function it appears in.)
example.cc:8: parse error before ';'
```

Figure 2: Error Message from C/C++ Compiler

language, this program generates the error shown in (Fig. 2), which is indecipherable gibberish to the beginning student.

The net result of these problems is that many students leave the discipline because they perceive programming as a battle against an arbitrary and hostile machine; they may never experience it as the creative activity that it is. These problems may especially affect women, who, studies have shown, often prefer constructive activity to the sort of tinkering that characterizes programming in languages like C++ (Mark 1992).

3.2 The State of the Art

Rice University's TeachScheme! Project (Felleisen et al. 1998) has developed a superior technological solution for high school and introductory college courses:

1. The Project uses the programming language Scheme (Abelson & Sussman 1985), which has been successfully used by several other programs. The use of Scheme solves the problems listed for C++ above.

2. Project members have developed DrScheme (Findler et al. 1997), a programming environment that is specially designed with the pedagogic needs of beginners in mind.

In the remainder of this section, we will describe these components in greater detail, and explain how they address the problems described above.

3.2.1 The Scheme Programming Language

The core of Scheme has a simple syntax that can be mastered by a beginner in a day. More importantly, students can learn the language as a simple, natural extension of high school algebra. As a result, students start writing programs on their very first day, and within a few weeks can write more sophisticated programs than they do after two semesters of C++. They can do this because they concentrate on the essence of the problems, instead of managing the details of the underlying hardware.

Scheme checks every operation to make sure the data are sensible and, when they are not, it halts immediately with an error. This is especially important for students, who must receive immediate and meaningful feedback on whether or not their programs are functioning correctly. Scheme also manages administrative tasks such as memory management, so that students can concentrate on solving the problem at hand and ignore extraneous details.

3.2.2 The DrScheme Programming Environment

DrScheme is a modern, pedagogically-motivated programming environment for Scheme. Its salient features are:

1. Like a calculator, DrScheme is *interactive*, except that DrScheme implements the entire Scheme programming language, whereas calculators provide just arithmetic or graphing functions. Thus students can type expressions and immediately see the results of evaluation. This makes it easy to test all the pieces of a program before combining these pieces to build larger programs.

2. When a program contains an error, DrScheme immediately halts execution and highlights the source fragment that generated the error, unlike C++, where students must employ a special-purpose tool, the debugger, to re-construct this information by hand in a painstakingly cumbersome fashion.

3. DrScheme presents the Scheme language as a sequence of increasingly complex layers. These layers correspond to the natural sequence of language concepts as they are presented in Scheme courses world-wide. Thus beginners get detailed error messages and do not have to confront errors from portions of the language they have not yet covered, while advanced programmers still get all the power of the language.

4. DrScheme is completely graphical, and its programs run without change on all platforms (Windows, Macintosh and Unix). Thus teachers can create graphical libraries for students even if they use two different platforms.

The powerful combination of Scheme and DrScheme makes it easy for students to study real-world contexts with little effort. For instance, they can write programs that implement the laws of physics (and study the consequences of changing them). They can build symbolic models that mimic voter behavior. Or they can study concepts from pure mathematics—because the core of Scheme is truly mathematical. Finally, students can study computing concepts such as Web browsers, compilers and machine architectures, with very little work beyond that necessary to describe the simulated world. Most of these ideas are inaccessible in the first year of C++ because the language and environment make it difficult to write the code that supports these models—that is, because the underlying technology is outdated.

4 The TeachScheme! Curriculum

The TeachScheme! Project is at the forefront of a quiet revolution that is sweeping computer science curricula. It harnesses both Scheme and DrScheme to provide a novel high school curriculum that is being adopted by progressive schools around the country. In contrast to traditional computer science curricula, which at best prepare students for a career in computer science, the Rice curriculum has two advantages.

1. Students develop sufficient skills to apply programming in a wide variety of disciplines, including the physical and social sciences. Thus they are prepared to harness computation as a tool in their professional careers no matter what career they choose.

2. Due to the intimate (but implicit) connection between Scheme and algebra, students are building and reinforcing their algebraic skills while writing programs, even when the programs deal with material that falls

outside traditional algebra textbooks, such as Web sites and computer games. Studies have found a strong correlation between algebra and the likelihood of success in professional disciplines, so furthering these skills is important for students' professional advancement, no matter what they end up pursuing.

The TeachScheme! Project offers various materials, including lecture notes, software, teacher's guides, exercises, and solution sets, that smoothly integrate Scheme and the programming environment. The Project also conducts a summer workshop for teachers who want to learn more about the curriculum and implement it in their classes. The Project welcomes high school teachers who teach one or more of computer science, mathematics and the physical sciences. All material and resources published by the Project, including the summer workshop, are distributed *free of cost*. Financial support is available for both attendance and implementation. Additional details are available from the Project's Web site (Felleisen et al. 1998).

5 Conclusion

Computer science education has traditionally failed to consider a key technology: the programming language and its environment. As we have argued, however, choosing a good combination has strong effects on the curriculum and on students' acceptance of the field. The decision has impact throughout the curriculum. Rice University's TeachScheme! Project offers a modern solution that prepares students for a contemporary computer science education.

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Project *FOCAL* Point: Attracting Females to the Computing Sciences

Sandra Madison, Ph.D., Associate Professor
Department of Mathematics and Computing
University of Wisconsin-Stevens Point
Stevens Point, WI 54481 USA
email: smadison@uwsp.edu

Min Deng, Ph.D., Associate Professor
Department of Mathematics and Computing
University of Wisconsin-Stevens Point
Stevens Point, WI 54481 USA
email: mdeng@uwsp.edu

Abstract: Project *FOCAL* Point is a multi-strand project designed to increase female participation in the computing sciences. The project targets two crucial groups: high school computing teachers and female high school students. Features include a two-week teacher workshop, a one-week Computer Camp for Young Women, mini-grant projects and a follow-up conference for teacher participants, and listservs for both teacher and student participants. This paper focuses on the high school student participant responses and reactions to the one-week computer camp during the project's inaugural (pilot) event.

Introduction

Few people doubt that technological skills will become increasingly important as our country enters the 21st century. Specifically, the demand for qualified computing professionals already exceeds the supply and is expected to double in the next decade. In view of the high percentage of Caucasian males currently employed in the field and continued national concern with affirmative action, businesses continue to seek out qualified women and people of color. However, despite acknowledged career opportunities and known financial advantages, these groups continue to be under-represented in the professional work force and in technology-related majors (Frenkel, 1990; Scragg & Smith, 1998). Concerned educators must question the reasons for the continued imbalance and search out avenues for addressing the equity problem.

Women who persist in computing are just as successful as men. However, women who are just as competent as ultimately successful men become discouraged and leave. Authors pose various reasons for women's migration from computing and other sciences. Consistent with Bandura's (1986, 1988) social cognitive theory, studies have, for example, found that feelings of comfort and self-efficacy—rather than achievement—are important factors influencing the decision to enroll in a computing course and to continue in the discipline. Spertus's (1991) report on the staggering cultural biases facing women who choose to pursue computing careers suggests another reason. Other authors suggest that girls grow up viewing computing as a male-oriented activity and that women feel isolated in classes populated almost exclusively by men. Still another theme recurs persistently: the notion that women are uncomfortable in the competitive atmosphere that permeates most [computer] science classrooms. From childhood, they have been raised to value cooperation and collaboration. The literature is consistent. Women are more comfortable working in collaborative than competitive environments, they are more successful and more persistent when they are comfortable, and they tend to develop comfort through positive experiences (Beyer, 1990; Frenkel, 1990; Howell, 1993). What is needed then are means to increase female self-confidence, success, and feelings of comfort with computing experiences. Project FOCAL Point seeks to provide high school girls with such experiences during a one-week Computer Camp for Young Women.

Project *FOCAL* Point: Implementation

The overarching goal of Project *FOCAL* Point is to increase female participation in the computing sciences. Specific objectives as related to the student participants are to:

- Introduce young women to computing in a collaborative, supported, evaluative-free environment.
- Provide female high school students with career information and role models.

The objectives are largely addressed through a one-week computer camp for young women. The 19 campers who attended the inaugural session lived together in double rooms in a residence hall on campus. They shared meals, classes, and recreational activities.

Afternoon activities included two panels of female computing professionals who spoke about their careers. Panelists included several women who worked for insurance companies, a systems analyst who worked in the medical field, the university postmaster, and a help desk manager. Two guest speakers introduced the campers to historical and contemporary women in science, mathematics, and technology. A fieldtrip to a nearby water park was designed not only to be fun, but also to help forge a sense of community among the campers. A fieldtrip to a nearby insurance company included a tour of the computer room and introduced the campers to the culture of a large Information Systems department.

Evening activities included movies, swimming, basketball, tennis, a planetarium show, a banquet at one of the finer area restaurants, and ample free computer time. An optional C++ course taught by the project director was added to the evening agenda at the request of the campers.

Seven high school teachers--who had received training in gender issues, computer and information systems concepts, and computer and network applications—taught the morning lessons. Each teacher mentored a group of three or four girls, providing ample opportunity for individual attention. Lessons included an introduction to the university network, electronic mail, Internet use, and web-page development. One group, led by a technology education teacher, learned to use AutoCAD.

At first glance, instruction in these topics may seem unnecessary. It is easy to assume that everyone uses e-mail and "surfs the net." Experience has shown this assumption not to be the case. Each semester we encounter computing students—including advanced computing students—who have not yet ventured into cyberspace. Moreover, the college students regularly volunteer that they would not do so if they were not required to do so. The literature offers that women are more likely than men to do only what is required of them in class (Linn & Hyde, 1989), to feel less efficacious with computers (Bernstein, 1991), and are more likely to feel alienated by a culture they view as impersonal, unfriendly, and withdrawn (Spertus, 1991; Turkle & Papert, 1990). The instruction was designed to expand the campers' computer comfort zone and to help them identify more positively with the computer culture. The remainder of the paper elaborates on the evaluation of the inaugural session of the computer camp.

Evaluation Study

The evaluation study attempted to answer the questions:

- What changes in computer attitudes did campers report as a result of their participation in Project *FOCAL* Point's one-week computer camp?
- What changes in computer skills did campers report as a result of their participation in Project *FOCAL* Point's one-week computer camp?

The participants were 19 junior and senior high school girls. All girls applied to participate in the project. Since response to the call for participation was nominal, all applicants were accepted. All lived within two hundred miles of the university. There were no fees associated with the project. As reported on their applications, some had extensive computer experience while others had minimal experience. The campers and their parents signed informed consent documents before any data were collected.

The Computer Attitude Scale (CAS) was used to measure computer attitudes. The 40-item CAS has been shown to be valid and reliable (Loyd & Gressard, 1984; Loyd & Loyd, 1985). The CAS is composed of four 10-question sub-scales designed to measure computer anxiety, confidence, liking, and perception of usefulness. Items on the CAS with negative wording were re-recorded so that for all items, a higher item score indicates a more favorable attitude. The campers completed the CAS on the first day of their project participation to use as a pre-test measure and again on the last day of the summer program. (The second questionnaire serves as an interim post-test measure. It will be completed again after one year and at the project's conclusion.) The results are shown in Figure 1.

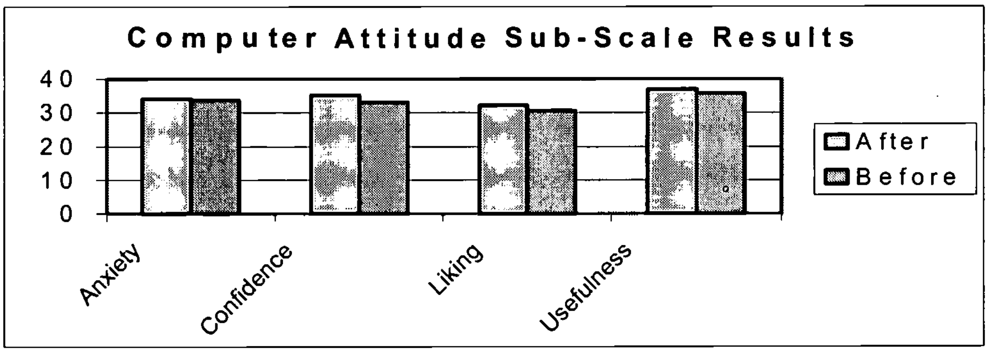

Figure 1. Computer Attitude Scale (CAS) Results

We did not expect to see dramatic changes after one week; however we did expect that scores would not decrease. That expectation proved true. The means for all sub-scales increased slightly. As each sub-scale is composed of 10 questions that can be scored from 1 to 4, each sub-scale could have a mean ranging from a low of 10 to a high of 40. The high pre-test means (all above 30) make it difficult to detect large changes. The pattern might well change with a different, less experienced cohort.

Scatter plots of the four sub-scales show individual responses. Circles above the reference line indicate a more positive post-test response while circles on the line indicate no change, and circles below the line indicate a less positive post-test response. The scatter plots confirm the results shown in the earlier bar graph--no dramatic changes and a possible ceiling effect (shown by the clustering of circles near the high end of the scale). However, the positive changes in those whose scores were initially low is particularly encouraging.

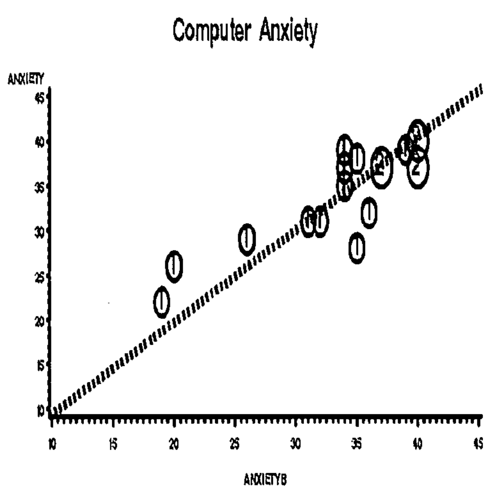

Figure 2. Computer Anxiety

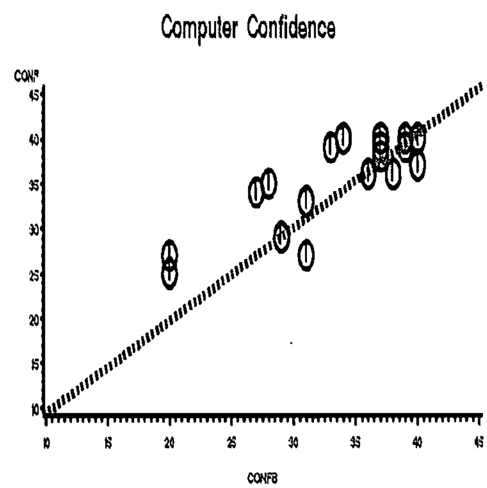

Figure 3. Computer Confidence

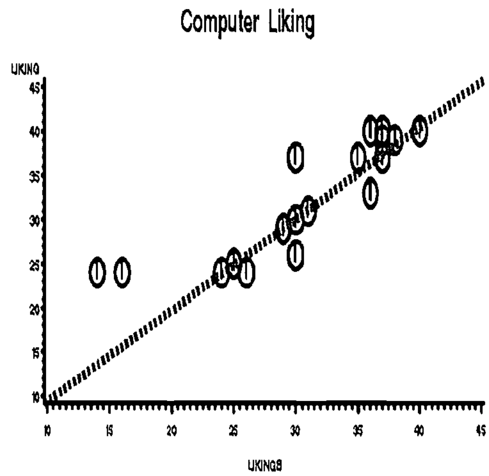

Figure 4. Computer Liking

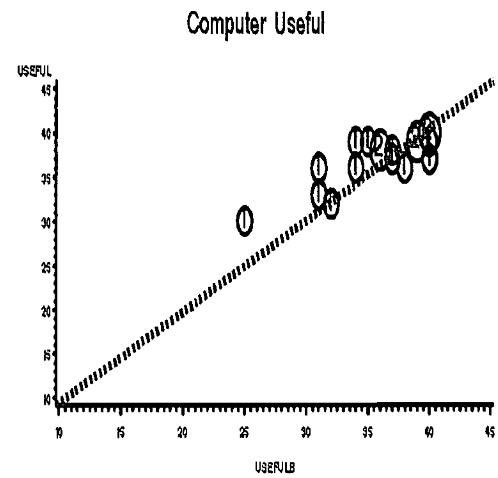

Figure 5. Computer Usefulness

The results may be skewed because some of the girls, especially the younger girls, had difficulty understanding some awkwardly worded negative statements. For example, question 13 in the CAS (Anxiety Scale) reads: 'I feel aggressive and hostile toward computers.' Campers questioned the statement's meaning on the last day of camp, but not on the first day. They may not have been comfortable enough initially to inquire about the meaning and answered by guessing. The National Science Foundation, the organization that funds Project FOCAL Point, has indicated that an evaluation study need not necessarily be bound to a survey that has undergone the rigors of validity and reliability testing. We will change the troublesome wording before administering the survey again.

Campers were asked to complete a self-assessment of their computer experience/skill level changes on the last day of the one-week experience. Figures 6 to 9 and Tables 1 to 4 show the before/after difference in reported computing experience levels.

Frequency	High	Moderate	Low	None	Total
Before N	3	15	1	0	19
Before %	15.79	78.95	5.26	0.0	
After N	9	8	1	0	18
After %	50	44.44	5.56	0.0	

Table 1. Level of Experience with Computers

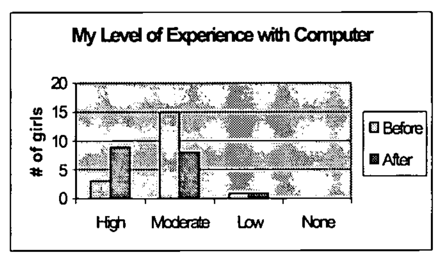

Figure 6. Level of Experience with Computers

Frequency	High	Moderate	Low	None	Total
Before N	3	7	3	6	19
Before %	15.79	36.84	15.79	31.58	
After N	12	6	1	0	19
After %	63.16	31.58	5.26	0	

Table 2. Level of Experience with E-mail

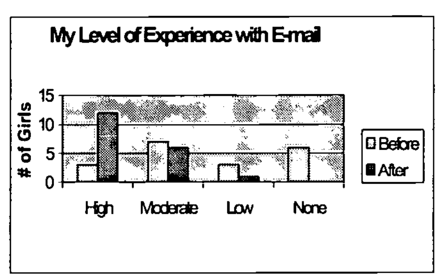

Figure 7. Level of Experience with E-mail

Frequency	High	Moderate	Low	None	Total
Before N	6	4	6	3	19
Before %	31.58	21.05	31.58	15.79	
After N	10	9	0	0	19
After %	52.63	47.37	0	0	

Table 3: Level of Experience with Internet

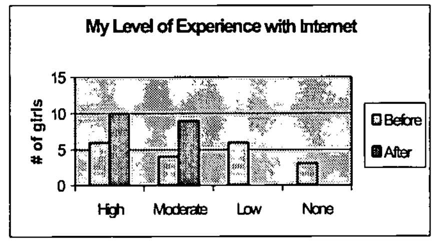

Figure 8: Level of Experience with Internet

Frequency	High	Moderate	Low	None	Total
Before N	3	0	5	11	19
Before %	15.79	0.00	26.32	57.89	
After N	2	13	3	1	19
After %	10.53	68.42	15.79	5.26	

Table 4: Level of Experience with Web Pages

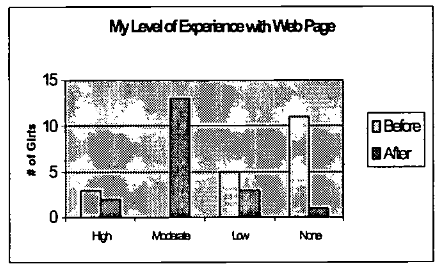

Figure 9: Level of Experience with Web Pages

As revealed in the frequency tables and bar charts, there were significant (practical and statistical although the inferential statistics are not reported in this paper) changes in all four areas of skills development and experience. The only area of notable decrease is the high level of experience with web pages. It may well be that one girl arrived at camp thinking she was an accomplished web page developer only to find that she had an opportunity to incorporate voice, video, graphics, etc. It is perhaps a tribute to the girls that most of them recognized that the skills they had acquired in a few days did not make them experts. The lone response of "none" in the after-column of web page development merits explanation. One technology education teacher did not feel prepared to teach web page development; instead he introduced his students to AutoCAD. We assigned the most experienced (according to their applications) campers to him, expecting that they would see what the other girls were doing and teach each other. Apparently that expectation was not borne out.

As is customary for conferences and workshops, the campers were asked to evaluate the various activities. The scale ranged from Awesome = 1 to Awful = 5. The inverse rating scale was selected intentionally to avoid the bias that could be created with the notion that "more is better." The campers' responses to the individual sessions are shown in Table 5. The uniformly positive ratings (ranging from 1.2 to 2.8) indicate that the girls generally enjoyed the computer camping experience.

Session	Mean Rating	Activity Type	# of 1's
Morning Teaching	2.2	General Teaching	4
Monday Career Panel	2.8	Career Information	1
Rainbow Falls	1.2	Recreation	16
E-mail Activities	1.5	Lesson	11
Internet Searching Activities	1.9	Lesson	7
Web Page Development Activities	2.0	Lesson	7
Everyone Needs a Computer Consultant	2.7	Guest Speaker	1
The Intrepid Women Scientists and Mathematicians	2.5	Guest Speaker	2
Thursday Career Panel	1.8	Career Information	9
Mean Rating	2.06		

Table 5. Session Ratings

Given that the mean rating for every session was higher than 3 (O.K.) and that all sessions received at least one rating of 1 (Awesome), it can be assumed that all campers took something of worth from the week. The overall mean rating of 2.06 suggests that the camp was generally a positive experience. Perhaps more enlightening (or at least more interesting) than the numbers are the open-ended comments the girls provided when asked the most important thing they learned during the week. The responses included: 'There are really a lot of women in computer related and high technology jobs.' 'Women can succeed in high technology jobs.' 'My most memorable experience was learning how to use e-mail and working on our web page.' and 'I can't wait to log on to the computer system, so I can check my e-mail.'

In conclusion, it does seem that the computer camp was successful in meeting its objectives. The session ratings provide evidence that every camper found something of worth. The open-ended comments focused on the objectives we sought to achieve. Moreover, the campers generally perceived themselves as being more skillful and experienced at the close of the workshop than they did at its inception. In addition, those with low initial scores perceived themselves as more confident and less anxious and having a stronger liking for computers.

Researchers studying the barriers to female retention in computer science at the SUNY at Geneseo concluded that females were turned away from computing before they ever reached the university (Scragg & Smith, 1998). Their recommendations: summer workshops for high school teachers and summer camps for girls. Project *FOCAL* Point is an exemplar of those recommendations.

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Acknowledgments

The Computer Attitude Scale was developed by Brenda Loyd and Clarice Gressard. Doug Loyd granted permission for its use.

Major funding for the project is provided by the National Science Foundation grant HRD-9711023. Other funding provided by Wausau Insurance Company, Course Technology, Incorporated, and AAL.

Learner-Centred Algorithm Simulation for Computer Programming Learning

Hoi Kau Yuen
Department of Curriculum Studies
The University of Hong Kong
Pokfulam Road, Hong Kong SAR, China
hkyuen@hkucc.hku.hk

Abstract: The teaching of computer programming and algorithm design is a subject of great difficulty, however, its value has not been addressed in the curriculum of computer studies in secondary schools. The aim of this paper is to discuss the development of the Traffic Light System Simulator (TLSS), a learner-centred algorithm simulation tool for learning computer programming. The primary goal of the TLSS is to provide a daily life problem in a learning environment. In solving the problem, students are encouraged to think and construct and test their own possible solutions. TLSS is designed to help students to construct meanings by forging links between visual simulation and symbolic representation developed by learners. It is believed that the TLSS would inspire students to look beyond the traffic light simulation and transfer the insight to the learning of computer programming.

Introduction

Computer programs are composed of data structures and algorithms. Computer programming consists of two major activities - designing the underlying algorithm and representing that algorithm as a program. Yet algorithm design is usually the more challenging step in the programming process. To design an algorithm is to find a step-by-step procedure for solving a problem. Algorithm design is an exceedingly diverse activity and involves complex cognitive skills. Students always find difficulties to discover algorithms in the learning of computer programming. The teaching of computer programming and algorithm design is a subject of great difficulty, however, its value has not been addressed in the curriculum of computer studies in secondary schools.

Algorithmics is the spirit of computing (Harel, 1992). An algorithm is a finite sequence of unambiguous, executable steps that will ultimately terminate if followed (Brookshear, 1988). Algorithm design has been revealed as an activity that demands abstraction, analysis, and synthesis abilities from students (Guimaraes & de Lucena, 1995). Therefore, the learning of algorithm design contributes not only to the teaching of computer studies, but also the cognitive development of students (van Merrienboer, 1990). The aim of this paper is to discuss the development of the Traffic Light System Simulator (TLSS), a learner-centred algorithm simulation tool for learning computer programming and algorithm design. TLSS is meant to provide a window to understand the nature of algorithm in action.

Effective use of multimedia would enhance learning motivation and retention. Multimedia also provides an authentic environment which is relevant to daily life. The TLSS, which consists of simulation, animation, sound, text, graphics and video, aims to create a learner-centred environment to support the learning of algorithm design in secondary schools.

Methodology for the Development

In the development of the TLSS, the prototyping paradigm is used. Prototyping is a process that enables the developer to create a model of software that will be built. Like all approaches to software development, prototyping begins with requirements gathering (Pressman, 1992). However, the "development of an educational program always begins with an initial idea which seems to have the potential for enhancing particular teaching and learning processes" (Marques i Graells, 1993). Thus, the development of the TLSS

requires the basic principles of learner-centred approach as well as the understanding of teaching and learning algorithm design in secondary schools (Whiteside & Whiteside, 1994). Grounded theory (Glaser & Strauss, 1967), which is a methodology for the systematic generation of conceptual models from qualitative data, was used to collect and analyse information from the interviews of teachers and students (Yuen & Richards, 1994).

The label "grounded theory" means "the discovery of theory from data" (Glaser & Strauss, 1967). Grounded theory is an approach to the handling of qualitative data and to the formulation of theoretical propositions in social sciences, and this methodology has been used successfully for conceptual analysis in a number of information system development projects (Pidgeon, et al., 1991).

The three major strategies for developing grounded theory are: (1) Constant comparative method - researcher simultaneously codes and analyses data in order to develop concepts. By continually comparing specific incidents in the data, the researcher refines these concepts, identifies their properties, explores their relationships to one another, and integrates them into coherent theory. (2) Theoretical sampling - researcher selects new cases to study according to their potential for helping to expand on or refine the concepts and theory that have already been developed. Data collection and analysis proceed together. (3) Theoretical saturation - the activities above continue until further data do not add new information about a theoretical construct.

Strauss (1987) presents a "concept-indicator model" to direct the conceptual coding of a set of empirical indicators. It is a possible operation of concept formation from qualitative data. Indicators are labels for actual data, such as behavioral actions and events, observed or described in documents and in the words of interviewees or informants. By constant comparison of indicators to indicators and their related data or documents, the researcher is forced into confronting differences, and degrees of consistency of meaning among indicators. This generates an underlying uniformity, which in turn results in coded categories, coded relations, definitions and properties of categories and relations, and theoretical concepts.

In order to develop a system "grounded" from the teaching and learning of teachers and students, twelve teachers and ten students from various schools were interviewed. The following issues were addressed in the interviews: (1) to identify the difficulties of teaching and learning of computer programming and algorithm design in secondary schools, (2) to examine the needs, skills, and interests of students in the learning of computer programming and algorithm design, and (3) to identify a series of problems fit the needs and interests of learners.

The following is a brief summary of some major findings which are useful for the TLSS development: (1) algorithm design is too abstract to some students, (2) students' English ability is an important factor of learning algorithm design and computer programming, (3) students are lack of logical thinking skill, (4) some teachers think that learning algorithm design is very important, (5) some teachers think that algorithm design can be learned naturally, (6) students' existing mental model is an important factor of learning algorithm design, (7) most students cannot decompose problem into sub-problems, (8) lack of teaching material in algorithm design, and (9) the curriculum is not related to daily life.

The results also reveal that teachers use either teacher-dominated method or subject-centred method. Teachers who teach with teacher-dominated method "are serving the immediate needs of the dependent, authority centred, linear thinking students" (McBeath, 1995). Teachers would direct students' learning through textbook and lecture. Teachers who teach with subject-centred method "are providing more information and use a greater variety of presentation method" (McBeath, 1995). The responsibility for learning is placed upon the students, while the teacher primarily provides opportunities for learning to take place. Most teachers adopt this subject-centred method. They teach with metaphors, examples, pictures or games. Apart from textbooks, they also prepare notes, laboratory sheets, and supplementary exercises as teaching materials.

Features of Learner-Centred Approach

In contrast with the teacher-dominated and subject-centred method, the learner-centred approach is based on the idea that "people learn best when engrossed in the topic, motivated to seek out new knowledge and skills because they need them in order to solve the problem at hand" (Norman & Spohrer, 1996). The TLSS is an interactive multimedia environment, which facilitates active exploration, construction and learning rather

than passive teacher-directed lecturing. It is also believed that this learner-centred multimedia tool would promote lifelong learning and enhance creativity and critical thinking.

The discovery method of instruction for teaching computer programming is one of the major focus in educational computing research (Seidman, 1988), and discovery learning occurs when a learner is motivated to act and allowed to formulate and test questions or answers (Keegan, 1995). A number of studies suggested to connect computer programming with logic, truth tables, switching circuits, gating symbols, flow charts, pseudocode and visual simulation would enhance the teaching and learning of computer programming in secondary schools (Brown, 1990). Proulx et al. (1996) suggest to use data visualisation and simulation to teach computer programming. Other studies suggested that algorithm animation would seem to be a useful tool for teaching algorithm (Kann, et al, 1997).

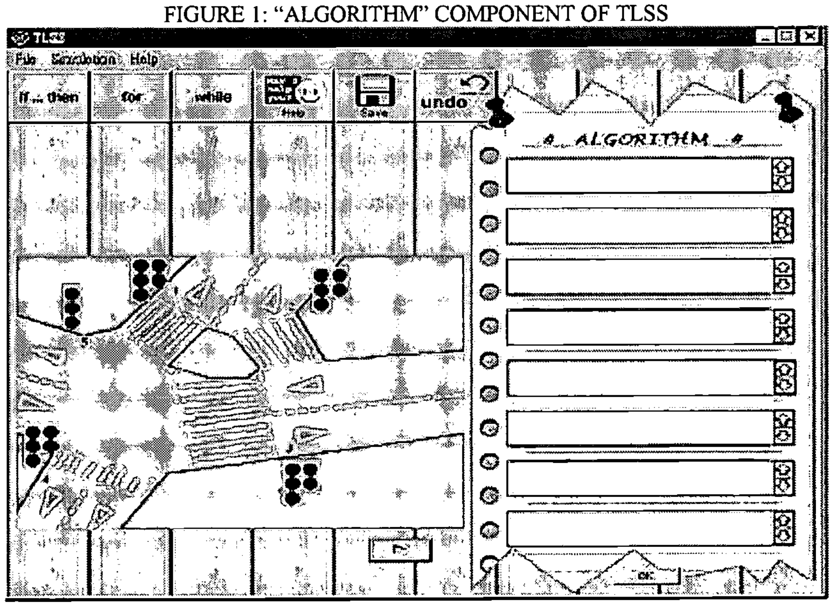
Further to these observations, this paper focuses on learner-centred approach which facilitates active, multi-functional, inspirational, and situated educational experiences. The basic principles of learner-centred approach can be summarised as: (1) problem-driven rather than structured analysis of the curriculum content, (2) to focus on the needs, skills, and interests of learners, and (3) to enable constructivist approach to learning.

System Description of TLSS

The design of the TLSS for learning algorithm design embraces two distinct features. First, the system provides students an authentic multimedia context that will motivate students to learn and explore (Woolf, 1996). The system provides continuous feedback and challenge to keep students to perform the learning activities (Schank & Kass, 1996). The TLSS is also bilingual in Chinese and English. Second, students might benefit from actively constructing the algorithm than passively watching the algorithm. Thus, the system provides a visualised simulation and animation environment, in which students allow to create, explore, test, and understand their implemented algorithms immediately.

The TLSS provides a dynamic model of a traffic light system with simulated roads, traffic lights, vehicles, pedestrians, and various traffic situations. It allows students to present and test their algorithm of controlling a traffic light system in animation. The system would also represent students' algorithm in Pascal programming language to reinforce programming language learning.

FIGURE 1: "ALGORITHM" COMPONENT OF TLSS



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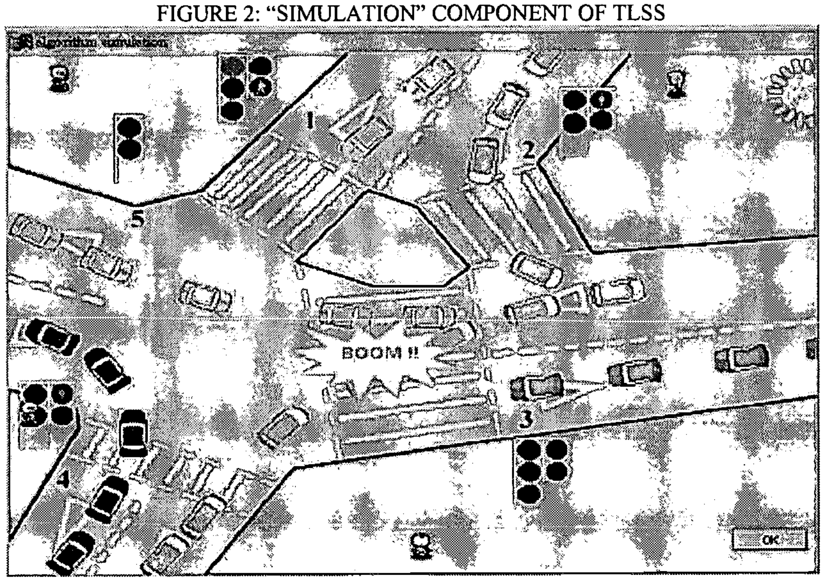
The TLSS consists of two major components, namely, "algorithm" and "simulation". In the "algorithm" component, users are asked to design an algorithm using "while", "for" and "if-then" to control five sets of traffic lights at a junction (FIGURE 1). The aim of the designed algorithm is to ensure the safety of pedestrians and vehicles. The "simulation" component simulates the designed algorithm in animation, and shows whether accidents would occurred. FIGURE 2 presents an example of car accident in the simulation. If accident occurs, users may go back to the "algorithm" component to re-design another possible algorithm and test it again. The simulation component is a window to integrate the algorithm representation and visualisation.

FIGURE 2: "SIMULATION" COMPONENT OF TLSS



Conclusion

A preliminary prototype of the TLSS has been developed using Lingo. A group of secondary students will be asked to use the prototype for learning algorithm design in their computer programming lessons. The process of using the prototype will be observed and teachers and students will be interviewed to examine their feedback and evaluation of the prototype. The prototype will be refined according to the feedback and evaluation. It is expected the final system specification of the TLSS will be furnished through the process of prototyping. Further evaluation and field study will be conducted to investigate students' cognitive skills in using the final TLSS.

The design of the TLSS is based on the learner-centred principles as well as grounded from the experiences of teachers and students. The primary goal of the TLSS is to provide a daily life problem in a learning environment. In solving the problem, students are encouraged to think and construct their own possible solutions. TLSS is designed to help students to construct meanings by forging links between visual simulation and symbolic representation developed by learners. It is believed that the TLSS would inspire students to look beyond the traffic light simulation and transfer the insight to the learning of computer programming.

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GENERAL PAPERS

Using a Free Commercial Site for a Web-based Course

George Atkins
Computer Science Department, Southwestern Oklahoma State University, USA
Tel: (580) 774-3201, Fax: (580) 774-3795, E-mail: atkinsg@swosu.edu

Abstract: A free, commercially available web-site was utilized for the on-line delivery of course materials and student assignments in a web-based course. On-line quizzes and a student-accessible grade book were also employed. A description of the web-site resources and course administration, as well as the course background and an overview of course materials are presented. Recommendations for future web-based courses are included.

Introduction

A web-based course entitled "Software Design Issues" was presented during the summer, 1998, session as an eight-week seminar. A free, commercially available web-site was utilized for the on-line delivery of course materials and student assignments. On-line quizzes and a student-accessible grade book were also employed. Software Engineering and computer ethics were the primary topics. *The Case of the Killer Robot: Stories about the Professional, Ethical, and Societal Dimensions of Computing* (Epstein 1997) was the text. A description of the web-site resources and course administration, as well as the course background and an overview of course materials are presented. Recommendations for future web-based courses are included.

On-line Course

The web-site utilized for the Software Design Issues course is called Blackboard Classroom. Blackboard, Inc. provides the site "for instructors who do not have the support of their academic institution and it is free" (Wang 1998). They do, however, charge for any required technical support. Their web address is http://www.blackboard.net/. Another product offered is Blackboard CourseInfo, which is to be installed on an institution's server. Information about CourseInfo may be found at their informational site, which is http://www.blackboard.net/courseinfo_frame.htm. All figures presented are copyrighted by Blackboard, Inc., and are used with their permission (Wang, 1998).

Figure 1 presents the introductory page of the course web-site. Announcements are updated as needed and used to alert students of new and amended assignments, on-line quiz availability, and updated grade postings. The Course Information and Staff Information areas are used to provide typical course description and syllabus material, and the Course Documents allow the instructor to post handout material for student acquisition. For the Software Design Issues seminar, assignments were posted on a weekly basis in the Assignment area. During the course, students are required to check the site frequently.

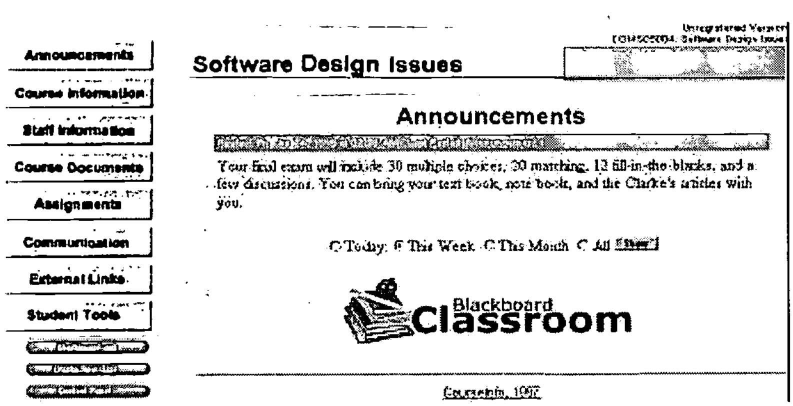

Figure 1: Course Web Page

The Communication, External Links, and Student Tools areas are the most important for day-to-day student activity. In the Communication area, shown as Figure 2, the Student Roster conveniently provides e-mail links for all students in the class, and the Discussion Board is utilized for responding to weekly discussion questions. Students often extended the discussion to related peripheral topics. Provisions to view student and group web pages and a Virtual Chat room are also provided. External Links allow instructors to provide links to pertinent Internet resources.

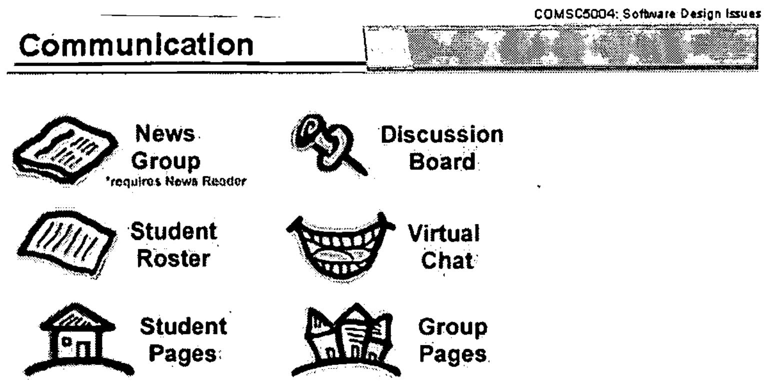

Figure 2: Communication

Students are also provided with a Student Tools area as shown in Figure 3 below. This component allows students to change their information, construct and edit individual and group home pages, send e-mail to the instructor, and check their grades. A homepage template is provided at the Blackboard Classroom site allowing students to develop a homepage without knowing any HTML. Students quickly learn they can enter HTML code to provide enhanced pages. A student manual is also available to assist students in learning to use the web-site.

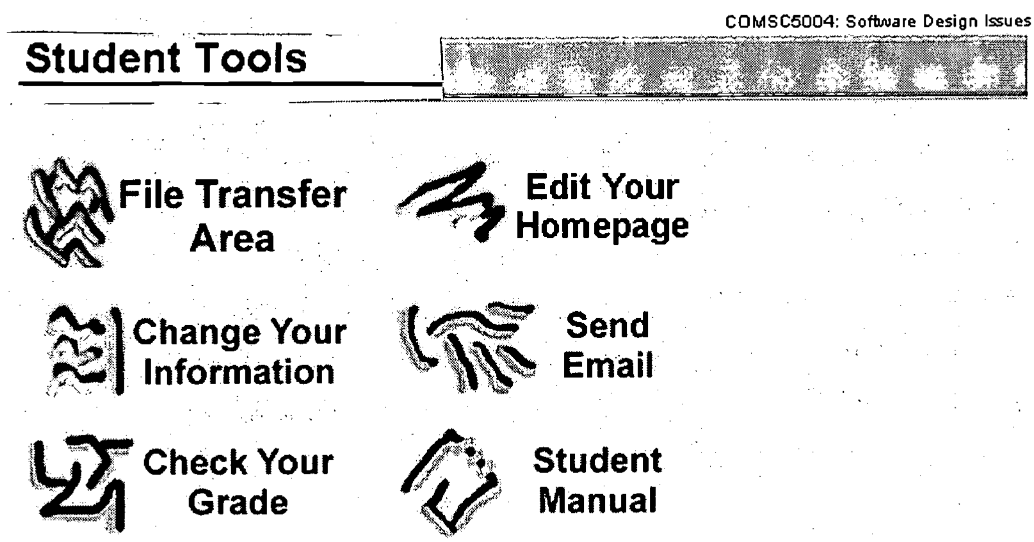

Figure 3: Student Tools

The instructor, via the Control Panel shown on the next page, designates which course areas require user-ID and password protection. For the Software Design Issues course, the Announcements, Course Information, Staff Information, and Assignment areas are available to anyone. Other areas are user-ID and password protected. For the interested reader, the site will be maintained through the summer, 1999, and a test student with both user ID and password of ZANYT (for Zany Test Student) provides access to all regular student-accessible areas of the course. The web address is http://classroom.blackboard.net/courses/COMSC5004/

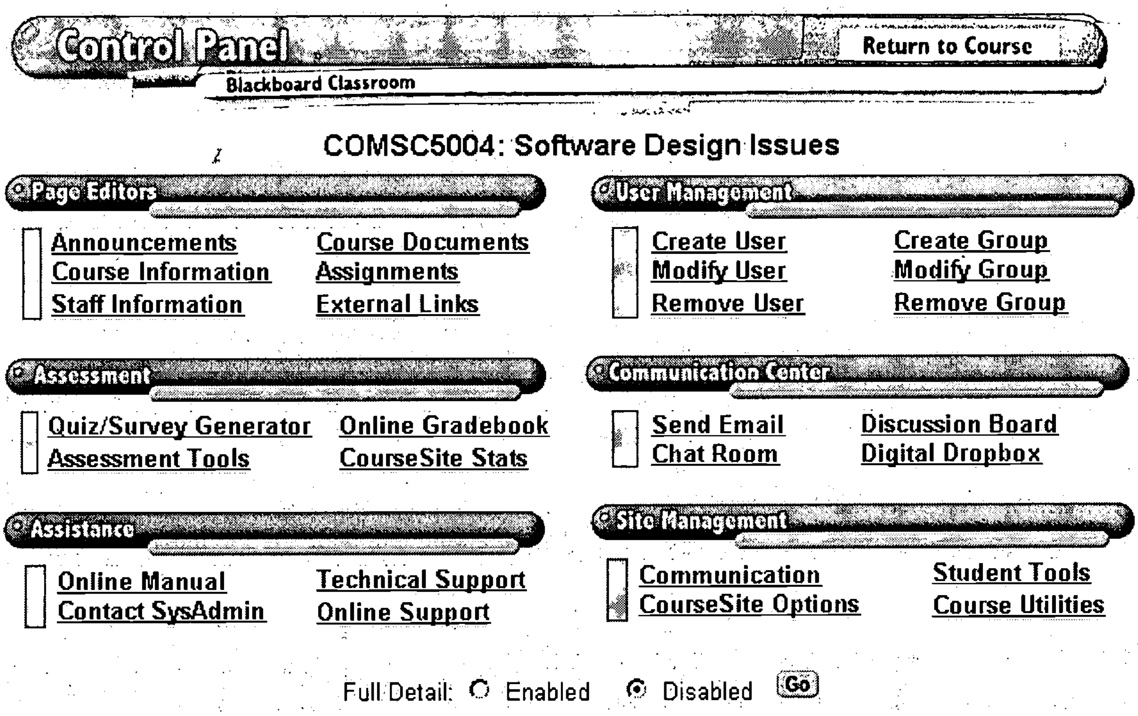

Figure 4: Course Control Panel

The control panel is accessible only to course staff. It is used by the instructor and assistants to administer the course web-site and provides access to the areas shown in Figure 4.

Course Background

The eight-week seminar Software Design Issues was offered for Junior and Senior Computer Science majors during the summer session, 1998. It was primarily a web-based course providing students the opportunity to investigate methods and ethical considerations in the development and design of large software systems. Software Engineering and computer ethics were the main topics of the course. In the fictional account, *The Case of the Killer Robot*, an assembly-line robot malfunctions and kills a worker. The lead programmer in the project is arrested for manslaughter. The story progresses (with much intrigue) from that point! Although fictional, many programming and software engineering concepts such as teamwork, software design, documentation, testing, software management, and computer ethics are addressed in the text. The last part of the text is factual and provides discussion of real computing, computer scientists, and computing resources in today's world, and also provides references to supporting literature and course discussion questions.

The course was administered entirely over the Internet. E-mail and an on-line discussion group provided communication between the students and instructor. The instructor met with each student the first week of the class to explain course logistics and requirements. The entire class met together to complete a final examination and a course evaluation. A significant amount of reading material was assigned from both the text and several computing periodicals. Readings, assignments, and quizzes were based on a weekly schedule. Assignments were due on Friday with a quiz over the week's material posted on the web-site the following Tuesday. Quizzes were developed on-line using the Blackboard Classroom site. The site provides capabilities to create and automatically grade multiple choice, true/false, and fill-in-the-blank questions. Essay type questions may also be included without the automatic grading feature. Students took the objective quizzes in an asynchronous mode. Students also submitted two papers, and a written final examination covered most of the topics covered in the course. Students were expected and encouraged to actively participate in the course.

Each student's task in the class was to understand the "killer robot" scenario, to grasp how it related to software design issues, and to discover and to discuss the (real) related resource material. Students maintained a course notebook, posted messages to the class discussion group, submitted a variety of material to the instructor, found Internet and library resources, read the text and several computing journal articles, and considered and reacted to the ideas presented. Further information about course details and experience may be found in the paper "The Virtual Killer Robot" (Atkins 1999).

A web-based course entitled "Software Design Issues" was presented during the summer, 1998, session as an eight-week seminar. A free, commercially available web-site was utilized for the on-line delivery of course materials and student assignments. On-line quizzes and a student-accessible grade book were also employed. Software Engineering and computer ethics were the primary topics. *The Case of the Killer Robot: Stories about the Professional, Ethical, and Societal Dimensions of Computing* (Epstein 1997) was the text. A description of the web-site resources and course administration, as well as the course background and an overview of course materials are presented. Recommendations for future web-based courses are included.

The Case of the Killer Robot

In John Bohlin's 1997 on-line book review he says the "*Killer Robot* addresses some of the ethical and organizational issues of computing more forcefully than anything else published to date, yet it's really fun to read. It is a milestone in the history of computing" (Bohlin 1997). The text explores the ethical, social, and professional dimensions of computing. An assembly line robot kills its operator. The investigation into the accident leads to many important considerations in software engineering, computer ethics, professional and workplace issues, and the social implications of computing. Epstein began developing the killer robot scenario several years ago (Epstein 1994), and the original *Killer Robot* material was placed on several Internet sites, including http://ricis.cl.uh.edu/FASE/Killer-Robot.html.

The text consists of an "outer" book containing supporting factual materials about computing and computer science and an "inner" book containing the fictitious materials. The outer book consists of the Preface and three Appendices--Real People and Institutions, Endnotes and References, and Discussion Questions. The inner book presents the saga of the killer robot as a series of 29 (fictitious) chapters presented as newspaper articles, radio talk show transcripts, and a computer journal article. The fictitious killer robot scenario covers a wide range of computing and software engineering topics.

Assessment

This was the author's first experience with course delivery almost completely on-line, and the results were definitely satisfactory. Student evaluations were very favorable. Without question the course was successful. Students reacted well to the material presented and, with only a few exceptions, actively participated in on-line course discussion on a daily basis. Occasionally a student required prompting to participate in a timely fashion, and in one case a phone call was required. Lack of face-to-face encounters with students was a new experience requiring adjustments. Frequent personalized correspondence via e-mail was required to maintain the instructor-to-student connection. Several students experienced difficulty with the "remoteness" of the on-line course and regularly visited with the instructor. Those contemplating this form of "distance learning" need to strive to cultivate instructor-to-student bonding via a variety of methods. Utilization of the Virtual Chat area for on-line office hours and occasional individual or small-group meetings are planned for future similar courses

The Blackboard Classroom is very simple to learn and use. The available tools made creating and maintaining a course web-site extremely easy. However, development and posting of assignments and quizzes on a daily and weekly basis for the on-line course proved to be very labor intensive. A student assistant was most helpful in maintaining the announcements, assignments, quizzes, and on-line grade book. Without student help, the on-line course likely required more effort than a standard class. Hopefully the seminar can be offered again in the near future, and the resources developed can be reused.

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Acknowledgements

The author wishes to thank Blackboard, Inc., for permission to use web-site screen graphics.

Technology and Problem Solving for Middle School Teachers

Judy Beauford
Mathematics
University of the Incarnate Word
United States
beauford@universe.uiwtx.edu

Zhanbo Yang
Mathematics
University of the Incarnate Word
United States
yang@universe.uiwtx.edu

Abstract: This paper is a report of the classroom application of the use of technology in a problem solving course for middle school teachers. Graphing calculators, Internet resources, and Geometer Sketchpad (GSP) were used to reinforce and apply the classroom investigation and discussion of the real number system, data analysis, and topics in geometry in a problem solving environment. The course was a three week summer institute funded by an Eisenhower Professional Development grant followed by an academic year course spread throughout two semesters. Teachers used the TI-86 calculator to experiment with rational number sequences, random number generation, probability, linear correlation, and descriptive statistical analysis. They used GSP to investigate topics in geometry and build graphic representations for communicating other mathematics. Experience with Internet resources and data analysis helped them strengthen other problem solving skills.

Introduction

A consortium of school districts in the San Antonio metropolitan area found a common need for a sustained high level professional development program where their identified weaknesses in problem solving could be addressed. Problem solving skills needing attention were using estimation, identifying and using a wide range of solution strategies, using mathematical representation, and evaluation of the reasonableness of a solution. An Eisenhower Professional Development grant was received by the University of the Incarnate Word to meet their request for assistance.

A significant part of the reason for the unsatisfactory abilities in problem solving was the students' inability to analyze and solve problems and the teachers' deficiency in the ability to communicate the philosophy and skills of problem solving to students. Project objectives were to broaden teacher knowledge of problem solving strategies, to strengthen pedagogical approaches to problem solving, to encourage and complement the use of technology, particularly computer and Internet resources, and to introduce this population of teachers to the opportunities for professional development and resources available from national, state, and regional organizations.

Recent research in mathematics education gave the project instructors' clear guidance in building the course. Kaput and Thompson (1994) noted "three aspects of technologies that enable a deep change in the experience of doing and learning mathematics" (p. 678). They are interactivity, control of the learning environment - "making powerful resources immediately available to aid thinking or problem solving" (p. 679), and connectivity - among students, among teachers, among students and teachers, and among disciplines. Part of the task of building better problem solvers was to give participants the same opportunities recommended for young learners, opportunities in "recognizing and formulating their own problems." (National Council of Teachers of Mathematics, 1989, p. 138).

The Instructional plan

Each day of a three-week summer institute (45 contact hours) covered components addressing the implementation of the state and local objectives, problem solving strategies, and learning theory, and providing experience with using technology as a problem solving tool and as a teaching tool. The class included participants with varying degrees of experience with graphing calculators, computer programs, and Internet resources. They were given the opportunity to experience using these tools in both doing mathematics and communicating mathematics. The academic year follow-up extended these strategies to focus on the connection of mathematics with other disciplines, emphasizing the mathematics found in problem solving in the sciences, social sciences, and literature.

The format for the academic year course was a combination of whole-group meetings, small-group class visits, and an ongoing email discussion. Participants met as a whole four times during the academic year. The first sessions was a problem solving party at which these teachers were given the opportunity to solve many different kinds of problems from varied disciplines. At the second meeting a team of presenters from NASA met with the group to introduce them to the Internet and print resources available from that agency and to give them experience with the use of some of their materials. A third session focused on the use of the graphing calculator in combination with the computer, and the fourth session looked at the assessment of progress in a problem solving centered mathematics classroom. Groups of two to four teachers supported one another as they began to implement what they had learned at the summer institute. They learned from each other during conversations and visits to each others' classes. One of the instructors later visited each teacher in the group and facilitated a small group gathering for summary and synthesis of the experience. The distance learning portion of the course was implemented through a email discussion centering around Internet searches and investigations of the major resource sites for mathematics. Each participant was required to visit sites as provided by the instructor, search for their own sites, and report back findings. Classroom experience with the materials collected were reported in the discussion.

Implementation

The mathematics topics included in the project were a development of the real number system, data analysis including descriptive statistics and simple linear regression, and selected topics from geometry. Each day included problem solving opportunities for the teachers, development of topics in mathematics and learning theory, and practical and frank discussion of how these ideas would be translated to classroom action. Alignment of assessment strategies with the development of a problem solving classroom environment was particularly addressed. Discussion emphasized the importance of assessment as an integral part of instruction used to understand student thinking and formulate plans for further instruction.

The three major categories of technology to which the participants were introduced were Geometer Sketchpad (GSP), the TI-86 graphing calculator, and the Internet. The participants used Geometer Sketchpad to experiment with geometric shapes, constructions, and measurement. Materials and resources are noted in the reference list below. Experiments with the graphing calculator included work with the graphing function, list processing, linear correlation, and descriptive statistics.

Example

The following (Fig. 1) is an example of how technology was used both as a teaching tool and a tool to aid in problem solving Teacher participants used GSP to construct a golden rectangle, then used the measures from the rectangle as the beginning point in an investigation of the relationship between the Golden Ratio and the Fibonacci numbers. Resources for building this activity came from Bradley (1995) and Wyatt, Lawrence, and Foletta (1998).

Fibonacci Sequence and the Golden Ratio

Part A: Construct a Golden Rectangle using GSP and *Geometry Activities for Middle School Students*, p. 178 (Wyatt, et. al, 1998).

1. If the length of the side of the square is 1, what is the length of the arc you constructed from its midpoint to the upper right vertex?
2. What is the length of the new rectangle you constructed?

Part B: The Fibonacci Sequence is defined recursively by the equations

$t_1 = 1, \qquad t_2 = 1, \qquad t_n = t_{n-1} + t_{n-2}$

Its first few terms are entered in the table below. The sequence has some surprising connections to the golden ratio,

Find t_{11}, t_{12}, t_{13}, t_{14}, t_{15}, the eleventh through fifteenth terms of the Fibonacci Sequence.

1	1	2	3	5	8	13	21	34	55

Figure 1: Fibonacci Sequence and the Golden Ratio

Results

The implementation of what these teachers had learned was apparent in the development of their own classes during the academic year. Most of them had established a Problem of the Day or Problem of the Week, and incorporated problem solving as a integral part of their classroom environments. They report having a better understanding of the students' struggle with problem solving, having refreshed their own experiences with such tasks. They reported being better attuned to their students' need for time, encouragement, and permission to be wrong as they build their confidence and skill in problem solving. The importance of the opportunity for thinking beyond the solution has become more apparent to these teachers and their students.

The class visits among the teachers were particularly successful. Every teacher was required to visit at least two others and be visited by two. Their instructions were to invite their colleagues when they were using problem solving and/or technology to reach the learning objectives of the day. The visitors were there to learn from the instructors. The visitors were asked to write a short report of their visit describing the lesson and teaching strategies used and evaluating how they might apply what they had observed to their own classes. They were encouraged to include suggestions for how to expand or improve on the lesson. This level of peer interaction between teachers is all too rare in schools, but such observation and reflection without the burden of evaluation allows exciting opportunity for growth of both the observer and the observed teacher.

The email discussion began with an assignment posted once every two weeks. The first posting established connection as the teachers reported how they were beginning their construction of a problem solving environment in their classrooms. The second posting required that the teachers visit at least three web sites related to their classroom teaching assignments. They were later encouraged to check out others' findings and report the results. The next several postings directed the participants to some of the major Internet resources for mathematics teachers. These included the sites established by the Eisenhower National Clearinghouse, National Aeronautics and Space Administration, Math Forum, Texas Instruments, and the National Council of Teachers of Mathematics. Teachers found these sites, chose particular items of interest, and reported back to the group about their experiences. Many teachers reported downloading materials which they then used in their classes. This exposure to the wealth of resources available was eye-opening and exciting for many of the participants.

The combination of whole-group sessions with email discussions seemed to help maintain the group dynamic begun during the summer institute. The usual frustrations with Internet access difficulties and the intrusion of this additional obligation in the teachers' already busy academic year needed the counterbalance of stimulating reinforcement and encouragement at the face to face meetings. The small group interaction made the implementation of new strategies into the teacher's repertoire more easily accomplished, observed, and reinforced. The most tenuous of the three-armed effort was the email discussion. The continuance of teacher participation needed reinforcement from these other means of communication and continued acknowledgement of the value of their contributions.

The reform efforts in mathematics come at our classroom teachers from every direction. They are pressured by national, district, administrative, and parental initiatives to make real changes in their classrooms and to show very real results in the performances of their students. Such movement can be overwhelming for those teacher who remain isolated in their efforts and limited in available tools. The vast wealth of information and support available from professional organizations, governmental, and industrial sources, through the Internet and other means must be made apparent to these teachers from whom we are expecting such important results.

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Acknowledgments

This project was partially funded by the Texas Higher Education Coordinating Board, Eisenhower Professional Development Grants Program, Eisenhower Mathematics and Science Act Grants, Grant #6077UIW.

Multimedia Tutorial in Data Storage

Barbara Beccue, Ph.D.
Department of Applied Computer Science
Illinois State University
United States
bbeccue@ilstu.edu

Joaquin Vila, Ph.D.
Department of Applied Computer Science
Illinois State University
United States
javila@ilstu.edu

Abstract: This paper describes a computer based multimedia tutorial on data storage types. The tutorial was designed as a supplement to lecture material presented in an undergraduate 200-level course entitled, Hardware/Software Concepts. Information in the tutorial is presented in two ways: in text format for the student to read, and as examples that depict, via different media, what is described in the narrative. The tutorial uses a book metaphor. The student can navigate linearly within a chapter and nonlinearly among chapters. The application provides for self-evaluation of the material covered through interactive quizzes. The content of the tutorial is organized into five chapters. There is a chapter for each of the following topics: introduction to number systems and conversions; text representation using ASCII and EBCDIC standards; image formats including bitmap and JPEG; audio files including WAV and MIDI formats; and numeric data types such as integers and floating point representations.

Introduction

For some of the courses taught by the Applied Computer Science Department, it may be difficult to find a textbook that includes coverage of all the topics for a course at the desired level of detail. This means that often an instructor must supplement the text with additional materials. Traditionally, these supplemental materials have consisted of either articles or exerts from other sources or the instructor's lectures and notes. Incorporating material that is not covered by the text often causes students problems or at least perceived problems with this material, especially in lower division courses.

Lack of adequate textbook coverage of a particular topic such as data representation is currently a problem with the 200-level course, Hardware/Software Concepts. This course is a required core course in the undergraduate program, and its students are comprised of mostly freshmen and sophomores. The topic of data representation is part of the foundation for the remainder of the course material. The instructors have to acquire additional information from multiple resources to share with the class. Furthermore, even though the text does have some coverage and examples, the examples are difficult for the students to follow. Historically, students taking this course have had difficulty assimilating this material. Another problem that has become apparent is that the topic coverage is quite varied and is dependent on the instructor. This variation in coverage has become a problem in follow-on courses in which students are expected to have mastered this particular topic. In order to alleviate the problems of inadequate and inconsistent coverage of data representation, it was decided that a tutorial to cover this topic should be developed.

Contents of the Tutorial

The topic, data representation, is the focus of the multimedia tutorial presented in this paper. A solid understanding of this material by the students will provide a good foundation to build upon for the remaining part of the semester. The objective of the tutorial is to help students learn how data is represented, stored and processed within computers. The tutorial provides coverage of data storage including sound, graphic/photo images, characters and numbers. Each topic is presented by a detailed narrative and corresponding representative examples. The examples are produced using a variety of media in a step by step manner with voice over explanations of each step. The tutorial also includes self-administered tests that allow the student to get immediate feedback on how well he/she understands the material.

The tutorial opens with an initial screen that allows the student to choose from 5 topics: Introduction, Text, Images, Audio and Numbers. The student can choose the topics in sequence or in a random order. However, once the student selects a topic, that topic must be viewed sequentially. At the end of each section the student has the choice of taking an interactive test for that topic.

The Introduction chapter covers different number systems and emphasizes base 2, base 8, base 10 and base 16. There are several conversion examples accompanied by voice over to aid the student's understanding of the number systems and the conversion between number systems. The interactive test for this chapter tests the student's understanding of the number systems and the conversion between them.

The Text chapter discusses the different standards to represent character data. The two standards that are discussed are ASCII and EBCDIC. The interactive test has the student convert text to its binary representation using both the ASCII and EBCDIC conversion tables.

The Image chapter presents information about compression techniques and file formats for the storage of images. The differences between vector and bitmap image representation are discussed. The concept of image compression is introduced and exemplified by explaining the JPEG format. The interactive test for this section tests the student's understanding of the concepts presented about image data representation.

The Audio chapter introduces the concept of a sound wave and how it can be digitized. It discusses two types of sound files, WAV and MIDI. The interactive test for this section tests the student's understanding of the concepts presented about audio data.

In the Number chapter, the pros and cons associated with the storage and computer utilization of integers and real numbers are discussed. The discussion first centers on positive and negative integers. For negative integers, complementary representation is discussed. Floating point representation using the IEEE 754 format is discussed. Arithmetic operations are demonstrated in a step by step format with a voice over explanation in order to help the student better understand how the arithmetic is done. The interactive test for this chapter tests the student's understanding of integer and floating point representation.

The tutorial uses a book metaphor. Each of the 5 topics included in the tutorial represent a chapter in the book. The student can navigate linearly within a chapter and nonlinearly among chapters. The tutorial opens to the Main Menu, which includes a button for each chapter in the tutorial. Pressing the button for a particular chapter will take the user to the beginning of that chapter. This feature allows the student to move directly to any chapter or topic that he/she needs to study. Then, every page of the tutorial has a navigation bar that contains navigation tools for ease of movement through the tutorial (See Figure 1). The navigation bar contains buttons for the following navigation options: Exit, Menu, Glossary, Test, Previous Page, and Next Page. In addition, the text box in the center of the navigation bar displays the specific topic of the current page. This information coupled with the Topic or Chapter Title at the top of the page keeps the student informed about his/her exact location within the tutorial.

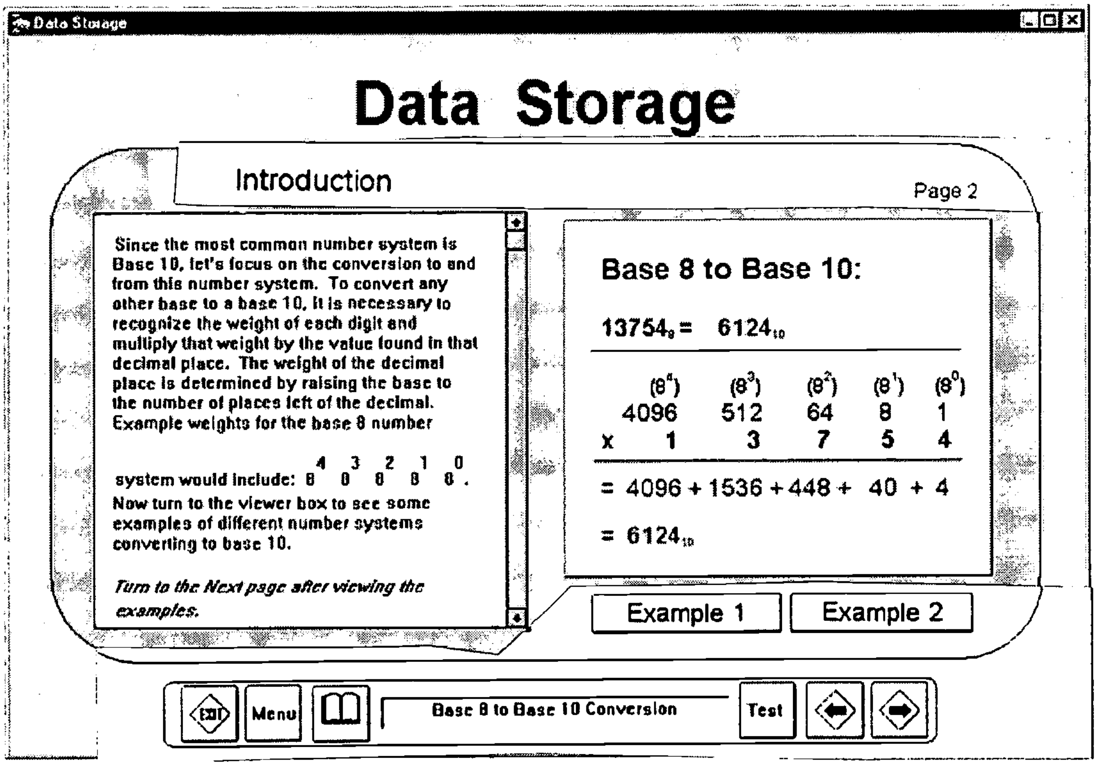

Figure 1: Data Storage Tutorial Screen from the Introduction Chapter

The navigation bar provides the user with various options for moving through the tutorial. The Exit button allows the student to exit the tutorial at any time. The Menu button will take the user back to the Main Menu. Once there, the user can select another chapter to review or study. The Glossary button will open a viewer window that has a drop down list containing all the words in the glossary. The Test button will open the first page of the Interactive Test for the current chapter. The user can then take the Test. The Previous Page and Next Page buttons provide the user with the capability of moving linearly within the tutorial. Non-linear navigation is implemented through the main menu and the hyperlinks included in the narratives.

Figure 1 depicts one of the pages in the Introduction Chapter of the tutorial. The name of the tutorial is centered at the top of the screen. This name appears on every page of the tutorial. The informational content of the tutorial is displayed in an open book. The left page or side of the book contains a window that provides narrative information for the student to read. The right page or side of the book provides a stage that will be used to display examples of what is described in the informational text. In Figure 1, the informational text is about converting a number in base 8 to a number in base 10. On the right side of the book, the user can select the button for either Example 1 or Example 2. Each example works through the conversion process one step at a time. Each step is accompanied by an audio selection that describes the step. The process is cumulative, so when the last step is completed, the student sees the entire process. Figure 1 shows the completed process, and basically, each step is indicated by changes in the color of the numbers being displayed.

Figure 2 shows the first page of the Image chapter. This page is typical of pages in the tutorial. It presents a student with both a narrative discussion about a topic and suitable examples of the concepts being introduced. On this page, the student can read about image representation. Additionally, the student can choose to view the two types of images discussed, a bitmap and a vector image. The image displayed in Figure 2 is a bitmap image.

Figure 2 has an example of a hotword or hyperlink, "flatbed scanner." In the tutorial, a student can look up the definition of the term in two ways. One way is to use the hyperlinks that are provided. The other way is to click on the Glossary icon, the open book, on the navigation bar and select the term from the list displayed in the drop down list.

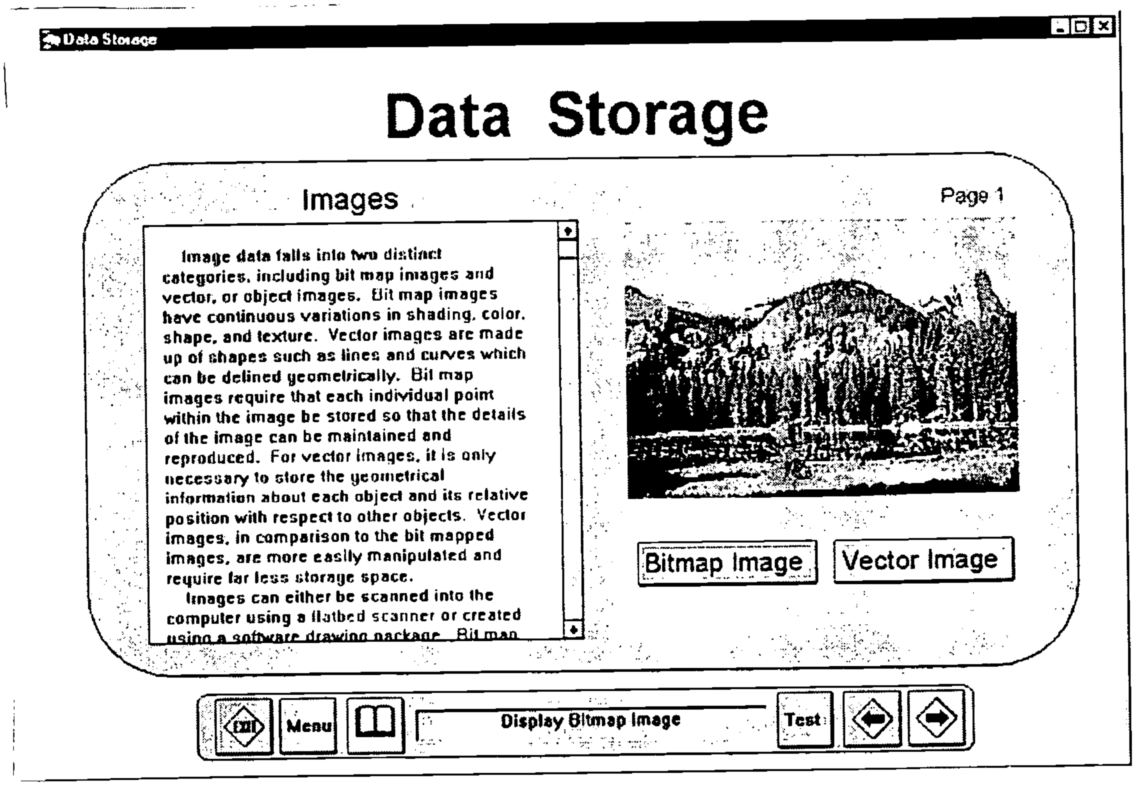

Figure 2: Data Storage Tutorial Screen from the Images Chapter

Figure 3 is an example of a page from an interactive test. This particular example is from the interactive test for text data storage. The student can page through the chapter sequentially until he/she reaches the test or skip ahead to the quiz by selecting the Test button on the navigation bar located on each page of the tutorial. Each test is composed of multiple choice questions. The answer choices are contained in a drop down box. After the student selects an answer, a check mark is displayed to the right of the question if the answer is correct. If the answer is incorrect, the student is prompted with a try again message, and the student can try again. Question 1 in Figure 3 shows an example of a correctly answered question. Question 2 shows an example of the drop down box that displays the possible answers for the question. When the student has correctly answered all the questions in an interactive test, he/she can print the test for his/her review of the material.

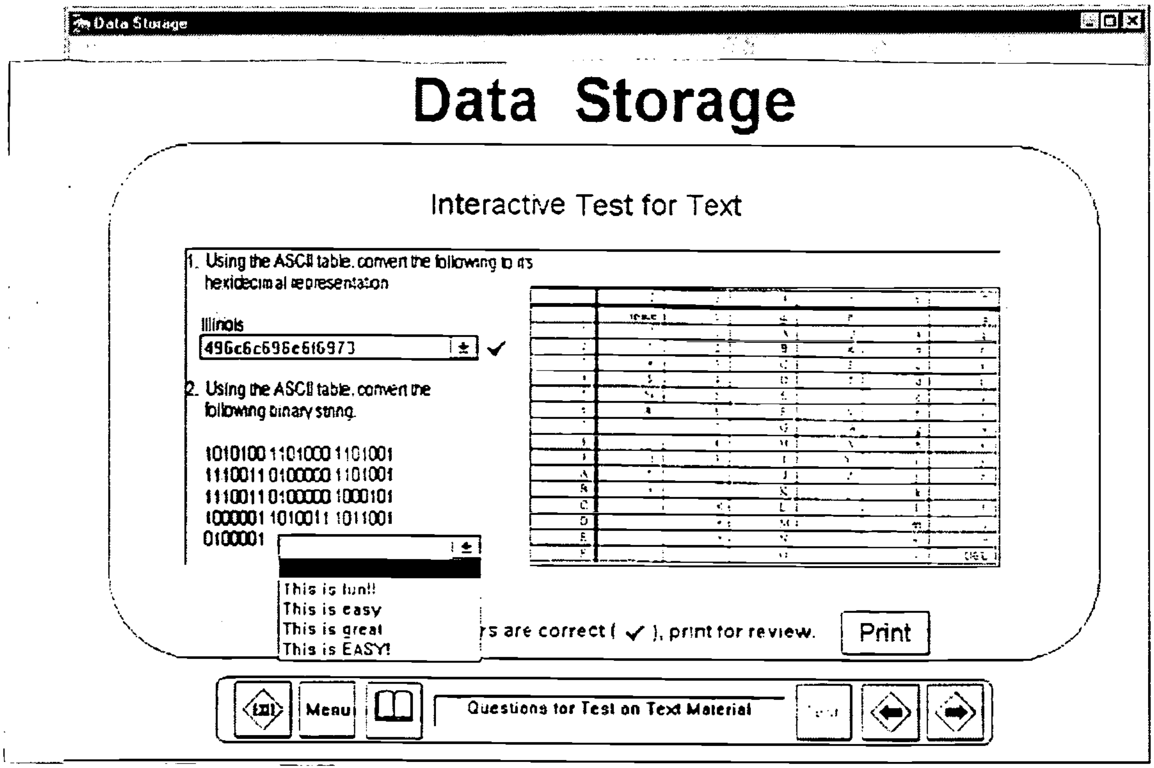

Figure 3: Data Storage Tutorial Screen from the Interactive Test on Text Data Storage

Tutorial Implementation

The tutorial was developed using Asymetrix's Multimedia Toolbook, version 4.0. Image processing was done using Adobe Photoshop, and audio sequences were digitized using Windows' Sound Recorder.

Rapid prototyping techniques were used throughout the development life cycle to capture requirements, to design the page layouts, and to design the navigation strategies for the tutorial.

The tutorial will be deployed on CD-ROM. The application requires a multimedia PC to run.

Discussion and Conclusions

Preferred learning styles and paces vary among students. Over time, many different combinations of teaching methods and styles have been used to create and deliver instruction in ways that would accommodate different learning styles (Jonassen & Mandl, 1990, Parkers, 1994, Pirolli & Wilson, 1992). Many of today's students were brought up in an environment that included "Sesame Street" type television programming, interactive games and the use of computers. Consequently, in today's university setting, instructors are competing against the students' expectations gained from their experiences with these enticing television programs and sophisticated computer application programs or games. Currently, it is economically and technically feasible to implement web-based and multimedia based interactive tutorials to supplement classroom instruction; therefore, a computer based multimedia tutorial seemed an appropriate vehicle for presenting the material on data storage.

In addition, the decision to develop and use a multimedia-based tutorial supports a research agenda. The authors have been engaged in researching user preferences in multimedia environments (Beasly & Vila, 1992, Beccue & Vila, 1994). Tutorials like the one described in this paper are instrumental for carrying out experimental research that might provide some insight on the way students interact and learn from multimedia environments. For example, one factor that is being investigated is the relationship between the navigational strategies used and the instructional objectives of the tutorial (Beccue & Vila, 1996). Another factor being investigated is the impact of audio sequences or voice-overs on the learning success of students using computer based tutorials (Koenecke, 1997).

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Acknowledgements

The authors wish to acknowledge the work done by Gina Sweatman in the development of the first version of Multimedia Tutorial on Data Representation.

The authors also wish to acknowledge Ms. Cathy Holbrook and Dr. David Doss for their contributions to the development of the first version of the Multimedia Tutorial on Data Representation.

MTP^3-Lessons Learned From The Milwaukee Telecommunications Project

Dr. Craig A. Berg, School of Ed. The U. of Wisconsin-Milwaukee, USA, caberg@uwm.edu

Abstract: The primary purpose of this paper is to describe a collaborative professional development effort focusing on using Internet for instruction and educational reform. This is a collaboration between a large urban district and science educators at an urban university for the purpose of working with science, mathematics and social studies teachers to develop their abilities to use telecommunications for professional development, curriculum development, and instruction in the classroom. This paper will address the program design, targeted outcomes, and successes, as well as, the difficulties faced by urban teachers as they attempted to implement Internet-based instruction and the solutions that enabled them to develop effective and collaborative Internet-based lessons.

Introduction and Statement of Need

In Milwaukee Public Schools and the surrounding districts there was, and still is, a great need to provide the knowledge base and implementation skills for teachers to begin using, or vastly extend the use of Internet for professional development, curriculum development and instruction in Science, Math and Social Studies. School districts are learning that fulfilling the stated goals and principles embedded in reforms such as Project 2061's Science For All Americans (1989), Benchmarks for Scientific Literacy (1993), The National Science Standards (1996), The Mathematics Standards (1989), and the National Geography Standards (1994) means rethinking curriculum and retooling instructional practices to fill the re-defined and expanded boundaries of classrooms. Some reform goals emphasize the necessity to greatly facilitate communication between students, develop global classrooms and learning communities, and to increase student knowledge through this interaction with science-related issues and problems. Other goals are quite explicit in defining the need for developing advanced capabilities to work with technology. These goals suggest the need to foster use of technology with more powerful teaching strategies in which students are designing investigations, reaching conclusions based on the evidence collected, and comparing results with fellow students between schools and regions.

How can Internet facilitate reform? Many factors affect and impede teachers as they strive to remain current on educational research, curriculum developments, and pedagogical strategies. Telecommunications may be one of the more promising activities to foster professional development as well as nurturing collaborative efforts between schools to develop broad communities of learners. State-of-the-art programs in science education are facilitating these goals by using technology and telecommunications to develop far greater access to resources and information about curriculum and instruction that help to improve science, mathematics and social studies instruction and thereby contribute to reform efforts. Teachers report the professional gains from telecommunications to include communicating with other educators, accessing information, and combating professional isolation (NSTA Reports, 1993). Yet, a Bank Street College nationwide survey of telecommunicating found that "ninety-six percent of the respondents are self-taught in telecommunications...opportunities to learn about networking through school- and district-sponsored workshops [were] very limited." In short, we initiated this Internet effort because teachers needed preparation on and assistance with regard to effective uses of Internet in the classroom as a tool to support instruction and educational reform.

Targeted Goals and Objectives

For this project the targeted goals included: developing advanced capabilities to work with technology in the context of powerful teaching strategies in which students are designing investigations, reaching conclusions based on the evidence collected, and comparing results with fellow students between schools and regions; greatly facilitating communication skills between students, developing global classrooms and learning communities; and increasing student's content knowledge through interaction with science-related issues and problems. More specifically, teachers learned to use the Internet to:

- *Locate and obtain innovative lessons, units, software and other teaching resources from other teachers across the country.*
- *Access and retrieve science- and social studies-related information from global databases so that students learn current and cutting-edge content and use multiple sources of information for learning and decision-making.*
- *Share data between classrooms, communicate with other teachers and students project-related inquiry and incorporate strategies to help students learn to analyze data.*
- *Use technology to facilitate and enhance equitable teaching strategies that promote interaction, issues analysis and conflict resolution related to science, and social studies.*
- *Successfully complete collaborative, inquiry-based, on-line projects (teacher-developed projects or sponsored projects).*
- *Explore new and advanced uses of Internet such as video-conferencing software and technology.*
- *Guide the use of Internet for instruction in their school and provide mentoring to addition teachers in their schools during the year.*
- *Promote increases in science achievement, with ancillary improvements in Mathematical areas such as graphing and data analysis, and in areas of Social Studies such as Geography.*

Through this project, teachers and students participated in a variety of Internet-based and supported instructional sessions such as collaborative online investigations. As an initial venture, they were asked to locate and join a project that another teacher had already developed, was administering, and seemingly had the potential for a successful first effort. This might have been a national project, or a project with more local relevance. In either case the goal was to locate a project that was compatible with powerful instruction resembling something such as inquiry learning, problem-based learning, or engaged learning. After successful participation, they then were expected to develop a project that fit their curriculum and interest (having a single collaborating classroom as a partner was enough to consider the effort a success). In addition, teachers and students were to locate and compile web sites that supported their instructional efforts and provided access to current, and content-rich information, as well as, resources to directly use in teaching science, mathematics or social studies to children. In short, during this project teachers and students were to use the Internet as a tool for learning, as a way of communicating with others, and as a source of information for the content they are studying.

Program Design and Operation

Each year, the design and operation of the professional development program underwent transformation due to feedback from the participants, and evaluation efforts. During the first two years (1995-97), efforts began with an intensive one-week workshop in August. At that time, much less was known about how to effectively use the Internet for instruction. There were fewer established projects to join, and technological infrastructures at schools and at home were dismal compared to the present time. Internet service providers were limited, and the Internet was still largely a text-based environment. The web (with browsers and helper applications) was in its infancy, so activities and in-service topics included many aspects of using the Internet that are largely phased out of the current efforts (e.g. gophers, archie, and other supporting software such as separate picture viewers). Workshop efforts also included installation of modems and software, followed by testing to ensure that participants could take the machines back to their school or home and not be hampered by equipment or software difficulties (school phone lines were still a major problem). The August in-service sessions were followed by three half-day meetings during the school year (December, February and June) that served as checkpoints for accomplishing the expected tasks. The participants' first challenge was to locate, join, and complete a project, and then return to the December meeting ready to describe their efforts to the other participants. The February meeting served as another opportunity to meet and exchange ideas and solve problems, as well as to introduce more Internet-based teaching strategies and ideas. The June meeting served as a forum for the participants to describe the project they developed, and offer strategies and suggestions for success, as well as summarize their efforts to mentor other teachers in their building.

Mentoring and Developing a Community of Learners

The twenty-four teachers participating in year one were paired up with and expected to mentor a new group of twenty-four teachers during year two. In some cases, mentoring worked quite well. Mentoring was more successful if the mentor had successfully overcome and completed the technological and instructional challenges of year one. Occasionally, the year one mentor was less skilled than the year two teacher, in which case the year two teacher quickly located another, more skilled mentor, or mentored directly with the project director. The third year was similar in that we worked hard to facilitate electronic and in-person mentoring, and to further develop a project web site that supported the participants' efforts, disseminated their results, and served as one of the mechanisms to keep the community of learners together. The third year was different in that the initial August workshop session was shortened to a two-day institute with three follow-up days during the school year. While the in-service format of August and three follow-up days worked for years one and two, it was evident that year three participants needed more, and periodic contact to support their efforts. Electronic mentoring didn't seemed to satisfy their needs, and the time in between contact with their mentor was too long. It seemed that the mentors had to initiate most of the contact, rather than mentored teachers inquiring when necessary. Future efforts with a new group of teachers will include bi-weekly sessions throughout the school year. This will provide regular contact between instructors and workshop participants. Therefore, problems should get identified and solved much quicker and participants are more likely to achieve success in their first effort online. Perhaps this periodic in-person format will also develop the necessary personal relationships that will in turn foster greater success with electronic mentoring.

During the first three years, workshop participants were selected from all grade levels. This included middle and high school teachers who usually taught one of the subjects in math, science or social studies, as well as elementary teachers who taught everything including math, science and social studies. Was there enough of a common curricular bond between participants to foster optimal collaboration between teachers, and mentoring between year one teachers and year two teachers? Possibly not as many teachers were unified by little more than grade level. For example, specific topics taught were often personal favorites more so than components of the district curriculum. Therefore, even teachers from the same grade level lacked the curricular bond that might have aided them in joining forces and working together in developing and completing an online project.

Consequently, important modifications were made to the year-four program design that reacted to the importance of developing and supporting communities of learners. Efforts included developing grade-level specific sub-groups of teacher participants (fifth, eight, and Biology teachers) who will have a mentor teacher that is an experienced Internet user, was a participant from the first three years, and is a classroom teacher from that grade level. In addition, now that the district has defined a very specific and targeted curriculum for each grade level, there will be a common bond between the sub-groups of teachers and a focus of their Internet-instruction efforts. For example, the group of fifth grade teachers will focus their collaborative projects and resource location efforts to a few targeted science topics such as electricity, magnetism and ecology. Eight grade teachers will focus solely on the specific targeted eight grade curriculum topics.

Current Program Design & Operation

What follows describes the professional development and critical contact points of the most current program. The professional development activities consist of a two-day summer institute with scheduled, periodic follow-ups during the school year; electronic and in-person mentoring; and a project web site that supports the participants' efforts and disseminates their results.

Summer Institute in August: In order to accommodate the varying levels of Internet experience and computer usage we are incorporating a flexible schedule in addition to a variety of participant options. A breakdown of the main components are as follows:

Day 1: A review or introduction to basic Internet functions including web browser usage, sessions on advanced Internet skills; basics of collaborative on-line projects and associated teaching strategies; presentations from the pilot project teachers; data analysis and software introduction (tailored to grade levels, .e.g line graph, scatter

plots, stem and leaf graphs); mapping software; a demonstration of teaching using the Internet; as well as using the Internet for professional development and subject matter updates.
Day2: Examining existing projects both exemplary (Berg and Jefson, 1998) and in need of repair, looking for a project to join for the fall semester, planning projects; grade level planning meetings and coordination; using the Standards in instruction; powerful instructional strategies; optional - machine setup and technical support assistance for people who need help overcoming the technical glitches in utilizing on-line services (our application process will screen out participants from schools that don't yet have the technological infrastructure necessary to be successful).
Fall Semester: There will be 7 three-hour classes for each sub-group during the fall semester (September through December) with the focus on topics extending the initial work introduced in August on Internet-based instructional projects, as well as, work within grade-level groups to compile and share the teaching or curriculum resources obtained from the Internet. A session in mid-December will be used for the participants to share their project experiences and results, and to discuss what they have learned about participating in successful collaborative projects. These topics will help the participants evaluate the success of the first project and how to improve their approach to the second project which they develop and complete during the spring semester.
Spring Semester: The spring semester will follow the same format with seven sessions (January - June). The final session in June will be devoted to sharing the results of the projects the participants developed, or joined. They will also provide an overview of their mentoring efforts within their school building and perhaps bring the mentored teacher to the final meeting in June to listen to the participants describe their successful collaborative on-line efforts.
Contact Between Meetings: We plan to facilitate a large amount of informal communication between the summer institute and the follow-up meetings via E-mail, E-mail reflectors, and forums. The teachers have access to each other and instructors for sharing, guidance and collaboration. Workshop instructors compile project ideas from various sources and forward them to the web page coordinator who will paste them into the web pages under a listing of potential project areas, as well as forward them to the participants. In short, there is a large amount of contact between workshop instructors, mentor teachers and the project participants outside of the official workshop meetings. Note that the pilot project web page also serves as a major vehicle for support and dissemination of participant's efforts (http://www.csd.uwm.edu/~caberg).

Difficulties Faced

There were numerous challenges to overcome as teachers attempted to complete Internet-assisted instruction.

Challenge	Solution
1. Unfamiliarity with installation of software and use of modems.	a) Installation and testing of modems and software at workshop site.
2. Completing online collaborations with other schools when school Internet connection is non-existent or unreliable.	a) Encouraging various levels of Internet use including email interaction and method of accomplishing all aspects of the collaboration b) Using the home computer as the Internet connection and relay between the teacher's students and other classrooms.
3. Maintaining sufficient contact between participants and mentors.	a) Requiring participants to regularly check in via email to mentors (didn't work). b) Scheduling workshop meetings every two weeks during the school year.
4. Developing and maintaining communities of learners.	a) Focusing collaborative projects on targeted content for grade-level specific groups of teachers. b) Using Forum and Links software to facilitate discussion and compile useful URL's (Berg, 1998).

Outcomes

Internet collaborative projects appear to have fantastic potential to affect large numbers of teachers and students. Initial efforts have demonstrated the potential for significant and widespread impact on teachers and children far beyond the initial group. For example, just one of the past projects had over one hundred teachers respond to an initial invitation to participate in a collaborative online investigation. That collaborative effort not only included classrooms from Milwaukee, Wisconsin and other states, but also classrooms located in Europe, Canada, South America and the Pacific Islands. Students from the Saudi Embassy in Washington, D.C. were involved. While this is not the typical response, any project which puts students in Milwaukee Public Schools in contact with other children from different cities, rural areas or countries across the globe serves to lessen barriers of distance, culture and politics. The potential multiplying effect of in-servicing a group of teachers is tremendous - much more so than the normal teacher in-service project. For example, consider the broad participation from one of the collaborative projects (Fig. 1).

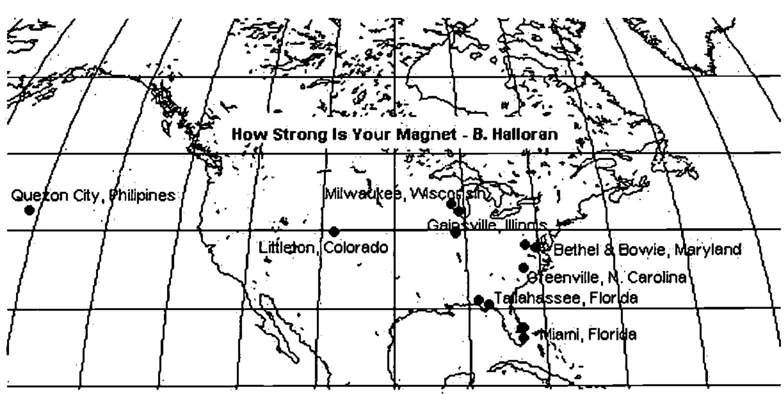

Figure 1. Map of Participants From the Magnet Project

As we looked for indicators of success, the following factors were of importance: successful efforts to mentor additional teachers; types of projects attempted and completed; numbers and locations of participants who join the collaborative projects; types of learning activities generated by the collaborative projects; how successfully the participants used the Internet to locate teaching resources or update content knowledge; and assessing the positive effect Internet usage had on developing the breadth of student knowledge within a specific content area.

The participants involved in this project have once again demonstrated that teachers who have access to tools for learning (in this case the Internet) can skillfully and artfully incorporate the Internet into research-based teaching in a manner that supports reform efforts. There is great potential for doing science and accomplishing the goals of reform, especially in the areas of developing global classrooms and learning communities, and increasing student knowledge through this interaction with science-related issues and problems. Many of the online activities foster use of technology with more powerful teaching strategies in which students are designing investigations, reaching conclusions based on the evidence collected, and comparing results with fellow students between schools and regions. This is what the science community does and science classes should reflect real science. The Internet supports this effort and is a superb tool for educational reform.

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Maximizing Use of Web Pages To Support Collaborative Inquiry

Dr. Craig A. Berg, School of Ed. The U. of Wisconsin-Milwaukee, USA, caberg@uwm.edu

Abstract: Science and mathematics teachers have demonstrated that the Internet can be utilized as a very successful tool for collaborative inquiry in which teachers and students in classrooms around the world carry out a common investigation, share data, compare conclusions, and in general interact around a common experience. However, accomplishing a successful collaborative inquiry can be challenging, depending upon the technological expertise of the person organizing the collaboration, the participating teacher's and their students' expertise, and/or access to hardware and software. This paper contains information about what we learned after four years of working with teachers who were doing Internet-based collaboration in a large urban district. We learned that there are many ways of helping all participants find collaborative projects to join, how to make it easier to join projects, how to automate the sharing of data between schools and how to facilitate discussions between project participants. Building these capabilities into a supporting web site can greatly ease the difficulty of completing a successful collaboration and entice novice Internet-based instruction teachers into joining and enjoying the experience.

Introduction

Most Internet-based collaborative inquiry efforts are now supported by a project web site and contain features that attempt to facilitate the inquiry process and foster the goals of the project. What are those features and how can a project administrator develop or modify a web site in order to maximize inquiry? An answer to this question is premature until the reader understands the author's perspective of collaborative inquiry in the context of exemplary science instruction.

Internet-based collaborative inquiry might be defined as one classroom interacting with one or more classrooms based on a science-related investigation or topic. There are many variations (Berg & Jefson 1998), including observing, sampling and analysis of wildlife, self-characteristics, environmental data, or resource awareness and consumption. Other collaborative activities may revolve around debates using science knowledge, or problem solving and engineering challenges. Yet, collaborations are often similar in that they provide experiences and opportunities for students to develop process-science skills and content knowledge that are common to Project 2061 (1989), Benchmarks for Scientific Literacy (1993), and The National Science Standards (1996). Collaborations should, and often do foster goals for students. For example, as a result of collaborative inquiry, students should further develop in terms of: 1) knowing how to identify problems as well as solving problems; 2) actively constructing knowledge from what they observe and experience during the science activities; 3) having positive attitudes about science and view science as having meaningful connections to their daily lives; 4) developing communication skills as well as an understanding of the nature of science; and 5) using their scientific knowledge to generate more questions or pose and assess potential solutions to science-related problems (Berg & Clough, 1991).

Many of the goals for students listed above are facilitated when students are immersed in exemplary instruction and actively participating in science-related activities. Exemplary science is often defined by what students are doing in science classes. For example, students are actively working toward these goals when they obtain real data, draw conclusions, interact and communicate with others about the investigation, compare and contrast ideas and results, and debate differences based on the merit of the data. It also involves asking questions, testing ideas, interpreting data, gathering information, challenging ideas, physically and mentally manipulating objects and experiences, working cooperatively with other students as well as independently; accessing and retrieving information, and using the existing body of scientific knowledge to investigate phenomena. Therefore, maximizing a project web page to support collaborative inquiry and exemplary science instruction means utilizing the goals and indicators listed above as guide-posts when developing Internet-based instruction.

District-wide Web Support To Maximize Collaborative Inquiry

One of the goals of the district-wide Milwaukee Telecommunications Project (Berg, 1998a) was to develop a web site that supported teacher's efforts to successfully complete an *Internet and Instruction* project.

Many components were useful and often necessary in order for teachers to locate, join, and complete a project (Tab. 1).

Table 1. Web Site Features That Support Teachers Who Are Developing Projects

Category Containing Links For	*Useful For*
Projects - Types and Examples	• Identified types of Internet activities and provided examples of each; participants could begin to understand the potential and diversity of Internet-based projects. • Found at http://lrs.ed.uiuc.edu/Activity-Structures/Harris-Activity-Structures.html
Project Registries and Clearinghouses	• Sites such as Global SchoolNet Foundation, I*Earn or Intercultural E-Mail Classroom Connections were listed so participants could easily locate projects.
Projects - How To	• Links to articles and sections that described how to successfully complete an on-line project such as Harris, 1995.
Projects - Concluded; In Progress; and Future	• Past, present and future projects so that participants could peruse and get a better understanding of well-developed and administrated projects.
Mapping Sites	• Provided for teachers and students so they could find appropriate maps pertaining to their study; project administrators might create a map of the project participants.
Standards and Reform	• Connections to Standards sites so teachers would have access to information on reform efforts.
Search Engines	• Links to individual search engines as well as to sites containing links to multiple search engines; a goal of the project was to have teachers fine tune their knowledge and skill level of searching techniques.
Compiled Lesson and Resource Sites	• Teachers were expected to locate and use resources obtained from the Internet. We provided them with an initial set of educational links.

Maximizing Web Page Development For Specific Projects

Perhaps one way to separate the various potential components of a project web page is by the type of student or teacher activity it fosters or supports. When examining various collaborative projects the following categories of activities and supporting components were identified.

Communication and Interaction

Communication and interaction between project participants might occur for several reasons. Examples include planning out details of data collection and investigative procedures, as well as modifying expectations and timeframes when the partners are from diverse backgrounds or locations. Participants also might need to discuss the project results and to query partners about disparate conclusions, or might want to

interact with an expert source of information such as a scientist who specializes in the area of inquiry. To support this type of activity, web pages might include the following (Tab. 2).

Table 2. Communication and Interaction Components.

Interaction Components	*Useful For/How*
1. E-mail buttons next to a list of participants	Participants can easily locate and contact any other participant.
2. A Forum area (for an expanded description see Berg, 1998)	Participants can leave questions, responses and interact in a public forum.
3. Talk to a scientist	Might be just an e-mail button connection, or the scientist might respond to questions in the forum area, or might be a video connection using CUSeeMe software.

Content-rich Connections and Decision-making

Many learning strategies in science immerse the student into a content and data-rich environment. Strategies such as Issues Analysis (Hungerford, 1990) and Cooperative Conflict (Simpson and Scott, 1992) have students searching for and sifting through information pertinent to the topic being investigated. Information may be in the form of content-rich web pages (zebra mussels or mutated frogs), pictures (maps of zebra mussel distribution), real-time or archive video-camera footage (nesting birds), quick-time movies, real audio files, or files containing current or archived data (stream quality). To support this type of activity, web pages might include the following (Tab. 3).

Table 3. Content Rich Connections.

Content Rich Connections	*Useful For/How*
1. Talk to a scientist	a. E-mail button, Forum discussions, or video connection.
2. Links to content-rich web pages	a. Suitable web sites are listed and actively linked. b. Web sites are compiled by the collaborative community using Links software (Berg, 1998b).
3. Real-time Images	a. Participants can view an activity in action, and collect data via direct observations.
4. Archived Images	a. Prior activities can be viewed.
5. Database of project-related data	a. Participant's data are listed individually or compiled into a master database.
6. Archived data	a. From prior year's activity. b. From scientists, industry or government agency.

Displaying Student Work and Artifacts

Some projects result in student-generated artifacts such as artwork, or reports that are published to the web (Tab. 4).

Table 4. Displaying Student-generated Artwork and Writing.

Displaying Student Work	*Useful For/How*
1. Artwork	a. Students trade or publish drawings of engineered designs, as well as draw invented animals that demonstrate adaptations or other artistic rendering of science-related things.
2. Writing student reports and publications	a. Students get involved in an original scientific investigation that project organizers display on the web site for public scrutiny. b. The Forum software can be used as a table of contents to many student-generated reports.

Teacher Support Area

While an inquiry activity is occurring, students should be the driving force and the main contributors to learning and decision-making. Yet, the teacher still has a huge role in this process, largely to ensure that an inquiry environment has been established, as well as the useful tools and ingredients for success are available when needed by the students. This requires some planning and forethought by the project administrator so fellow teacher-participants have the tools and support when collaborating on the investigation (Tab. 5).

Table 5. Supporting Components For Teachers.

Components Supporting Teacher's Role	*Useful For/how*
1. Project Description and Requirements	a. Distributed via text, movies and photos.
2. Mechanisms for sending and sharing data or information.	a. E-mail directly to individuals. b. E-mail reflectors (basically functions like a listserv; send an e-mail to one address and it is routed to all participants). c. Web site forum. d. Stored directly on web site.
3. Teachers manual	a. Contains the necessary supporting material; might include connections to science education standards.
4. Project-related news and announcements	a. Information for project participants is highlighted and disseminated in a key area that contains time-urgent information.

Examples of Web Sites Containing Supporting Mechanisms

The following web sites contain some or many of the components described above and listed in tables 1-5. Examining these web sites will provide the reader with a working knowledge of how these supporting mechanisms are used by various project administrators.

The Vernal Pool: http://earth.simmons.edu/vernal/pool/vernal_1.htm

Road Kill 98 Dr. Splatt: http://earth.simmons.edu/roadkill/rk_protocol.html

Plants – Ethnobotany: http://earth.simmons.edu/plants/plants_protocol.html

View Nesting Birds: http://www.pitt.edu/~dziadosz/

Biological Timing Online Science Experiment: http://www.cbt.virginia.edu/Olh/

Journey North Tulips: http://www.learner.org/jnorth/fall1998/tulip/index.html

Genetics MiniUnit: http://www.netlabs.net/hp/ebend/genetics.html

Acid Rain: http://earth.simmons.edu/acidrain/acidrain.html

Global Water Sampling Project: http://k12science.stevens-tech.edu/curriculum/waterproj/index.html

Boil, Boil, Toil and Trouble: The International Boiling Point Project: http://k12science.stevens-tech.edu/curriculum/boilproj/index.html

Worldwide Eratosthenes Experiment: http://www.eduplace.com/projects/eratos.html

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An Analysis of Online Projects for Math and Science

Carol Brown
Instructional & Curriculum Leadership
The University of Memphis
United States
cabrown@memphis.edu

Deborah L. Lowther, Ph.D.
Instructional & Curriculum Leadership
The University of Memphis
United States
Lowther.deborah@coe.memphis.edu

Abstract The purpose of this study was to determine how Internet online projects provided opportunities for solving real-world problem tasks using data from the Internet within a collaborative learning environment. The study used a qualitative analysis of a variety of projects that were available via the World Wide Web (WWW). The results indicate that if teachers want to effectively use online projects for inquiry learning within a group dynamic, they should (1) plan for students to generate new learning as a result of integrative and elaborative activities that include problem identification and reflective dialog, (2) plan culminating activities that will result in artifacts that reflect the newly generated learning, and (3) design problem statements based on real-world events in which students can sift and sort through data to generate their own solutions.

Introduction

Life rarely presents problems that can be solved using a straightforward cookbook approach. Traditional approaches that encourage students to learn facts and apply principles within a sterile scenario have often failed to develop adequate problem solving skills for the work environments of today. Some teachers are addressing this problem by incorporating Internet-based problem-solving projects into their classroom curriculum.

Many of the Internet online projects are designed to help students use authentic data from the real world (Lynch & Walton, 1998; Oliver, 1997). These are designed to lead the student from just doing science experiments to solving problems using data. Oliver (1997) has examined a variety of online projects and websites to determine their versatility and effectiveness in the classroom. He found that many classrooms used cooperative groups to brainstorm, formulate problems, and gather information before collaborating with partner schools or online experts. The projects added to their knowledge base while providing rich multicultural information exchanges with other students. By exchanging ideas with students from distant locations, students focus on their own lives within the context of many diverse perspectives. They used these enriched knowledge bases to produce artifacts that could be placed on display for peers and parents.

Problem Identification

Research indicates that not all Internet projects support higher level learning for students. Sugar and Bonk (1995) did an analysis of online dialog between high school students and experts in the area of environmental issues, and they found that students were able to view issues from a higher perspective, but interacted only minimally with their peers. They also found that factual questions posed to the online experts were nonchallenging and only required lower levels of thinking.

Windschitl (1998) has expressed concern about the lack of empirical research in the area of Internet-based projects and the effect on student learning. Currently, most publications have only reported anecdotal information about successes and failure at various sites. There has also been considerable information published about technical issues and project planning, but little on the relationship between "technology, pedagogy, project-oriented curricular, and student learning" (p.28).

The purpose of this study was to determine how online projects provided opportunities for solving real-world problem tasks using data from the Internet. Three questions must be answered to determine the effectiveness of these projects for classroom use. First, does the content and design of online projects give evidence of problem solving strategies that include problem identification, gathering of data, analysis of data, and drawing conclusions? Second, what is the quality of products being generated by students involved in online projects? Do these products give evidence of new knowledge construction and original ideas? Last, are dialog exchanges rich in cognitive scaffolding? Using interdependence and information sharing, are students able to develop a variety of cultural perspectives?

Method

The method used for the analysis of online projects was a qualitative analysis of a variety of projects that are available to any classroom teacher with access to the Internet and the World Wide Web (WWW). Waugh, Levin, and Smith (Windschitl, 1998) describe three types of collaborative activity which served as the basis for selecting projects for use in this study. These can be categorized according to the design and function of the project. The first category is loosely structured and allows creativity and freedom for knowledge exploration but, according to Windschitl, may result in incomplete projects. The Global SchoolNet sponsors this type of project. The second category is more formalized and is based on Riel's (1994) *Learning Circles*. These projects are sponsored by AT&T Learning Network and are diverse in design and purpose. Professional staff is available to offer guidance and support to the teacher, reducing the chance that a project will fade before culmination. The third category includes sophisticated projects that my not provide the opportunity for the creative exchange of ideas or analysis of data. One example of this category are the materials publicized by the National Geographic Kids Network. Many of the projects are designed and moderated by educational specialists who closely monitor progress by the participating schools. Using these three networks, a random sample of projects from each site was selected for analysis.

Procedure

A random sample of projects was selected from various sites that could be classified as one of the three categories. To ensure a representative sample from all online projects suitable for K-12 classrooms, nine additional sites were included in the study. The *Alta Vista* search engine was used to return a search for "online collaborative projects" from the WWW. *Alta Vista* was used because of its comprehensive search capabilities (Prosise, 1996). In a survey of the literature and from random "browsing of the web", the most common and popular project sites are selected and presented at the top of the "hit" lists returned by search engines. *Alta Vista* follows this pattern and was used to randomly select nine projects from the first return of hits Within these nine sites, a purposive (Patton, 1990) strategy was used to select projects identifying themselves as collaborative and investigative in design. Patton recommended purposive procedures when an additional criterion is needed for control of the sample selection. A total number of 75 projects were selected.

Using specific criteria from earlier research (Joyce & Weil, 1996; Jonassen, 1995), a rubric was developed containing seven major categories and 27 subcategories. A careful match was made between the project descriptions and each item in the rubric. An occurrence of a criterion within the project carried a value of 1. Thus, the maximum score possible for a project would equal the total number of criteria shown in the rubric. Points were not cumulative within an individual project. For example, if a project included online chats among students and experts in the field, 1 point was indicated on the tally sheet. Whether one or several experts participated from different locations, only 1 point was counted for this particular category in the rubric. The following criteria were used to analyze the data.

1. Activities that require students to develop problem identification skills (Molyneux, 1992).
2. Activities that require data collection from collaborating schools or distant locations (Riel, 1993; Jonassen, 1995).
3. Activities that require analysis of data (Joyce & Weil, 1996).
4. Activities that require that students draw conclusions or form hypotheses based on the analysis of their data.
5. Dialog or artifacts that encourage students to see a problem or issue from a variety of perspectives (Kaye, 1992).

6. Dialog exchanges or artifacts that encourage the exchange of information, especially information that is unique to students' culture or geographic location.
7. Dialog exchanges that promote personal accountability for project completion (Johnson & Johnson, 1989).

Results

The purpose of the study was to determine how effective online projects are at promoting problem solving and inquiry based learning. Not quite half of all the projects analyzed showed evidence that students would be prompted to identify the variables necessary to solve a problem. Though many of the projects contained other important criteria for collaborative inquiry, less than half asked for students to think critically and at high levels for this type of analysis. One half of all the projects did require data collection and over half required some kind of data analysis by making comparisons, identifying differences, and looking for patterns. The numbers drop to only 42% for projects that require students to form hypotheses and draw their own conclusions. Forty-five percent of the projects require students to engage in dialog or exchange artifacts that encourage multiple perspectives on the problem. Only 34% of the projects required that students take a different role, such as a tutor or mentor, during synchronous discussions. The lowest scores reflecting the criteria are in the last category with only 32% of the projects requiring students to generate an artifact, contribute data to a national database, or participate in an online "chat" as a culminating activity.

Data are presented in Figure 1. which shows a comparison among all the projects analyzed (n=75). A comparison, among the main categories defined for the study, clearly shows the predominance of Data Analysis (category III) while Generation of Artifacts (category VII) is the weakest representation of activities observed in projects

I. Requires student to identify variables within a problem.
II. Data collection from collaborating schools or from distant sites.
III. Analysis of data: comparing, contrasting, and looking for patterns.
IV. Forming hypotheses and drawing conclusions.
V. Dialog or artifacts that prompt students to see a problem from a variety of perspectives.
VI. Dialog or artifact exchanges that prompts student to take a different role, draw conclusions, or participate in an online discussion.
VII. Prompts students to generate an artifact, contribute to a national database, or participate in an online discussion.

Figure 1: Results of the analyses show that projects were strongest in prompting students to analyze data, compare, contrast, and look for patterns in data.

The projects tend to be polarized in their design, either strongly data collection and analysis or leaning toward social collaboration and discussions about the data rather than quantitative analysis of the data. The term *data*, for this study, should be defined as any student-collected measurements or student-generated artifacts. These would include such items as survey questions, open-ended interviews and creative writing that students post to a WebPages.

A more in-depth analysis for each category shows that Category I, *Identification of Variables Within a Problem*, was evenly divided across all projects. About half of the projects lead students to identify variables, define objectives, and ask "what do I need to know?' The weakest area was in prompts to define objectives or possible solutions (subcategory I.3). Category II, which involves activities for data collection and analysis, hovered around 50% for all projects. The strongest criterion was in collecting simple data and prompts to generate a chart or graph. Most projects were weak in asking students to use complex data and in generating an organized list from the data. The term *complex data* refers to data collections with changing values or data that contains many variables. Only 41% showed evidence for these criteria. Category III prompts students to compare and contrast data sets. Over half (67%) of all the sites required some type of comparison activity. This figure would reflect projects requiring simple, complex, or both in the data collection activities. Only 37% of the projects guided students to identify abnormalities in the data. Category IV shows that, as project activities become more complex, the number of projects that include these activities decreases. The more highly structured projects showed the most fidelity to higher level learning and rigor in the problem solving process.

One disappointing outcome from the analysis was the number of projects that prompt students to exchange cultural viewpoints within the problem. From the random sample selected, only 25 to 36% included activities to view social issues from a different cultural perspective. Many of the loosely structured projects posted requests for keypal exchanges from distant locations, however, there was little emphasis on exchanges in viewpoints within a problem.

Conclusions and Recommendations.

Using the rubric to assess the quality of a random selection of sites has revealed many outstanding projects for K-12 classrooms. In addition to the visual appeal of Netscape browsers, there were many projects that were interactive in that students could manipulate data online and in real-time. More sophisticated sites, like those sponsored by AT & T Learning Network, offered video, sound, and synchronous chats with NASA scientists. With these kinds of bells and whistles, motivation for young students could be a major advantage with online projects. There is still the question of whether they actually help students learn and transfer their learning beyond the classroom environment.

From this study, there is evidence that online projects often lack activities to extend thinking processes. Jonassen refers to the computer as a Mindtool (Jonassen, 1996). If the computer can be used as a tool for the mind, then thinking processes must be extended beyond rudimentary data collection and analysis (Walters, 1997). Too often projects begin with great zeal and energy, but fail to bring the learner to a constructed conclusion. Goals are formulated, hypotheses submitted, and plans are discussed within a group environment, however, some of the most important learning exercises are often neglected. Networked projects hold great potential for providing the extensions needed for producing rather than only reproducing knowledge (Jonassen, 1995).

The first recommendation for meeting this potential focuses on how learners process the data in order to solve problems and construct new learning. Theories for information processing support generative learning strategies. New information must be integrated into prior knowledge before the learner can generate new learning.

The second recommendation involves student performance within project activities. Every author, every actor, and every expert needs an audience for reflection and affirmation. This is motivational, but it is also important for accountability in learning (Riel, 1990, 1993, 1994). How we perform is a natural culmination to what we've learned. The new medium of websites and WebPages greatly enlarges the audience for our performance. Students might present their conclusions via electronic Science Fair (Levin, et al., 1989), or multicultural viewpoints can extend students' perspective on social issues through final reflections posted on a web-based newsletter. Many projects examined for this study displayed excellent planning and appropriate structure, but lacked creative opportunities for students to share culminating experiences with other project participants.

Finally, many of the projects began with an experiment designed to help students learn a particular concept or principle. Solving problems in the real world rarely begins with a list of particulars that neatly guide to a conclusion (the myth of the cookbook strategy). Problems begin with many variables and issues. Walters, in a report to the National Science Foundation (1997), found that students collect data to match the theory rather than examining variables that may apply to an open-ended question. When using inquiry-based strategies, the learner must first mine the vast resources available, define the variables, then suggest solutions and possible theories. A site that uses this type of inquiry learning was designed by

Bellingham Public Schools
[online:] Available: [http://www.bham.wednet.edu/online/smoking/smoke1.htm]).

This project leads students to question why people start smoking cigarettes. The project does not begin with commonly known facts about tobacco as a carcinogen that results in metastatic carcinoma, rather, students are provided with statistical information that leads to a problem statement. "Why do 3,000 American students start smoking everyday, and what can be done to reverse this trend?" Ample resources for collecting and analyzing data are provided at the project site. Project participants are instructed to gather, sort, and sift through information. Then, based on the selected data, students should summarize, synthesize, and make recommendations for reversing the trend for teenage smoking of tobacco. Students are even guided in personal reflections of why they may begin smoking and how they might stop. Reflective dialog among students from diverse cultural and socioeconomic backgrounds are the key issue here. Conclusions from the data can be refined or expanded in a more dynamic exchange of ideas than would be possible from one neighborhood, one school, in one geographic location.

In conclusion, when planning for effective online projects for inquiry learning within a group dynamic, participating teachers and project mangers should (1) plan for students to generate new learning as a result of integrative and elaborative activities that include problem identification and reflective dialog, (2) plan culminating activities that will result in artifacts that reflect the newly generated learning, and (3) design problem statements based on real-world events in which students can sift and sort through data to generate their own solutions. The extra effort will result in a new dimension for high level learning and reasoning for students in school classrooms.

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Effects of a Computer Literacy Course on Pre-Service Secondary Teachers' Attitudes and Self-Efficacy

Erdinc Cakiroglu, Cengiz S. Askun
School of Education
Indiana University

Hasan Karaaslan
Faculty of Education
Middle East Technical University, Ankara, Turkey

Abstract: The purpose of this study was to investigate the effects of a computer literacy course on the use of computer applications in school of education of a large Turkish university. A one-group pre-test post-test research design has been used. Results indicate that the course had a significant positive influence on pre-service teachers' perceived computer self-efficacy on course related specific tasks. However, no significant influence was observed on pre-service teachers' attitudes toward computers.

Introduction

Teacher education is one of the most important requirements in the development of the countries. This is especially true for the developing countries such as Turkey. With the advances of new computer and communication technologies, teaching computer literacy has become a mandatory element in the curricula of teacher education programs.

Turkey is in a process of introducing computers and Internet in its elementary and secondary education curricula. This is supported by a government project to establish computer laboratories, computer supported classrooms, and Internet infrastructure in schools. There have also been some efforts in the teacher education institutions in the same direction. However, no matter how eager the administration in the success of this project is, the success depends on a lot of variables. One of these variables is the availability of computer-literate teachers. If the system cannot produce teachers who are literate and confident in using computers, we cannot expect them to facilitate learning in computer-supported classrooms.

The recent changes in the teacher education programs in Turkey require every prospective teacher to take a course on computer literacy and the use of computers in education. In the Middle East Technical University (METU) the teacher education programs have been requiring students to take the course called "ScE300 - Computer Applications in Education" on computer literacy since 1993. This course was among the first in Turkey's teacher education institutions. The course format is 2 hours lecture and 4 hours practice with a guidance of a teaching assistant. The content of the course includes introductory computer skills, basics of operating systems, Internet applications, word processing, and spreadsheet applications. The course also includes teaching problem-solving skills with basic algorithms. Students' evaluation is based on their assignments in practice sessions and three written exams.

Self-efficacy

Self-efficacy has been defined as the individual's judgments in his/her performance capabilities for a particular type of task (Bandura, 1986). It usually refers to specific judgments in specific situations (Stipek, 1998). According to Bandura (1986) a person's judgments about his/her own capabilities affects his/her behavior more than any other cognition. Most of the time, people do not perform optimally even though

their knowledge about the task is sufficient. For example, "different people with similar skills, or the same person on different occasions, may perform poorly, adequately, or extraordinarily" (Bandura, 1986, p. 390) since self-referent thought mediates the relationship between knowledge and action (Bandura, 1986). Further, according to Bandura (1986), "competent functioning requires both skills and self-beliefs of efficacy to use them" (p. 391).

Confidence and self-efficacy of pre-service teachers in using computers is important in terms of several ways. Various studies indicate that perceived self-efficacy could influence individuals' performances. They influence the choices individual make, and the courses of actions they pursue (Sexton & Tuckman, 1991; Pajares, 1996). Efficacy beliefs help determine how much effort people will expand, how long they will preserve when confronting obstacles, and how resilient they will prove in the face of adverse situations. Individuals relatively high in self-efficacy set higher goals, chose more difficult tasks, and persist longer with task (Zimmerman & Bandura, 1994; Sexton & Tuckman, 1991). Hacket (1995) also found that self-efficacy judgments are even predictive of career choices. It means that, even if the teachers hold the necessary skills about computers, if they lack the confidence, it is likely that they will probably not use the computers in their teaching practices.

As the use of computers in educational settings getting increase in Turkey, educating teachers who can use computers in their teaching practices is as important as their content area or pedagogical knowledge. Reporting the results of the study, the researchers hopes to contribute to the research base regarding the use of computer technologies.

Our aim in this study was to investigate the effect of this course to the perceived computer self-efficacy and attitudes of pre-service teachers towards the computers using the subscales of comfort/anxiety, and usefulness. The particular questions that this paper focuses are "What is the effect of the course 'Computer Applications in Education' on the students' perceived self-efficacy in certain tasks of word processors, spreadsheets, and Internet applications (e-mail and WWW)?"; "What is the effect of the course 'Computer Applications in Education' on the students' attitudes toward computers?"; "Is there a difference between the effects of this course on perceived self-efficacy and attitude scores of female and male students?"; and finally "Is there a difference between the effects of this course on perceived self-efficacy and attitude scores of students from different teacher education major areas?

Method

A one-group pretest-posttest design was used in the study. The pretest was administered at the beginning of the semester using paper-pencil instrument and the posttest was given at the end of the semester in the same format.

Subjects

The subjects of this study were all the students who were enrolled to take the ScE300 course in 1998 Fall Semester. Participation in the study was voluntary and confidentiality was guaranteed. The test was administered to about 160 students who were mainly in their sophomore or junior years from different teacher education major areas. However, only 81 of these students included their names in their responses that allowed us to use the data in the final analysis. Table 1 shows gender and major area distribution of the subjects.

Of the 81 subjects, 57% has not taken computer courses while 37% taken only 1 course, 6% taken 2 or more courses directly related to use of computers prior to taking the course ScE300. About 44% of the subjects had access to a computer at their homes or dormitories. More than half of the subjects (56%) responded in the posttest that they have used computers about 1 to 3 hours per week other than their required lab work.

Major area of study	Gender		Total
	Female	Male	
Foreign Language Education	29	6	35
Science Education (Physics, Chemistry, and Biology)	18	17	35
Physical Education And Sports	2	9	11
Total	49	33	81

Table 1: Major area of study versus Gender.

Instrument

As an instrument, we used the *Attitude Towards Computer Technologies Survey* developed by Delcourt and Kinzie (1993). The Likert type questionnaire composed of two main sections namely attitude and self-efficacy. The attitude scale includes the subscales of comfort/anxiety and usefulness. An example comfort/anxiety subscale statement is: *"I feel comfortable about my ability to work with computer technologies."* An example to the usefulness subscale is *"I do not think that computer technologies will be useful to me as a teacher."*

The instrument also includes a self-efficacy section, modified from its original version developed by Delcourt and Kinzie (1993), for the tasks in word processors, spreadsheets, and basic Internet applications. The original version included statements from word processing, electronic mail, and CD-Rom databases. However, in the modified version, self-efficacy section additionally includes statements related to spreadsheets and Internet applications excluding CD-Rom databases. These sections are the three of the major topics in the ScE300 course at METU. A sample statement for the word processing is *"I feel confident using the search feature in a word processing program."*

Internal consistency reliability estimate for the overall attitude scale was .88. The reliability of individual comfort/anxiety scale was .86 and that of usefulness was .79.

Results

For the first two research questions, *t*-test analysis has been used to see effects of the course on self-efficacy, comfort, and anxiety. The result of the test is shown in Table 2. The analysis indicates that the course did not have any significant influence on students' comfort/anxiety and usefulness scores. For the three subscales of the self-efficacy section, on the other hand, the mean scores of students for word processor ($p < .001$), spreadsheet ($p < .001$), and the Internet ($p < .01$) significantly increased at the end of the course.

Table 3 shows the mean scores of female and male pre-service teachers in both tests. The comparison of pretest and post-test mean scores of females and males in both comfort/anxiety and usefulness subscales resulted in no significant difference. The t-test results indicated a significant increase in female scores on three self-efficacy subscales after the course. However, for pre-service male teachers, only the word processing self-efficacy scores have shown a statistically significant increase. The Internet and the spreadsheet self-efficacy subscales indicated no significant difference between pretest and posttest scores of the pre-service male teachers.

Scales		Mean	SD	N	T
Comfort/Anxiety	*Pre*	3.73	.714	79	-.075
	Post	3.74	.674		
Usefulness	*Pre*	3.89	.427	79	.830
	Post	3.84	.520		
Word processing	*Pre*	3.38	.831	73	-6.557**
	Post	4.01	.681		
Internet	*Pre*	3.67	.912	73	-3.573*
	Post	4.07	.680		
Spreadsheet	*Pre*	2.81	1.160	79	-5.453**
	Post	3.63	.867		

***NOTE:** Higher scores indicate positive attitude to self-efficacy. The highest possible score is 5 and the lowest score is 1.*

* $p < .01$
** $p < .001$

Table 2: Mean scores of all students in pre- and post-test.

		Mean			
Scales		**Pretest**	**Posttest**	**N**	**T**
Comfort/Anxiety	*Female*	3.60	3.68	49	-0.770
	Male	3.96	3.84	30	1.062
Usefulness	*Female*	3.86	3.88	49	-0.251
	Male	3.93	3.78	30	1.643
Word Processing	*Female*	3.25	3.98	45	-5.144**
	Male	3.58	4.06	28	-4.564**
Internet	*Female*	3.64	4.03	45	-2.889*
	Male	3.72	4.14	28	-2.099
Spreadsheet	*Female*	2.51	3.51	48	-5.690**
	Male	3.26	3.83	31	-2.077

***NOTE:** Higher scores indicate positive attitude to self-efficacy. The highest possible score is 5 and the lowest score is 1.*

* $p < .01$
** $p < .001$

Table 3: Mean scores of female and male students in pretest and posttest.

The mean scores of female and male students in both tests were also compared. The comparison shows that the mean scores of female students were always lower than that of male students in pretest. However, the difference in pretest scores of female and male students was significant only in spreadsheet self-efficacy scale ($p < 0.01$). The mean scores of female students in the posttest, on the other hand, were higher than that of the male students in usefulness subscale. However, this difference was not statistically significant. There was no significant difference between female and male students in any scale in post-test.

The t-test analysis based on the major area of studies is shown in Table 4. The mean scores of foreign language education (FLE) students in comfort anxiety and usefulness scales did not show any significant

change between pre-test and post-test. On the other hand, there was a significant increase in the word processing, Internet, and spreadsheet self-efficacy scales. For the science education (SCE) students, the mean scores of word processing and spreadsheet self-efficacy scales in the post-test was significantly higher than the pre-test scores. Finally, no significant difference between the pre- and post-test scores of physical education and sports (PES) students was observed in any scale.

Comparing the mean scores of the three major areas in the posttest did not indicate any significant difference between FLE, SCE, and PES students.

		FLE		SCE		PES	
Scales		Mean	T	Mean	T	Mean	T
Comfort/Anxiety	*Pre*	3.62	-1.142	3.96	.767	3.38	.264
	Post	3.75	-1.142	3.86	.767	3.30	.264
Usefulness	*Pre*	3.96	-.228	3.86	.712	3.70	1.110
	Post	3.98		3.80		3.49	
Word Processing	*Pre*	3.27	-5.748**	3.59	-3.392*	3.03	-1.977
	Post	4.08		3.99		3.84	
Internet	*Pre*	3.48	-3.814*	3.84	-1.644	3.74	.264
	Post	4.17		4.09		3.67	
Spreadsheet	*Prc*	2.33	-7.746**	3.08	-3.100*	3.54	.785
	Post	3.64		3.78		3.11	

***NOTE:** FLE: Foreign language education, SCE: Science education, PES: Physical education and sports.*

* $p < .01$
** $p < .001$

Table 4: Mean scores of pre-service teachers based on the major area of studies.

The Pearson correlation coefficients between the attitude subscales and self-efficacy subscales were also calculated to see the relationship between them (Table 5). The correlation coefficients between all of the scales were significant.

	Comfort/Anxiety	Usefulness	Word Processing	Internet
Usefulness	.643** *(N=80)*			
Word Processing	.437** *(N=77)*	.463** *(N=77)*		
Internet	.332** *(N=77)*	.255** *(N=77)*	.558** *(N=77)*	
Spreadsheet	.474* *(N=80)*	.361** *(N=80)*	.640** *(N=77)*	.518** *(N=77)*

* $p < .05$
** $p < .01$

Table 5: Correlation coefficients between attitude and self-efficacy scales.

Conclusion

As explained in the previous section, there was no change in the comfort/anxiety and usefulness scales in any of the gender and major area of study groups while there was increase in self-efficacy mean scores. The self-efficacy section in the questionnaire was asking students to rate their confidence in attaining specific tasks, for example, "replying to an e-mail message." The selected tasks were parallel to what they were doing during the laboratory practice sessions. Having direct experience with these tasks during the course could be a reason for increased self-efficacy scores. On the other hand, comfort/anxiety and usefulness

scales were composed of more general statements about how they feel and believe about computers. Possibly, the time spent between pre-test and post-test was not sufficient to change such general views. Moreover, for most of the subjects, the course was their first experience with computers, which could be another reason for observing no significant change between pretest and posttest scores for the comfort/anxiety and usefulness scales. Their overall limited experience with computers might not be sufficient to change their attitudes towards computers.

There was not any significant difference between the post-test scores of female and male students. The course had significant influence on female students' spreadsheet self-efficacy, while it did not have any on male students. This could be explained by the considerably lower pre-test scores of female students. The existing gap between the female and male students' spreadsheet self-efficacy prior to the course was closed by the time post-test had been administered. Similarly, the course had different influences on the self-efficacy scores of the students from different majors. At the end of the course, there was no significant difference between the scores of students from different majors.

Future research should continue the relationship between the student-student and student—instructor interaction to further understand the effects of a computer literacy course on attitude and self-efficacy. Moreover, understanding students' general computer beliefs and perceptions of computer related tasks would provide more meaningful attitude and self-efficacy measures.

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The Interaction Between Content and Technology: Tools Transforming Teaching

Patrick Callahan
Callahan@math.utexas.edu

Systemic Research And Design Center
for Mathematics, Science and Engineering Education
The University of Texas at Austin
United States of America

Abstract: This paper will discuss the design and theoretical framework for a series of new courses for pre-service secondary mathematics teachers. These courses take a hard look at the interaction between the mathematics content and technologies in the classroom. Active engagement in mathematical modeling plays a crucial role in framing and mediating the teachers' experiences. We focus on how the tools shape the mathematics itself. These courses are part of a new teacher preparation program at the University of Texas at Austin.

Introduction

The inadequate and ineffective use of technology in the classroom is well documented. The President's Committee on Advisors on Science and Technology (PCAST, 1997), states "...new teachers typically graduate with no experience in using computers to teach and little knowledge of available software and content." The Office of Technology Assessment Report (OTA, 1995) describes the situation as "Overall teacher education programs in the United States do not prepare graduates to use technology as a teaching tool." A recent study by the ETS Policy Information Center (Wenglinsky, 1998) showed that how technology was used in the classroom made a significant difference on student achievement. They reported that although "Teacher's professional development in technology and the use of computers to teach higher-order thinking skills were both positively related to academic achievement in mathematics and the social environment of the school... The use of computers to teach lower-order thinking skills was negatively related to academic achievement and the social environment of the school."

The situation is not surprising considering that the teachers themselves receive little if any training in the use of technology. In particular, when pre-service teachers learn about technology it is often disjoint from any particular content area. Students are required to pass "proficiency" exams where they must demonstrate competence at such tasks as saving a file on a disk, changing fonts on a word processor, or sending email. These are all considered general computer literacy and avoid having any specific subject matter specificity. On the other hand, mathematics courses at the university are typically devoid of technology. Thus, pre-service teachers and students in general are not receiving any instruction on how to effectively use technology in their instruction or their studies.

The UTeach program

At the University of Texas at Austin the College of Education and the College of Natural Sciences have collaborated to design a new secondary teacher education program. This program (the UTeach program) is now in its second year. Through a combination of policy efforts, early and aggressive recruitment, and development of exemplary field and content courses, the program intends to provide the leadership for catalyzing a statewide response to the shortage of qualified secondary mathematics and science teachers. The hallmarks of this program include 1) a variety of early guided field experiences that are supervised by master teachers, 2) use of emergent learning and communication technologies in both education and subject-matter courses, 3) particular attention to issues of equity, both as they affect student recruitment and support as well as program content, and 4) the development of exemplary undergraduate courses that model Standards-based instruction and effective use of

technology. These content courses are a combined effort by faculty in the College of Education and the College of Natural Sciences. The goals of these courses are to:

- Model effective pedagogy using technology as a tool to engage and shape content.
- Have students participate in rigorous and deep mathematical activities.
- Have students deepen their own understanding of the content they will likely teach.
- Have students reflect on their own learning and knowing.

Modeling effective pedagogy is of extreme importance. Often the subject courses closest to the secondary level are taught in large lecture formats and treated in a very superficial manner. Our goal is to provide courses which model pedagogy which could be used in the high school classroom. The way teachers teach is greatly influenced by the way they themselves were taught. Our courses demonstrate and allow the students to participate as learners and observers in a variety of group activities, problem solving, and class discussion techniques.

A criticism of many mathematics courses designed for pre-service teachers is that they tend to water down or trivialize the mathematics. If any group of students need to understand mathematics at a deep level it is the teachers. In addition, research shows that students in traditional mathematics classes tend to develop very little conceptual understanding (Monk, 1989). This has been shown even for the top students (Carlson, 1998). Thus, mathematics majors and particularly pre-service teachers are often receiving degrees without ever engaging deeply with rigorous mathematical content. Our goal is to provide courses where this can happen.

There is a pervasive belief in many mathematics departments that the best way to prepare teachers is to have them take many advanced mathematics courses. Although taking advanced mathematics is not a detriment, there has not been evidence that it has any impact on the effectiveness of teachers. We feel that much of this has to do with the disconnect between then content of advanced mathematics courses at the university and the mathematics which is generally encountered at the secondary level. Having a course in algebraic topology in college does not seem to help one teach algebra in high school. Our goal is to have pre-service teachers engage deeply with the mathematics of the secondary level. We also do not view content as a list of topics to be covered. In light of the use of new technologies the content itself is being transformed. We will discuss this more below.

Finally, it is crucial that students reflect on their own learning and what it means to know something. Part of the design of the UTeach program is that pre-service teachers take a special course on "Knowing and Learning" during their first two years. This course focuses on the latest theories of cognition and pedagogy. Students then can uses these frameworks to analyze their own development.

To date, the first of the proposed exemplary content courses, Functions and Modeling, has been piloted and is on its second iteration of revision. The next course in the pipeline is Geometry and Visualization, which is planned for Fall 1999. Other courses include Biometry and Applied Physics and Engineering.

Functions and Modeling

This course is designed to focus on topics typically found in algebra, trigonometry, pre-calculus, and calculus. One of the major themes is that of modeling. Students investigate a wide variety of problems ranging from sequences of integers to computer simulations of population dynamics to analyzing bouncing balls with motion detectors. The emphasis is on having the mathematical structures emerge from the phenomena. This is in contrast to the more common practice of introducing mathematics abstractly and "applying" it later. Students grapple with why the height of a bouncing ball decays exponentially within the framework of such questions as "What makes a particular situation exponential?" and "What is special about quadratic functions?". Students move back and forth between qualitative and quantitative approaches. There has been a great deal of research in qualitative calculus and graphical environments (Stroup, 1998). One of the challenges of this course is to make the transition between qualitative and quantitative or more analytical techniques. Attempts in this direction include Interactive Diagrams (Confrey, Castro-Filho, and Maloney, 1998) and FunctionProbe (Confrey and Maloney, 1998)

FunctionProbe is a particularly powerful program which allows users to move between several representational environments. In Figure 1 below shows the Graph window and the Table window. This software proved to be an important tool. Students would often collect data from a situation, place the data in the table, then

analyze the data using differences and ratios. Points can then be sent to the Graph window where they can be manipulated and transformed geometrically. The use of tables was a very powerful tool, not just as a bridge between the qualitative and quantitative but as a way to explore and understand various mathematical structures. But this will be discussed at a later date.

FunctionProbe Screen

Figure 1.

Other software that was used included StarLogo and Geometer's Sketchpad. Both of these programs are very open ended and allow for a wide range of student models. The important fact to keep in mind is that the technology and the software was used as tools for investigating and generating questions. It is insufficient to view technology as a means of "illustrating" mathematics in the way that diagrams in a textbook illustrate mathematics. Technology not only shapes the way we view mathematics but transforms the mathematics content itself. We stress the importance of activities which engage the students in a rich tableaux of mathematical experiences

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Improving Qualitative Understandings on Mathematical Representations in Kinematics

Cheng-Chih Chien
Department of Educational Technology
Tamkang University
Taiwan, ROC
Email: cchien@mail.tku.edu.tw

Abstract: The article describes how a web-based courseware is developed to help students convert abstract symbols into real world phenomena. The Chain Model integrating content domain needs, active learning, and web-based interactive simulations for kinematics courseware design is described. A common problem in learning kinematics is that students exercise equations and graphs as mathematical problems without knowing how these representations are related to real motion. The courseware is used in a cooperative learning environment to engage students in an active learning process. The benefits of using web-based instruction with Java components are also discussed.

Introduction

For many students, the equation of motion is learned in high schools or is the entry knowledge in a college introductory physics course. The commonly seen exercises found in textbooks are like: "Given $x = t^2 - 2t + 3$. When $t = 5$, what is x?" Most students in a high school physics course can answer this type of problems without difficulty. However, if we ask students the following question: "Now that the above equation is called an equation of motion and represents the motion of an object, can you describe (qualitatively) how this object actually moves?" Even college science and engineering majors may not be able to answer correctly.

The above example shows that spending a lot of time on exercising algebra does not necessarily help students improve understanding. On the other hand, many textbooks focusing on conceptual understanding try to avoid mathematics. These books are usually used by non science-and-engineering students. Do mathematics and conceptual understanding have to be separated in a science class? Can we help students improve physics understanding through mathematical representations? The following of this article describes the design model of the courseware and how these design principles are implemented in the classroom learning activities.

Courseware Design Model

This courseware is developed with the Chain Model for technology-based instructional design (Chien 1997), see [Figure 1]. In this model, content domain needs, instructional strategies, and educational technologies are linked as a chain to support the other elements. Among the three elements, an instructional developer should first identify what students will learn and what kind of problems students might have during the learning process. Then appropriate instructional strategies are carefully selected to help students effectively achieve the learning goals of the content subjects. Finally, educational technologies are incorporated into the design to both facilitate the selected strategies and illustrate the contents with the special features of the technologies.

In this kinematics courseware, the material development focuses on two common problems. First, students regard the "equation of motion" as mathematical exercises. Once familiar with the algebraic or derivative activities, they consider this chapter is finished. How these "equations" represent the "motion" is not discussed in kinematics. Second, many students interpret kinematic graphs as the track of the real motion (Beichner 1994). For example, if we ask students to describe the motion of a standard equation like $x = t^2 - 2t + 3$ after learning kinematics, most students would not be able to answer this question. Some students would respond

that this object moves in a parabolic curve, with which they are confused by the kinematic x-t graph. (In fact, this equation has only one spatial variable x. The equation itself would not describe a two dimensional motion such as a parabolic motion but a linear motion.) The goal of this courseware is to help students realize the meanings of the abstract symbols (equation and curve) used in kinematics and further learn to convert the descriptions of motion from one representation to another.

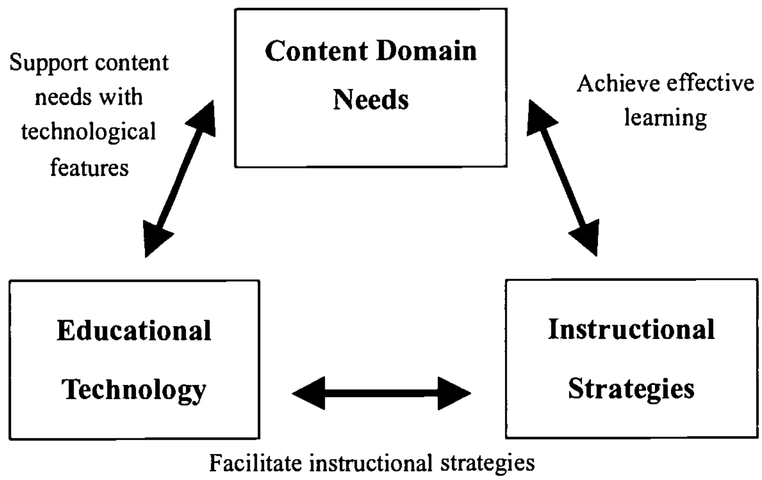

Figure1: The general Chain Model for technology-based instructional design.

From the constructivist perspective, learners must actively construct the meanings to achieve effective learning (Osborne & Wittrock 1983). For kinematics, it is unlikely to have students fully understand the concepts by simply viewing the contents. In this courseware, the learning activities are directed by worksheets after the basic concepts are introduced to students. The questions are organized into two stages to engage students in the learning process. In the first stage, a series of simple questions are designed for students to practice the basic concepts. In the second stage, students are directed to review their own answers to discover high-order rules.

For the technology element, computers are selected to support the content needs and the instructional strategies. One important feature of computers is the capability to transform one type of symbol system into another (Dickson 1985). For example, with an appropriate software program, a computer can convert a set of numerical data into a pie chart or a curve for different purposes. For kinematics, it is important to help students realize that abstract symbols such as equations and curves are just different representations used to describe a real motion. Computers not only provide visualized animations to illustrate the motion, but also allow students to manipulate the motion by controlling the equations. The structure of the three elements in the Chain Model for kinematics is illustrated in Figure 2. The following sections discuss how these features are implemented in the web-based courseware for kinematics.

Learning Activities

The kinematics courseware is developed for science and engineering freshman students and composed of six units. The first three units introduce how mathematical equations, motion diagrams, and kinematic graphs are used to describe motion. Units 4, 5, and 6 help students convert equations into motion diagrams, motion diagrams into kinematic graphs, and kinematic graphs into equations (and vice versa for all three units).

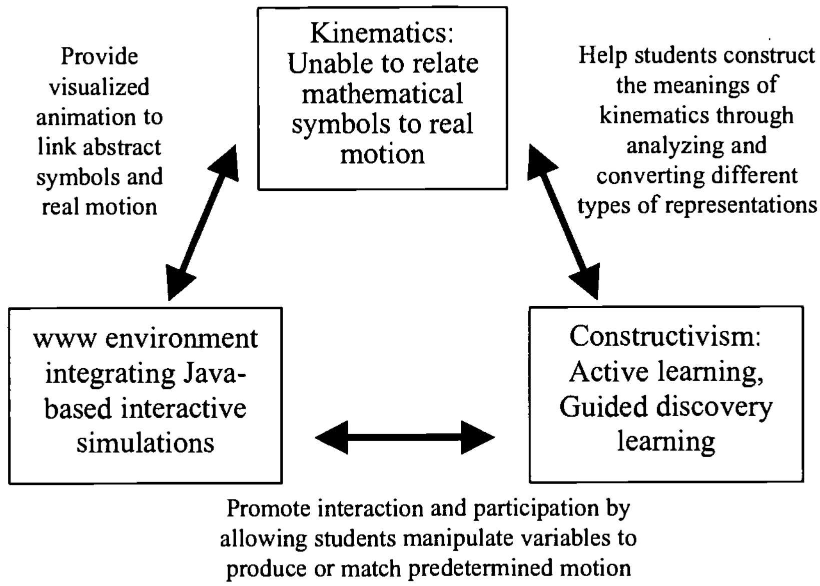

Figure 2: The Chain Model for the conceptual understanding, web-based interactive simulations, and active learning in kinematics.

In the Unit 1 "Equation" activities, students are first introduced with that the coefficients of the equation of motion represent the initial position, the initial velocity, and acceleration. Then an example is given for students to analyze these coefficients. In an example, a car is 10m away from the wall. The car initially moves at 3m/s toward the wall and slows down gradually at the rate of $0.5 m/s^2$ (Figure 3). This motion is described with different coordinates. After finishing three exercises, students find that the same motion may appear to be different equations when the origins and/or the directions of the coordinate are defined in different ways. Later, students are shown that the same equation may represent different cases of motion. These activities help students realize the meanings of the equation, as well as why these equations must be recognized but not memorized.

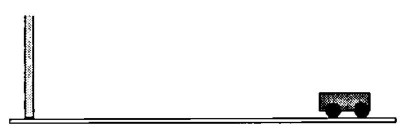

Figure 3: A simple car motion problem used to illustrate that the same motion can be described in different equations.

In the "Motion Diagram" activities, arrows (→) are used to describe the motion (Figure 4). This unit focuses on: (1) how acceleration affects the magnitude and direction of the velocity, and (2) how the sign of the acceleration is determined. Many students believe that when an object is speeding up, the acceleration is positive; when an object is slowing down, the acceleration is negative. These activities help students build up a mental image corresponding to the word descriptions of motion.

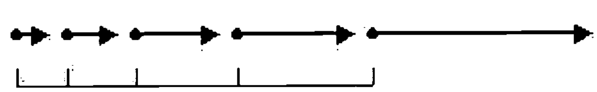

Figure 4: Arrows used to build a mental image of velocity and determine the directions of the acceleration.

After building a mental image of motion, the "kinematic graph" activities help students learn to describe a

motion with graphs. For a constant acceleration motion, students have very few problems with a-t and v-t graphs. For x-t graphs, a constant velocity motion (with straight x-t line) is used to help students determine what types of curves the x-t graphs are with changing velocity. After learning the three individual representations (equation, motion diagram, and kinematic graph), students then learn to convert one type of representations into another in Units 4, 5, and 6.

Instructional Strategies

The courseware is used in the recitation session after the fundamental concepts are introduced in a lecture. With basic understanding on kinematics, students are guided by accompanying worksheets to answer a series of questions to find the target solution. The purpose of this activity design is to engage students in the problem solving process as active participants, rather than passive viewers. For the same example discussed in the "Equation" activity, if we simply tell students that a motion can be described in three (or more) different equations, this fact may confuse students. In the courseware, students are directed by the activities in the worksheets to analyze the initial positions, initial velocities, and the accelerations with different coordinates to complete the equations. Then they are reminded to review the three equations developed by themselves. The students would realize the reason that the same motion can be described by different equations.

The courseware can be used in two ways. In a computer laboratory, students work in groups of three. When working with the courseware, each student makes his or her own predictions on the worksheets first. Then they discuss their individual answers in their groups. Finally they run the computer to check their answers and reconcile the differences. The courseware can also be used in a classroom with a computer and a LCD projector. Students do the same activities as in a computer laboratory. The only difference is that the instructor waits until most students finish their predictions and then runs the program.

Educational Technology

The courseware is a web-based instruction program. The key components are interactive simulations developed with Java language. There are several benefits using Java-based simulations in a WBI courseware. First, the interactive simulations help students understand the meaning of each representation through manipulating the variables. For example, in Unit 4 "Equation vs. Motion Diagram" activity, students are given a ball moving in a pre-specified way. A small car controlled through manipulating the equation is also presented in the simulation. The goal is to match the car's and the ball's motion (see Figure 5). If the car and the ball are not moving in the same manner, students will check the motion, determine how the motion should be changed (such as "shift a little left" or "move a little faster"), then modify the corresponding variables and try again. In this way, students will be guided to engage in more thinking activities to relate symbols and real motion than simply receiving feedback such as "Yes, you got the right numbers" or "No, try again." Second, using Java to develop the simulations can help control the file size to reduce the downloading time. Some of the simulations may be replaced with animations produced with authoring tools such as Director. These animations are much larger than Java simulations (a typical Java file is less than 10k in this courseware). The courseware contains six units and more than twenty examples and exercises; and the entire package can be placed in a floppy disk. Many simulations allow instructors or students to enter their own variables to create new problems. Therefore the learning activities are not limited in the given examples. However, programming Java codes is much more difficult than using an authoring tool.

Summary

This article describe the design of a courseware to help students realize that various symbols such as equations and kinematic graphs are just different representations used to describe motion in kinematics. The capability to relate abstract symbols to real world phenomena is very essential in further physics learning. If students do not realize the meanings of all those equations and graphs, the more physics they learn, the more they believe that physics is difficult and useless. In the fact the ability to read graphs and other representations is also

very important in engineering, social sciences, finance, et al. Similar courseware covering other physics topics will be developed in the future.

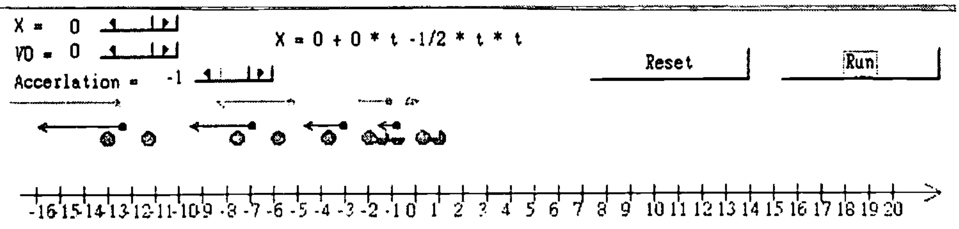

Figure 5: Students observe the difference between the motion of the ball and the car. Then they modify the variables in the equation accordingly so as to match the motion.

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Approaching Effective Network Cooperative Learning

Chiung-hui Chiu, Graduate Institute for Computer and Information Education, National Tainan Teachers College, Taiwan, R. O. C., cchui@ipx.ntntc.edu.tw

Huan-pin Chen, Graduate Institute for Computer and Information Education, National Tainan Teachers College, Taiwan, R. O. C., jason@austin.ntntc.edu.tw

Lai-cheng Wei, Graduate Institute for Computer and Information Education, National Tainan Teachers College, Taiwan, R. O. C., wlc@austin.ntntc.edu.tw

Hsin-wen Hu, Graduate Institute for Computer and Information Education, National Tainan Teachers College, Taiwan, R. O. C., husw@austin.ntntc.edu.tw

Abstract: Based upon social learning, cooperative learning, and network learning theories and research, this paper investigates the guidelines for developing activities and supporting systems, which together contribute to successful network cooperative learning. It is recommended that groups, tasks, incentives, and the environment, as well as individual accountability structures should be taken into consideration while designing a network cooperative learning activity and its supporting system. The paper is concluded with a brief discussion on a simplified activity and system, which was constructed using these guidelines.

Introduction

Influenced by the theories and research on social learning (Brown, Collins, & Duguid 1989; Lave & Wenger 1991; Vygotsky 1981), the social aspects of learning have received increasing attention. Learning is thought of as a process involving the internalization of social interaction, which involves other people and things people bring about. Therefore, many instructional methods have been developed to exploit the potential of social interaction. Cooperative learning is among these methods. Although some studies have produced contradictory evidence, the majority of the studies have shown that it often efficient for two or more students to work in concert for solving problems. Since the development of telecomputing and network technology, cooperation between students, teachers, or specialists is possible over great distances. However, simply placing learners in small groups or letting them conduct open discussions together will not necessarily help them learn better. This study analyzed the literature on cooperative learning (Bouton & Garth 1983; Graves & Graves 1985; Johnson & Johnson 1984; Sharan 1980; Slavin 1989) and network learning (Civille 1990; Harasim 1990; Hiltz 1986; Robottom & Hart 1990; Saunder & Heyl 1988; Smilowitz, Compton, & Flint 1988; Waggoner 1992; Sproull & Kiesler 1993), and found that certain essential prescribed conditions were necessary to facilitate effective, cooperative network learning. These conditions specifically involve group structure, nature of the task, incentive, environment and individual accountability.

Factors to Effective Cooperative Network Learning

The crucial conditions that determine the effectiveness of cooperative network learning include (Figure 1): *Cooperative group structure:* This factor is defined by the size of the group, heterogeneous condition of the group, group coherency, and composition of the group. A small group seems to function better than a large group, in which some members tend be "sleep" or excluded from interactions (Mulryan 1992; Salomon & Globerson 1989). For a project-oriented activity, 3~5 persons is the preferred group size (Harasim 1993), the group thus can be close together (while 7~15 of the groups are usually recommended for a network learning activity (Riel & Harasim 1994), then the aggregation is big enough to provide variety in thought and approach). The composition of a group should have members who are heterogeneous in age, gender, race, intelligence, development, performance, attitude, and leadership (Riel & Levin 1990; Watson & Marshall 1995). Satisfying this condition will usually not be a problem. If the members are grouped from distant locations, they will usually be quite heterogeneous. To have

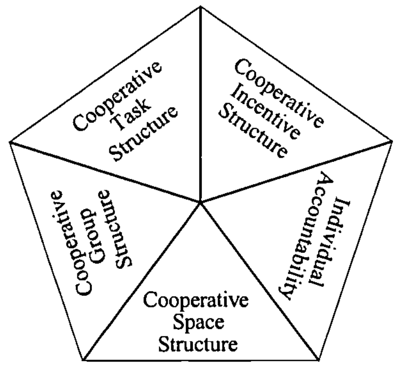

Figure 1: Factors to Effective Cooperative Network Learning

distant members work together, it is critical to create coherency among the group members. A strategy must be implemented to create the feeling of a group identity between the members. In order to further cooperation in the group and may decentralize the group's work, some roles with particular functions composing the group must be pre-arranged and pre-designed.

Cooperative task structure: Cooperative task structures are situations in which two or more learners are allowed, required, or encouraged to work together toward completion of some assignment. Two differing task structures are commonly used: task specialization and group study (Watson & Marshall 1995). In task specialization, each team member is given responsibility for a unique part of the activity. In group study, all members of a group work together and responsibility is not rigidly separated. Group study causes all group members to study and become equally familiar with the same information, while task specialization helps insure that all participate because certain responsibilities are given to each group member (Slavin 1983).

Cooperative incentive structure: The term "incentive structure" primarily refers to the means of rewarding learners for performing a learning task. The typical methods for establishing classroom cooperative incentives are: (a) group rewards based on the individual scores of group members, and (b) group rewards based on a group project or other product (Watson 1992). In theory, group rewards based on group performance should create group norms and peer sanctions favoring high performance (Slavin 1984; 1991a). Slavin (1984) indicated, according to a research review, as well as Hooper and Hannafin (1991) and Watson and Marshall (1995), that group rewards are likely to have positive or neutral effects on increasing motivation and performance. Hooper and Hannafin (1991) further found that learners in "group reward" situations cooperated more frequently than learners in "individual reward" situations. However, while applying group rewards, the problem of diffusion of responsibility should be avoided (Slavin 1983). It is further recommended that internal incentives should be used instead of external incentives. According to Levin, Rogers, Waugh, and Smith (1989), talking with other persons or showing things to an audience around the world has been found to be a great incentive.

Individual accountability: The way to decrease the opportunity for diffusion of responsibility is individual accountability (Watson & Marshall 1995). As Slavin (1983) pointed out "learning is enhanced by the provision of group rewards if and only if group members are individually accountable to the group for their own learning" (p. 59). Individual accountability ensures that group members know who needs more assistance, support, and encouragement, and know that they can not "hitch-hike" on the work of others (Johnson & Johnson 1994). This can be created either by providing specific group rewards based on members' learning, by arranging individual members to have some exclusive roles with particular functions, or by having individuals perform unique tasks and providing incentives for learners to learn from each other (Slavin 1983). There seems to be general agreement among researchers that individual accountability is essential if cooperative learning is to produce increased achievement (Watson & Marshall 1995).

Cooperative space structure: To facilitate effective cooperative learning, a physical space promoting interaction is necessary (Graves & Graves 1985). The channels and tools for full interaction within a group and among groups should be provided so learners can communicate, connect, and share resources. A group space, in which the group can meet, discuss, and learn, is needed, allowing group members to interact closely. A public space is also necessary, where group members or different groups can exchange data, results, and knowledge.

In addition to the above listed factors, if group members have the appropriate interpersonal and small-group skills, cooperative learning results can be further improved (Johnson & Johnson 1994). However, these skills require direction, practice, and accumulated experience. Similar to the role of teacher in a classroom, a

coordinator is very important for effective network cooperative learning. The coordinator assists the flow of learning activities, and helps solve technical problems (Levin et al. 1989; Riel & Levin 1990).

A Model for Network Cooperative Learning Activity

A network cooperative learning activity should create opportunities for learners to collect, analyze, and share data, ideas, and results, just as scientists do throughout the world. According to the suggestions of Lenk (1992), it is better if the activity is project-oriented, especially in subjects connected with science learning. However, through the activity process, the five conditions presented above must be applied completely (Figure 2).

Basically, the activity process can be divided into seven phases, excluding the preparation. The following is a description of each phase.

Phase 0: Preparation. Before the activity, numerous things must be prepared and arranged. These include the design of the learning objectives, contents, tasks for the group and individuals; the design of the group structure and participant recruitment; the incentive structure design and the arrangements for a coordinator.

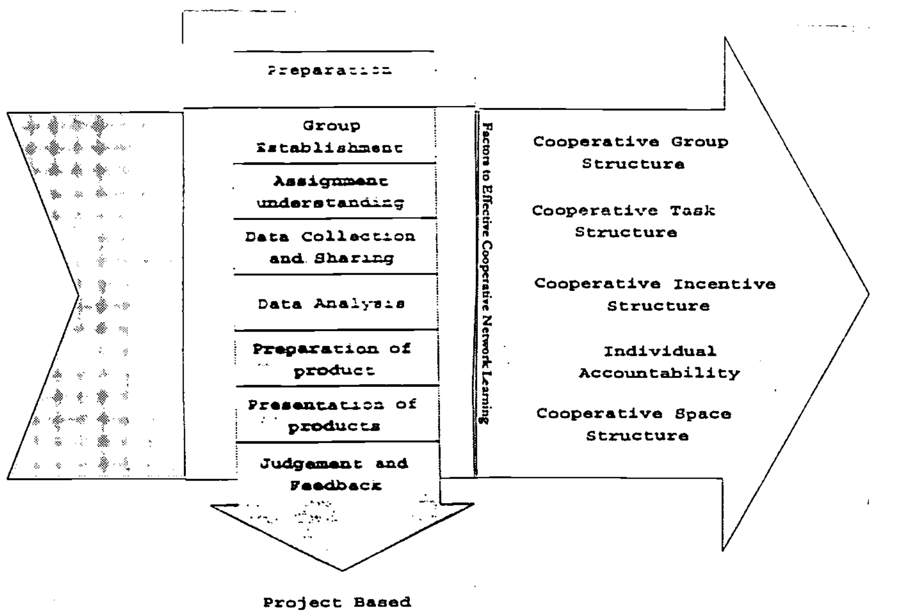

Figure 2: A Model for Network Cooperative Learning Activity

Phase 1: Group establishment. Before starting the formal activity, some introductory activities should be designed for the participants to get acquainted with one another, learn how to use the network, practice interpersonal communication and group skills, and develop a connection with the other group members.

Phase 2: Assignment understanding. Learning assignments, cooperative tasks, and required accomplishment standards should be identified so group members know and understand their objectives. Group members should be able to exchange their opinions and help one another to understand the group assignment and individual responsibilities.

Phase 3: Data collection and sharing. At this phase, the emphasis is put on the collection, presentation, selection, and sharing of data. Every group member may collect individual data according to the individual responsibilities and requirements. The collective data of a group will be shared with other groups.

Phase 4: Data analysis. Based on data collected by group members or from other groups, each group proceeds with the task of data analysis for solving a problem.

Phase 5: Preparation of the product. In this phase, group members must construct the required product. This work might be divided and given to particular individuals. However, in the process of completing and finalizing the product, group members must communicate fully in order to arrive at a common consensus.

Phase 6: Demonstration of the products. Each group passes the products to other designated groups, or

posts them publicly to allow access by all.

Phase 7: Judgement and feedback. Each group provides judgements and suggestions to other groups using network supported communications. Each group also cooperatively revises their products according to the feedback provided by other groups.

System Supporting Network Cooperative Learning Activity

For a cooperative learning activity to be effectively conducted in a network environment requires the support of a well-design system (Figure 3).

The network system should support a cooperative group structure. The system must assist with grouping, according to size requirements, roles, and role functions. To increase cohesion, the system should also provide a group identity by creating a special name and symbol for each individual group.

The network system should support a cooperative task structure. The system needs to specify group assignments, critical tasks in each phase, individual responsibilities, and required accomplishment standards. Secondly, to further promote positive interdependency among group members, tasks specific for particular members should be inspected by other group members at several check points required by the system. Cooperative work should be managed by a rotating system set up to disperse control and authority. Conflict management strategies must be employed to resolve conflicts.

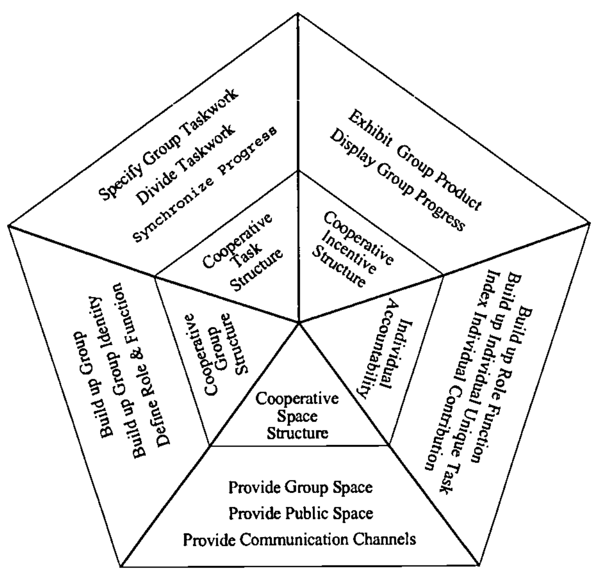

Figure 3: Framework of Designing Network Cooperative Learning Activity Support Systems

The network system should support a cooperative incentive structure. An audience is a very important and internal incentive for network learners. Therefore, the system should provide an easy method and channel for allowing participants to publicly demonstrate their group products. The system should also track and display how well a group communicates, cooperates, and completes its stage work to group members and other groups.

The network system should support individual accountability. To elicit each participant's devotion to learning, the system and activity designs must be both interesting and interactive. The system should define the roles, functions and tasks for individual members, and connect each member with those specific roles, functions and responsibilities to their counterparts within their or other groups. Some index for identifying individual contributions so group members can clearly see one another's efforts.

The network system should support a cooperative space structure. To facilitate inter group cooperation and sharing and discourage interference among groups, care should be taken in the system's design. The system should provide separate operating space for each group. This facilitates every group member having a group identity feeling. Among groups, communication channels must also be provided, but limited in order to avoid interference. The system should provide a public space that allows all groups to get together, synchronously or

asynchronously, to share resources, ideas, results, or to learn from one another.

In addition to the above, a stable system is the hinge on which successful network cooperative learning activities can exist. Therefore the system must be highly error-tolerant.

Use of System to Support Network Cooperative Learning

In starting a network cooperative learning activity, numerous things must be arranged in advance of system use. First of all, the participants should be provided with system accounts and usage authority. For different learning activities or participants with different computer skill levels, some system parameters may need to be adjusted. Roles, functions, and tasks may be restructured. Varied tables and tools for data input, analysis, organization, and processing may be needed. Directions or assistants may be necessary to decrease participants' difficulties. Different strategies or norms for dispersing control and managing conflicts must be planned. Awards or incentive structures may also need to be adjusted.

During the learning activity, data must be periodically backed up, abnormal system message must be monitored and handled, system reliability must be maintained, and technical support should be provided for participants.

After the learning activity is completed, data usage must be retained and analyzed. This information implies the appropriateness of the activity and the system, and will provide important clues for improvement.

Discussion Based on a Trial Network Cooperative Learning Activity and System

According to the suggestions presented above, a trial network cooperative learning activity support system on the WWW was developed. The framework is as shown in Figure 4. This system supported an activity involving

the physical characteristics of human beings. Through a general browser, such as Internet Explorer, participants from different places could form into a group and share their data and learning. In this design, three roles were designed into the group, a manager, recorder, and checker. The group task was simplified and included (a) looking for and recruiting group members, (b) learning about the task requirements, and (c) data collection for physical characteristics. Each role had its mission and responsibility. This system was investigated using students from three primary schools. Although the system still requires improvements in some aspects, the feedback from and observations of the students were very encouraging for us to continue with the development of this system.

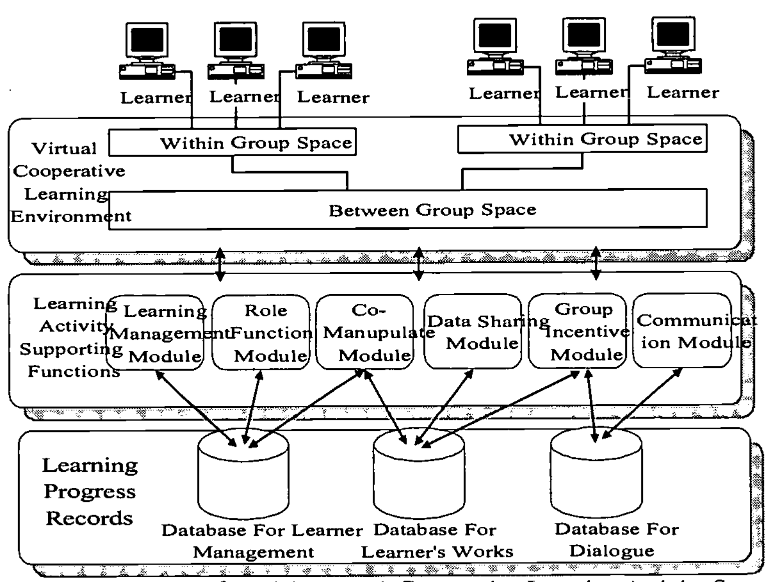

Figure 4: Architecture of a Trial Network Cooperative Learning Activity Support System

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Computers in the Mathematics / Science Classroom: Help or Hindrance

Kenneth Clark
Leadership, Technology, and Human Development
Georgia Southern University
United States
kclark@gasou.edu

Alice Hosticka
Early Childhood Education and Reading
Georgia Southern University
United States
Ahost@gsvms2.cc.gasou.edu

Denise Huddlestun
Middle Grades and Secondary Education
Georgia Southern University
United States
Dhuddle@gsaix2.cc.gasou.edu

Abstract: New research indicates that computers in education are seen as a hindrance to student achievement. This indicates that we must examine how computers are used in the school. A recently released report by ETS attributes the down side of the effect of computer use on achievement to the way many teachers utilize the computer in the classroom. We cannot leave the design of instruction to software producers who may or may not be curriculum specialists. We must take control as teachers and integrate the computer into the instruction process as a tool to enhance learning. This paper will discuss specific ways to effectively use the computer by providing instructional lesson plans that integrate the computer into the instructional process as follows: 1) a resource for information gathering; 2) a processor of information to allow learners to see trends and patterns in a problem solving situation; and 3) a tool for teaching mathematical reasoning.

Computers in the schools and in mathematics and science classrooms are seen as a necessary tool. New research that examines student achievement, rather than usage, suggests that the availability of software and hardware does not necessarily translate into increased achievement. Instead, the use of computers can be interpreted to have some potentially negative effects on student achievement.

Recent discussion in the press and political arena is aimed at the poor quality of our educational system as measured by student achievement on standardized tests. Rightly or wrongly, the implication is that achievement of our youth is generally poor. At least one state, Georgia, has earmarked lottery money to increase the availability of technology to P - 16 students in state supported institutions. Most of the money to date has been spent on hardware and software in an effort to improve student scores on national measures of achievement.

A report written for Education Week by Educational Testing Service (1998) points out some issues dealing with the type of research being done on computers in education and their relationship to achievement in mathematics. The report stated that previously available data and research did not show "...whether computer delivered instruction improved performance." (Policy Information Report, 1998, p. 2) In the Policy Information Report (1998) attempts were made to determine "...whether the computer is making a difference, and what kind of computer use had what kind of effect on which groups of students." (p.2) The findings from the research are as follows.

Technology could matter in eighth grade if it is used correctly.

- *Professional development for teachers in how to use and apply higher-order thinking skills through the use of technology is positively related to academic achievement in mathematics.* (Policy Information Report, 1998, p. 3) It is unclear if improvement in achievement was due to technology use in classrooms that addresses higher-order thinking or if the focus on higher-order thinking skills through a variety of mediums made the difference in achievement.

• *Frequency of home computer use is positively related to increased achievement in mathematics.* (Policy Information Report, 1998, p. 3)

• *Use of computers to teach lower-order thinking skills such as fact acquisition with drill and practice type exercises is negatively related to achievement.*" (Policy Information Report, 1998, p. 3)

• *Frequency of school computer use is negatively related to academic achievement.* (Policy Information Report, 1998, p. 3) This appears to indicate the majority of the use of computers in schools is for lower-order thinking skills involving drill and practice, especially with lower socio-economic status students and minorities. Several questions arise related to the use of computers in this way. Do most teachers have training in teaching higher-order thinking skills including those enhanced with computers? Is there incentive to teach higher-order thought processes from the educational and larger community? Is the use of computers for drill and practice an effort to get the students to master computational skills and lower-order thinking skills they have yet to master through other instructional strategies?

Several factors emerge about the use of computers in the fourth grade.

• *Using computers for learning games is positively related to academic achievement.* (Policy Information Report, 1998, p. 3) The reason for this could be that learning games are considered a higher-order thinking skills activity for fourth graders.

•*Professional development of teachers for using computers for learning games is positively related to academic achievement.* (Policy Information Report, 1998, p. 4)

• *Frequency of home and school computer use is negatively related to academic achievement.* (Policy Information Report, 1998, p. 4) This could be due to the preponderance of drill and practice programs for home and school use, the quality of both home and school software, and/or the skill orientation of teachers and parents. Many people do not believe that children younger than 10 years old can perform higher-order thinking; low expectations by the teacher or parent can lead to low achievement by the student.

The report concludes that computers are neither fads nor panaceas in educational communities. However, computers can be effective tools for improving academic achievement when used appropriately. (Policy Information Report, 1998) Tools are powerful in the right hands, but tools can cause great harm when misused.

Working on the assumption that schools prepare students for taking a role in society, examination of computer usage outside the school setting indicates there are three ways that society uses computer technology. The first is as a research tool to find, share, and use information. The second is to use the computer and the appropriate application system as a tool to answer "what if..." type questions. To do this, the computer serves as a model builder to display and analyze data. Finally, the computer is used as entertainment which includes the use of games and puzzles. All these uses require the user of the computer to be involved in higher-order thinking skills.

In field-based teacher training classes, a variety of uses among both faculty and in-service classroom teachers can be observed. Much of the variation can be accounted for by consideration of the teacher's comfort level with computers. In addition, essential curriculum objectives and their relative importance must be determined along with the necessary allotment of time to adequately teach them in the most appropriate manner. Even among faculty involved in teacher preparation, differences in philosophy exist about whether a skills based approach or cognitive processing approach (higher-order teaching skills) should be taken. Those differing philosophies determine if a program fosters teacher training or teacher education.

The emphases for using computers in classroom instruction include the following tenets: the computer should be used as a tool in the instructional process; skills are necessary to facilitate the higher-order thought processes but are not an end within themselves; developing higher-order thinking skills is a goal of education; and activities that demand intellectual engagement are the vehicles of instruction. It is possible to teach any lesson without the use of the computer. However, the computer can enhance the learning experience in many lessons and can provide the student with more opportunities to investigate the content presented in ways parallel to the way society uses computers.

When preparing instruction, lessons should meet the following conditions.

• The lesson must provide significant content as it relates to national, state, and local goals and objectives.

• The lesson must provide opportunities for students to think about and apply the content taught.

• The lesson must actively and intellecutally engage students.

Three lessons are presented using the computer as a tool, and each one uses the computer in a different way. The lesson on "Statistics and Physical Aspects of Flight using Paper Airplanes" uses the computer as a research tool by providing a vehicle for gathering multi-layers of information necessary for effective decision-making. In the lesson on "Economics and Model Building," the student is provided with the opportunity to use tool based application programs such as a spreadsheet to organize and present data. The lesson on "Mathematical Reasoning" uses commerical software to present problems that the student is to solve and does not lead the student or "teach" a procedure. This program is parallel to many of the game and entertainment programs available for the home.

For each lesson, the National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluations Standards for School Mathematics (1989) serves as a basis for the national goals. Furthermore, each of the lessons addresses various benchmarks as identified in the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy (1993). While national goals and objectives are derived from professional organizations, state and local goals and standards vary. For purposes of this paper, the state and local goals and objectives cited are from Georgia.

Lessons

Statistics and Physical Aspects of Flight using Paper Airplanes

Goals and Objectives

National

NCTM Standards: Problem Solving, Communication, Reasoning, Connections, Measurement, Statistics and Probability, and Geometry.

AAAS Benchmarks: Make the available science tools, materials, media, and technological resources accessible to students. Identify and use resources outside the school. Accurate record-keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.

State and Local

Physical Science:

- Uses process skills of observing, ...experimenting, constructing hypotheses and drawing conclusions
- Selects and uses multiple types of print and non-print sources.

Mathematics:

- Solve problems, reasons, and estimates throughout mathematics; selects and uses problem-solving strategies; and relates concepts and skills to practical applications
- Collects, organizes data
- Uses mean, median, and mode... and range to describe data
- Makes predictions or conclusions based on this data
- Selects and uses appropriate customary and metric units of measure for length...

Procedure

• Capture the interest of the students by having them build a paper airplane and test its flight. If weather permits, the class could go outside to test their planes. The students should estimate the distance their plane flew.

• After giving the students time to experiment with the plane they constructed, begin a discussion of the various distances of flight and the possible reasons for the greater distances of some due to their design.

• Ask the students for suggestions about methods of gathering information about building paper airplanes. Students should suggest books and internet sources. If necessary, guide the students through the steps in doing a search for the construction of paper airplanes. Ken Blackburn's Paper Airplanes and More (1998) provides directions about construction of various paper airplanes which can be downloaded to provide students with a variety of planes from which to choose.

• Encourage students to investigate paper airplane contests and have them develop rules for a contest of their own. Guide discussion of the rules to include these considerations: to what point to measure (the tail, nose, or point farthest from the starting point); whether or not to measure distances flown behind the starting point; number of flights from which to choose the best distance.

• Discuss proper methods of measurement as well as the various tools available for measuring the distances. In addition, review finding the mean, median, and mode and what each of them means to aid in their decision about their "best plane."
• Allow students to work individually or in groups to find a "best plane" for a contest. Have them conduct a specified number of trial flights and measure the distances. Remind the students to record the various distances in order to find the mean, median, and mode.
• Have students decide which type of statistical measure they will use to choose their plane for the contest.
• Conduct the contest according to the determined rules.

Extensions

A variety of extensions to this lesson can be made to include social studies and language arts in an interdisciplinary unit of five to ten days. Greater investigation could be done about various topics: the mechanics of flight; the history of flight; career opportunities associated with the flight industry; effects of flight on the economy and our lifestyles; and investigations into the consumption of fuel and other measurements used on planes. The creation of a report would involve language arts and social studies and provide opportunities for using word processing, spreadsheets, and graphs.

Economics and Model Building

Goals and Objectives

National

NCTM Standards: Problem solving, Reasoning, Communication, Connections, Patterns and functions, Statistics

State and Local

Mathematics:
- Collects, organizes data, determines appropriate method and scale to display data, and constructs frequency distributions, bar graphs, line graphs, circle graphs, tables, and charts.
- Reads and interprets data in frequency distributions, diagrams, charts, tables and graphs; and makes predictions or conclusions based on this data.
- Solves problems, reasons, and estimates throughout mathematics; selects and uses problem-solving strategies; and relates concepts and skills to practical applications.
- Makes predictions or conclusions based on this data.
- Solves problems, reasons, and estimates throughout mathematics.
- Solves non-routine problems for which the answer is not obvious.

Social Studies:
- Discusses scarcity and examples in the Americas, Europe and Oceania.
- Explains how people in all economic systems engage in certain basic economic activities...
- Identifies the changes that occur in the meaning, use, distribution, and importance of resources and defines scarcity and its impact.

Procedure

• The teacher constructs a spreadsheet that displays only the pertinent information in an economic model. An example would be a model lemonade sales stand. Possible headings are of number of glasses, cost per glass made, number of glasses sold and price per glass sold.

• The student will manipulate these data. Based on the student's input, the spreadsheet will calculate and display total expenses, total sales, and net profit.
• Give the student an electronic copy, show them how to input or change data, and have them observe what happens when one of the variables is changed. This can be an individual or small group exploration.
• Based on the exploration, have the students mathematically define the appropriate terms using the computer generated data. In effect, this is having the students construct the mathematical model for the operation of the lemonade stand.

This lesson is short and simple. It allows the student to quickly generate enough data so that they can see patterns and develop a mathematical formula to describe the situation. If the students had been given the

formulas they would not have been as intellectually involved with the higher-order thinking needed to generate mathematical models rather then calculate the outcomes of a given model. They are the model builders not the model users.

Extensions

Extensions that apply this type of spreadsheet exercise to other areas of mathematics are:

• mixture problems where the student will input the cost of the compound and the amounts of each part of the mixture. This provides the mathematical foundation of the thought processes used in many chemistry and biology applications.

• solving quadratic equations. In this case the student can enters the three coefficients, and the spreadsheet displays the number and type of roots.

• any topic where the calculations get in the way of building the model. The prinicpal is the same as the use of a graphing calculator with a more open tool rather then a single purpose one.

Mathematical Reasoning

Goals and Objectivies

National

NCTM Standards: Problem solving, Communication, Reasoning, Connections, Patterns and functions, Geometry

State and Local

Mathematics

- Solves problems, reasons, and estimates throughout mathematics
- Solves non-routine problems for which the answer is not obvious
- Analyzes effects of basic transformations on geometric shapes.

Procedure

The lesson uses the commercial software package, The Factory (1997), that allows the computer to effectively do a job that most teachers find difficult. Simulation and gaming software is structured so that the computer provides consistent feedback and makes no judgments on the input other than correctness or consequences of the solution.

Instruction on mathematical reasoning is delivered preceding the computer experience. Logical problems such as Math Mind Benders (1997) are used to stress the importance of information from indirect information. Processing direct and indirect information is coupled with accounting for all possibilities and indirect proofs.

• In a large group situation, use the software as a tool for providing the problem to solve and the feedback as to the appropriateness of the solution.

• Assign teams or small groups for discussion throughout the lesson. Open the program and ask the total class of students to brainstorm how the program might work. Use one student as the keyboard operator that takes directions from the teacher who gets ideas from the class. It is up to the class to discuss how they would find out what to do.

• As the class explores and learns how the program is structured, build a factory by asking for several machines to be entered before you see what type of product will be produced. Have each small group predict and draw what the product will look like.

• When each small group comes to a consensus, have them draw a picture for class discussion. Examine all the small group pictures, discuss likenesses and differences, and have each small group state their reasoning and what questions they have related to the product to the total group.

• Run the factory to see the actual product produced. Discuss what each group got right, what questions they still have, and what effect they think each machine had on theproduct in relation to the other machines.

• As the lesson progresses to the challenge aspect of the program, the computer generates a product. Have each small group design a factory to produce the product. Students should discuss the machines and the sequence of machines and the end result. When the group agrees on a factory, post its design using a written form for naming each machine determined by the small group for large group discussion.

• In the large group discuss each group's approach looking for similarities and differences among the groups. Enter each group's factories into the computer for verification. Debug those that did not produce the product.

Discuss those that did produce the product in terms of most efficient factory. This causes the user to think about and explore the problem by asking many "What if I…?", "Why did I..?" type questions.

Extensions

Extensions of this lesson:

•provide a lead into computer programming in areas of debugging, team work, the use of pseudo-code (student generated symbolization), and formal coding (program input statements).

•assign a cost to each machine and determine the factory that will be most cost effective in producing the product.

Summary

In the above lessons, decisions on how hard to try, what type questions to ask, how much time to take with the problem, and when to quit are all those made by the student. Motivation to solve the problem and decisions on what action to take are those of the student. The computer applications do not suggest an action to take or place a value statement on an action taken. These types of computer usage provide powerful tools for building higher-order thinking skills. In selecting applications of the computer for use in lessons developing these skills, and thus mathematical achievement, it is important to carefully evaluate the lesson to be sure it fosters thinking and does not focus on leading students to correct answers or testing their acquired knowledge.

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Greasing the Wheels: Powerful Assessment in a Technology-rich Math Curriculum

Karen Cole
Institute for Research on Learning

Abstract: This article describes a framework for analyzing and designing powerful assessment events. The research on which the framework is based was conducted during field tests of a technology-rich middle-school mathematics curriculum. The framework lays out the functions of assessment in terms of both the information generated and the work done by students during assessment events. By looking at both kinds of functions we can better understand how and when assessment events catalyze learning.

Introduction

Assessment is important in any curriculum, but its role is critical when students are using technology and design. In field tests of the Middle School Math through Applications Project curriculum, we had an opportunity to go "inside the black box" (Black and Wiliam 1998) of formative classroom assessment. That is, we analyzed sequences of assessment events in real classrooms to understand their impact. We explored the proposition that assessment should catalyze learning, rather than simply measure it (Darling-Hammond, Ancess et al. 1995; Wiggins 1998). The theory emerging from our research explains why and how assessment greases the wheels of a curriculum to catalyze learning. This theory explains the positive experiences many have had with authentic or performance-based assessment and can provide some guidance for the design of new assessments.

The MMAP Project

The Middle School Math through Applications Project (MMAP) is a comprehensive, standards-based, technology-rich middle-school math curriculum. In design-based units, students participate in design projects that mirror the work of adult math-using professionals, such as architects, population biologists, and cartographers. For example, in one cartography unit, students design and map city tours for customers with special needs. In an architecture unit, students design a research station for scientists in Antarctica.

The curriculum develops important mathematical concepts such as function, variable, and proportion. Students encounter these concepts first in the context of their design projects and then connect them to standard mathematical formalisms and notations.

The design-based units in the curriculum make use of computer-assisted design software. The software is specially designed to engage students in high-level mathematical analysis as they try to improve their designs. All software environments have easy-start interfaces, but with guidance from the curriculum and teacher, students are drawn into using the more sophisticated analysis features.

Assessment developed for the curriculum has played a critical role in helping students get the most out of their design projects. First, assessment is used to help focus students on the math in the projects, asking students to confront the mathematical issues in their designs. Second, assessment helps draw the math out of the projects and connect it to the discipline of mathematics. Students' use of math may be highly context-bound at first, but assessments and other project activities make it clear to students what math they are learning and how it relates to other math they know.

The curriculum supports the use of a wide variety of assessment techniques, including peer design review, individual writing, teacher-student conferences, teacher observations, quizzes, and concept mapping. Teachers are encouraged to choose a few of these techniques and use them as a coherent system throughout the unit to catalyze math learning and focus projects.

Assessment Research in MMAP

The theory developed in this paper is drawn from over 200 hours of classroom research. Data includes video tapes of assessment events, field notes, and student work.

Data collection took place in the classrooms of three middle school teachers over two school years. Two of the schools were urban and one was suburban. All had highly diverse student populations including ethnic, racial, and linguistic minorities.

Researchers observed whole class periods daily for entire MMAP curriculum units, which usually spanned at least two months of school time. In one school we observed continuously for more than one semester. We followed the experiences of student groups and individuals as they worked on MMAP units and other math activities. Analysis consisted of looking for connections between assessment events and growth in students' abilities to participate in more complex mathematical practices. Our analysis centered around assessment events, which were any occasion in which student work was examined, by students themselves or by the teacher. We looked at hundreds of these events, which ranged from formal design reviews to very informal conversations between peers.

Situating Assessment in a Situative Perspective on Learning

The MMAP curriculum is built on a theoretical perspective that views learning as increasingly complex and central participation in communities of practice (Lave and Wenger 1991; Greeno et al. 1998). The MMAP curriculum helps teachers organize a classroom learning environment that draws students into increasingly complex mathematical practices in service of large-scale design and problem solving using technology. For example, as students work on the problem of designing a wildlife management policy for the government of Alaska, they use mathematical modeling as a tool to craft and support their policy recommendations. This in turn requires them to create algebraic functions and interpret their behavior in terms of real-world implications for wildlife. To do their work as policy designers, students adopt increasingly complex practices of mathematical modeling. That is, they begin by creating simple functions, then modify them to try to produce the behavior they want, then begin creating even more complex functions. Their talk includes mathematical terms that are needed to describe their work. In short, their participation in mathematics shows in many ways not easily captured in a math test. The situative perspective allows us to describe math learning by following a class through trajectories of increasingly complex participation in mathematical practices such as modeling, creating functions, and defining variables.

Given this theoretical perspective, we asked ourselves the following question: *how can assessment be reconceptualized to play a supportive role increasing or improving students' participation in mathematical practices?* We collaborated with our teacher partners to design assessment systems that would support participation, and still do all the usual reporting and feedback functions of assessment. We watched as teachers piloted these systems, and modified them continuously as we came to understand their role in drawing students into participation (Cole 1996).

Functions of assessment for improving participation

It is a well-established idea that assessment can play many roles. For example, the NCTM assessment standards (National Council of Teachers of Mathematics, 1995) cite four main uses for assessment: monitoring student progress, making instructional decisions, evaluating student achievement, and evaluating programs. In general, these functions tend to be reactive; that is, some assessment data is collected and improved learning results from actions taken based on that assessment data. Because improved practice results indirectly from the information generated, not from the event itself, we call these the *indirect functions of assessment.*

The research in this paper, without negating any of the functions already named, suggests an additional set of functions for assessment based on the idea of assessment supporting increased and improved participation in practices. These functions are all *proactive*: that is, the assessment events themselves, rather than the information they generate, are integral and catalytic to the process of improved practice. Because these changes all occur as a direct result of participation in an assessment event, we call these the *direct functions of assessment.* These functions are:

1. Making connections

2. Defining quality work
3. Building accountability relationships
4. Defining assessment practices

These functions are very different in character from indirect feedback mechanisms, in three ways:

- These functions focus on the *work* students are doing during assessment events, not the *data* they receive through assessment. In powerful assessment events, students are active participants in defining what their work is, what it means to do it well, who they are accountable to and for what, and when and how they reflect on their work. No rubric or standard can take away the need for students to do this defining work for themselves in the context of their classroom communities.
- These functions describe aspects of assessment that add dimensions and depth to relationships in communities of practice. During powerful assessment events, accountability becomes defined in terms of real interpersonal interactions instead of in terms of abstract compliance to sterile rules. Quality is defined in relation to the actual characteristics of students' work.
- Indirect functions of assessment describe the flow of information about the quality of student work: Teacher assesses student work; student receives and incorporates feedback. Direct functions of assessment describe role of assessment in the broader evolution of academic practice: We used to do math this way, *we talked about our math*, our conversations gave us new ways to organize our math, now we do math a new way.

Assessment is not the only way to perform these functions, and not all assessment events perform them. Our data suggests that when assessment events perform these functions, they most powerfully catalyze learning. Our data also suggests that improvements in practice are not easily explained unless we look at both direct and indirect functions of assessment. That is, feedback alone cannot explain the changes we saw during and after real assessment events.

Two assessment sequences

Laying out four direct functions of assessment gives us a framework for analyzing real, complex assessment events. In this section, I analyze two sequences of assessment-related events. These two analyses are typical of many more from our data, in that we characterized the effects of assessment based on observations of many related events over time. This kind of analysis helps us understand what an assessment accomplished and explain both evolving and stable participation in academic practices. By connecting these assessment events to subsequent events in the classroom we can infer the functions these assessment events performed and relate that to the changes in practice we observed.

A group-to-group design review

The first event is a design review that took place midway through one of our architectural units, *Design a Dream Home*. Research data for this design review included video tape of one three-group review, student designs before and after the review for all the groups in the class, student notebooks, and field notes of observations before, during, and after the review.

This sequence is not a picture-perfect assessment. My purpose is not to describe an exemplary assessment event, but to show how by looking at the work students do during an assessment, we can better understand effects of even a rather unwieldy event. This is important because it is very common for so-called authentic or performance-based assessments to have unexpected or even undesired outcomes, and we are sorely in need of a framework for making sense of these outcomes.

Structure of the review

The class had divided into groups of four, and each group had one "client," usually one of the group members, who specified the requirements for a dream home. The groups all used a computer program called *Architech* to draw scale floor plans of their designs, which were supposed to meet the client requirements. The *Archtech* program allows students to draw multi-story floor plans with doors, windows, and staircases, and even add furniture such as couches, beds, sinks, and tables. The program calculates the cost to build and heat the structure.

The students were working with a budget of $300,000. This budget is more than adequate for the houses that most classes designed. This class, however, was designing unusually large houses. To make everything look proportional, they were drawing enormous furniture to fill their enormous rooms. They did not seem to realize that a four-meter bed was out of the ordinary. Some of the designs also had big conceptual problems, such as rooms that couldn't be accessed, missing doors, and inconvenient layouts.

The teacher, Ms. Martin, thought that a design review would help the students catch the flaws in each other's designs. Because the flaws were many and varied, Ms. Martin did not structure the review very tightly. She reasoned that any critique students got would be a starting place for improving their designs, and she knew there were many additional assessments in the unit. This one review did not have to fix everything.

Before the review, she did give the class a list of things to check each other's designs for:

1. Is the design possible?
2. Is the cost under $300,000?
3. Are the rooms a reasonable size?
4. Check the windows, doors, etc.
5. Does the plan meet the client's needs?

Ms. Martin asked students to copy the list into their notebooks before the review began. Then, she organized the class into three reviews of three groups each. The groups were responsible for critiquing each of the three group's designs in turn, without participation by the teacher. This was the first design review the class had ever done.

Class-wide changes in practice

Analysis of the review itself and subsequent events show that students' experience in the review varied tremendously, both in its character and in its impact on participants evolving project-related practice. It is clear that we need to look at both indirect and direct functions of the review to understand it. First, let's look at the changes in practice we observed that continued after the reviews:

1. Beginning of major revisions. Until the reviews, groups had been more or less on a straight arrow progression of adding rooms and furniture to their design without major revisions. After the review, 5 out of 10 groups made major changes to their designs, redoing major sections or, in two cases, starting the whole design over from scratch. For one group, the practice became ingrained and they produced four complete designs by the end of the project. The way that students described these revisions indicated continued self-assessment, for example, "We decided to throw out our design and start over, because you couldn't really build it [our old design]."
2. Interest in others' designs and access to them. The classroom was set up so that only half the groups could work on the computer at time. The day after the review, we noticed that each group working on the computer had another group of students standing behind it looking at the work and commenting. Some of the changes groups made or planned can be directly traced to what they saw in others' designs during the review.

On the other hand, the designs, although they changed a lot, did not always improve much, particularly in the area of reasonable sizes for rooms and furniture.

These changes in practice (or lack thereof) cannot easily be understood in terms of indirect functions of assessment, which in this case would be feedback on performance. This is because many students actually received very little feedback. Some received none at all.

To understand what led to the changes in practice noted above, we need to look at the work students did together during the review, the way accountability was defined, and the way assessment itself evolved. Video tape of one three-group review allowed us to observe this work.

What work was done?

We can describe the work done during one three-group review using the direct functions of assessment.

Defining assessment practices: The review institutionalized a new classroom practice: students evaluating the quality of their own and other students' designs. The existence of this practice was necessary for what

subsequently happened: a significant increase in the amount of revision and within-group argument we observed following the reviews.

Beyond that, students defined what it meant to review a design, almost regardless of what the teacher had described before the review. The review we taped began with Daniella ordering, "OK, start criticizing." So reviewing meant criticizing. Sylvia tried, but could only come up with the following fairly bland critiques, even though there were big size and scale problems with Danielle's design.

Sylvia: OK, you're spending too much time on the details.
Sylvia: Well, you guys have not really thought out the garage yet.
Sylvia: There is a lot of space there. There's a hole in your house!
Sylvia: Maybe you ought to put a couch.

Annie added, "There are too many doors." That was the end of the criticism for Danielle's design.
When Danielle's turn came to "criticize" Marty's design, she showed everyone what criticism was:

This is junky! There are too many doors, too many couches, giant bed, missing walls, have to jump over the toilet. It's so cluttered. There are too many doors. There's a secret entrance. How come it has a hallway leading into a cabinet. Oh that's the secret entrance, it's so stupid. How come this is open to the outside of the house. Y'all gotta be taking down what I'm saying. Marty, I think you need a lot of changes."

This was fun, except for poor Marty. Everyone else jumped on the bandwagon and found things about Marty's design to shout about. A few students even visited Marty's table after the review to add a few more critiques. So peer assessment was defined as no-holds barred criticism about the design (but not the designer).

Building accountability relationships: The opportunity for peer review by itself would not necessarily have made students accountable to their peers. What happened was that students, led by Danielle, took up the opportunity and acted as if they were accountable to one another. Danielle's admonition, "Yall gotta be taking down what I'm saying," is an example of this posturing. Furthermore, no one questioned any of the student-assessors' right to criticize or the content of their critiques.

To this researcher, the content of the criticisms of Marty's group seemed reasonable, but the tone was almost rabid. This was an implicit laying out consequences in the peer accountability relationship. Apparently, the penalty for a bad layout was quite severe. Combined with a relative lack of feedback from the teacher in this assessment, the reviews made the central accountability relationships between peers (within and outside groups).

Defining standards for quality work: With the popularity of standards and rubrics, it is easy to think that putting a list of requirements on the overhead defines standards for quality work. This review seemed to have the effect of defining standards different and more implicit than what the teacher was aiming for. With two exemplars and two assessments to work with (the third design never got reviewed), students acted as if a good design was like Danielle's and a bad design was like Marty's. After the review, Danielle's group made few changes related to the review, but substantial changes related to the fact that their design was over budget – the clearest of the standards the teacher had laid out. Marty's group completely re-did their design, making it look more like Danielle's group's with large, open rooms. William's group, the one whose design didn't get reviewed, made their design three stories, like Danielle's design, instead of one.

What work was not done?

Given that the students did little work that defined mathematical content connections or instituted mathematically-based standards for quality work, it is not surprising that few mathematically-based design changes ensued. This work fell to other assessment events, as we see in the next analysis.

A teacher-guided self-assessment

A second assessment event, much simpler to describe and analyze, was an informal teacher-student conference during the same unit. It was an assessment event because it created a context for the group to examine and evaluate its design. The teacher, Ms. Martin, had looked at a garage a group had drawn that was five meters wide for one car. She had given some written some feedback: "Check on the figures your group has for the basement/garage. What are the dimensions of an average car?" The girls, Natalie, Danielle, and Melissa, asked her what she meant. She told them to think about the size of their garage in terms of the size of a car.

Ms. Martin: Would a car be 5 meters wide? you could take a meter stick and see how big is 5 meters.
Natalie: But you need extra space, [for the car doors to open]
Ms. Martin: But would it be 5 meters? Take a meter stick and see if it would be 5 meters. You probably remember because you paced it off.

The girls measured out five meters in the classroom. It did seem wide for one car (over 16 feet!). The girls argued over whether three meters or four meters was a more reasonable size. They turned to the teacher for advice.
Natalie: Is three meters right?
Ms. Martin: You have to decide if three meters is right for a car. Maybe you should measure a car at home tonight.

The girls did not want to accept this solution, because they wanted to fix their garage right then. They asked the teacher twice if they could go outside to the street and measure a car. She told them she couldn't leave the classroom to go with them. Finally a researcher agreed to take them outside, and they were able to fix their design and move on.

What work was done?

In this event, the girls got feedback about the size of their garage, not so much from the teacher as from the five meter sticks they laid out. More important, the act of assessing their design engaged them in the intellectual practices the teacher was trying to promote- basing the design on the size of real objects, interpreting sizes express in metric measurements, and drawing accurately to scale. Let's look at this in terms of the direct functions of assessment that were most prominent in this event.

Making connections: Ms. Martin steered the students toward analysis in terms of the math content. This helped them to define their work as participating in mathematical practices, rather than as drawing pretty floor plans.

Defining quality work: Ms. Martin helped them to define standards for quality that specifically applied to their own work. That is, "reasonable" for a garage came to mean the measurement of the width of a car plus enough space to open the doors.

Building accountability that relates to learning: The students showed that they already had an accountability relationship with the teacher, because they asked her to clarify her written feedback, and then asked her if their new size, three meters, was "right." Ms. Martin gave them the tools and practices they needed to hold themselves accountable for a reasonably-sized garage. They kept working on this problem until they felt satisfied they had chosen the right size. The accountability relationship they were developing within their group directly supported the mathematical practices they were learning.

Conclusion: Beyond the feedback loop

The current emphasis in classroom research on making use of feedback is certainly a big step forward from dead-end measurement models of assessment. Feedback alone, however, does not explain why some assessment events are successful in improving practice and some are not. By looking at the direct functions as well (making connections, defining quality, building accountability, and defining assessment), we can see why so-called "authentic assessment" sometimes effectively catalyzes learning. To the extent that assessment directly involves students in increasingly central and complex practices, it is likely to make the whole community of practice evolve and function better.

Looking at learning as increasingly complex and central participation highlights another aspect of the functions of assessment. We followed this class through the whole unit, and followed the changes in practice for the duration. We saw that changes in practice that developed in the two assessment events described here did persist – at least for a while (days or weeks). But any practices that did not receive continued support eventually died off in favor of whatever *was* receiving support. The important lesson for designing powerful assessment is to view assessments in the context of an evolving network of practices and relationships. It is these networks, rather than imposed rules or standards, which give assessments the power to catalyze learning.

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Multimedia Based M*A*S*T*E*R Teaching and Individualized Learning of Mathematics and Science

S.A. du Plessis
Institutional Research Office
University of Stellenbosch
South Africa
Sadp@adm.sun.ac.za

J.H. Smit
The Institute for Mathematics and Science Teaching
University of Stellenbosch
South Africa
Jhs@maties.sun.ac.za

H.C. de Kock
Department of Applied Mathematics
University of Stellenbosch
South Africa
Hcdk@maties.sun.ac.za

Abstract: We have developed interactive multimedia presentations based on the M*A*S*T*E*R method of teaching and learning to present a course on functions via television transmissions (with direct audio feedback) to teachers and to accommodate their different learning and teaching styles. We have also developed computer-based tutorials which will be used by the teachers (and eventually also by their learners) to learn about models of teaching and learning and, very importantly, to individualize their learning experiences (while they are studying a course on functions). The first of these multimedia programs is used by the TV presenter to present the course material via TV transmissions to the teachers, and the second is used by the teachers after they have watched the TV transmission. An individualized tutoring strategy is also recommended for each learner that he or she can use on his or her own in combination with a multimedia based tutoring system or purely as advice on which study habits to pursue.

Introduction

The University of Stellenbosch offers in-service Further Diplomas in Education (FDEs) for Mathematics and Physical Science teachers in order to improve their subject knowledge and teaching skills. Instead of a mixed format of contact and distance tuition or pure "paper driven" distance education we are planning to offer these FDEs by making use of interactive TV transmissions and computer based tutorials.

The first phase of this project will be implemented in the first half of 1999. Two series of 6 one-hour lessons each in Mathematics and Physical Science will be offered to teachers via interactive TV transmissions and computer based tutorials. They will be expected to implement the material in their classrooms (Smit, 1998). We have already implemented the first of these lessons, one on linear and exponential functions, to demonstrate our methodology to potential donors (and to delegates at this conference!).

We have developed interactive multimedia presentations based on the M*A*S*T*E*R method of teaching and learning (Rose & Nicholl, 1997) to present the course material to the teachers and to accommodate their different learning and teaching styles. We have also developed computer-based tutorials which will be

used by the teachers (and eventually also by their learners) to learn about models of teaching and learning and, very importantly, to individualize their learning experiences. The first of these multimedia programs is used by the TV presenter to present the course material via TV transmissions to the teachers, and the second is used by the teachers after they have watched the TV transmission.

Multimedia Based M*A*S*T*E*R Teaching of Functions

The structure of our teaching methodology falls into six basic steps. They are easily remembered through the use of the acronym M*A*S*T*E*R (Rose & Nicholl, 1997): Motivating your mind, Acquiring the information, Searching out the meaning, Triggering the memory, Exhibiting what you know, and Reflecting on what you have learned.

We developed/utilised the following list of computer based educational aids in order to apply these six steps by means of our multimedia presentation to our course material: EasyTeach Authoring System (-Tutor, -Test, -Quiz, -Book, etc) (Wight, 1998), a mind mapping facility, an artificial psychologist (providing information on goal setting, stress management, self image, study habits, etc.), a V.A.K. expert (providing expertise on visual, auditory and kinesthetic teaching and learning strategies), student modeling procedures (electronic learning style inventories and models of teaching and learning), hypermedia summaries, flowcharting procedures, mathematical drawing programs, utility modules developed specifically for our functions course, baroque music on CD, quizzes (EasyQuiz), tests (EasyTest), kinesthetic tick off procedures, a memory manager (providing hints on good memory techniques), De Bono brain gym (to apply De Bono's CoRT Thinking program (De Bono, 1993; De Bono, 1998) and thinking games to topics from our curriculum), electronic teaching/learning journal (student's view), electronic teaching/learning journal (teacher's view), and a number of Internet WWW Pages (De Kock & Du Plessis, 1997). Exactly how this was accomplished in our demonstration lesson on linear and exponential functions is described below.

We tried to orchestrate a resourceful state of mind by showing that functions can be fun by utilizing them to create spectacular pictures; by demonstrating how functions could be used in everyday life; by providing inspiring facts about our brain and our potential; by motivating the teachers through powerful suggestions; by goal setting for the lesson; and by accommodating the teachers' individual learning styles.

Other methods that could be used include positive brain programming, and relaxation and breathing exercises. The "Artificial Psychologist" (Du Plessis, 1998) could also be consulted for inter alia help on emotional, stress and time management. Some of these techniques will be used in future lessons.

We tried to utilize visual, auditory and kinesthetic strategies to present the learning material to the student: The student was asked to look at graphs, mind maps, flow charts, step charts and real-life pictures; he listened to music, and the lecturer; participated in quizzes, the building of mind maps, the building of student models, and in cooperative learning; he took notes, draw mind maps as summaries and sketched graphs as representations of functions.

Other strategies that can be introduced include visualization, dramatic readings and movement. Some of them will be introduced in future lessons.

We tried to accommodate the preferences of the linguistic (LI), logical-mathematical (LMI), visual-spatial (VSI), bodily-kinesthetic (BDI), musical (MI), interpersonal (II1), intrapersonal (II2) and naturalist intelligences (NI) (Rose & Nicholl, 1997). A hypertext summary of the learning material was consulted (LI); a flowchart of the mathematical model building process was presented (LMI); a mind map summary of the learning material was built (VSI); tick off operations were conducted in the building of student models, and students built their own learning maps (BKI); Baroque music was played as background music (MI); cooperative learning took place through small group discussions, quizzes and feedback (II1); teachers had the opportunity to evaluate the teacher and also to reflect on their own learning experience (II2); and by

categorizing the various concepts and skills in the curriculum we also (indirectly) addressed the naturalist intelligence (NI).

Of course many more ways exist how this could be achieved. Some of the learning elements that could be used for this purpose, and will indeed be used in future lessons, include: Listings of keys points and written letters to friends or newspapers (LI); logical numbered lists and diagrams (LMI); colored posters, cartoons, video and visualization (VSI); role play and sorting of index cards (BDI); creating ads, rap songs and verses and writing own words for songs (MI); study buddies! (II1); teacher sharing his passion for subject (II2; and an ecological check (NI).

We tried to stimulate the students' memories on functions by first providing some necessary background information about our memories. We continued to derive an action plan on behalf of the students and provided them with some helpful hints on how they will best remember the study material. We encouraged them to frequently take breaks, we stimulated their multisensory memories, we tried to create a review culture and encouraged memory flashing. We will possibly try to further trigger the students' memories in future lessons by incorporating the following techniques: Deciding to remember, acronyms, flash cards, learn it as a whole, wordplay with numbers and stories and music.

The students will also be given the opportunity to learn about the peg system of memory and learn how to apply it to remember facts and figures, speeches and lectures, study material, and so on.

We gave the students the opportunity to demonstrate their knowledge through quizzes, interactive feedback, small discussion groups, the building of mind maps, and very importantly, by visiting the De Bono Brain Gym. There they were introduced to some of De Bono's programmes (De Bono, 1993) that teach people how to think, and were asked to apply some of his thinking tools to the curriculum. In the process they simultaneously learned how to think about the course material and about thinking itself.

In the upcoming lessons more of the thinking tools will be introduced. The students will also be asked to take other forms of evaluation, like interactive multiple choice tests, more quizzes and some homework exercises.

We took the student on a visit to a "tropical island retreat". There he was introduced to the concepts of a personal progress plan, and daily learning and teaching journals. Hopefully it provided him with the opportunity to reflect on his or her own learning.

Multimedia Based Individualized Tutoring of Functions

A fuzzy expert and a fuzzy decision-making system (Du Plessis, 1998) are used in a model of tutoring and learning that is based on Howard Gardner's theory of multiple intelligences (Rose & Nicholl, 1997; Dickinson, 1996) to match a student's preferred learning style with an appropriate tutoring strategy.

A computerized MI (Multiple Intelligence) quiz (based on Gardner's theory) is used to determine an individual student's dominant intelligence preferences. This classification is then fuzzified in order to describe to which degree one intelligence is dominant over the other (Du Plessis, 1998). Crisp information from the MI quiz is consequently converted into fuzzy values by mapping it into one or more degrees of membership. Predefined rules in the fuzzy knowledge base are then applied to the fuzzified data to determine weighted data. This fuzzy output then describes the student's preferences for the various intelligences. A hypothetical student may, for example, be classified as having very high preferences for elements of the bodily-kinesthetic, the intrapersonal and the musical intelligences; a high preferences for elements of the interpersonal intelligence; medium preferences for elements of the logical-mathematical and the visual-spatial intelligences; and very low preferences for the elements of the naturalist and linguistic intelligences. These preferences (very high, high, medium, low and very low) are then associated with the needs, avoidances and learning elements of each of the eight intelligences.

These needs, avoidances and preferences of the different intelligences are then mapped, together with their fuzzy preferences, onto a set of presentation elements that was implemented to present the course material to the learner. The following presentation elements are available within the proposed computer based tutoring system to implement different tutoring modes (combinations of these presentation elements): A point-and-query interface based on the QUEST model; computerized adaptive testing; a computerized problem solver / spreadsheets; a generic questioning module; a facility to build mind maps; explanations; flowcharts; step charts; monitoring systems; interactive advisors; step-by-step tutorials; examples; demonstrations; diagrams; theoretical readings; drill-and-practice exercises; the asking of stimulating questions; descriptions; pseudo-code listings for procedures to follow to accomplish specific tasks; a navigation facility; practical readings; cooperative learning activities; teaching games; case studies; an opportunity to reflect/think; an artificial psychologist for motivation; an artificial psychologist for study habits; an artificial psychologist for goal setting; an artificial psychologist for emotions; an artificial psychologist for procrastination; a mind map presentation; word processor / journaling; animation / graphics; software supporting role playing; and WWW exploration (De Kock & Du Plessis, 1997)..

A fuzzy decision making system (Du Plessis, 1998) that takes specific goals and constraints into consideration is then used to prioritize the suggested usage of these presentation elements. . The result is therefore an individualized model of tutoring and learning for each student, specifying preferences for certain kinds of presentation elements. A tutoring strategy that combines a number of these presentation elements is consequently recommended to the learner, and activated by the tutoring system.

The usage of the following presentation elements is recommended to our hypothetical student: Teaching games, the building of mind maps, the point-and-query interface, animations, flowcharts, case studies and computerized adaptive testing. It is also recommended that he/she consults with the artificial psychologist on goal setting and emotions. It is further stated that the following presentation elements also have a very high rating for our student: A mind map presentation of the learning material, the use of the internet for WWW exploration, practical readings and demonstrations.

The recommended tutoring strategy is then used within a domain- and motivational based multimedia tutoring system (Del Soldato & Du Boulay, 1995) to present the learning material to the student. In this way the learning experience of each learner is individualized.

The above described model of tutoring and learning can also be used in a non-computer setting to individualize one-on-one teaching of a student and his/her learning experience. When used for teaching the teacher will adapt his teaching strategy to the strategy recommended by the model, and when used for learning the learner will adapt his learning strategy to include the activities suggested by the computerized model. Our model of tutoring and learning can therefore be used as either an "expert system" within a multimedia tutoring system or as an advisor in a conventional teaching and learning situation.

Conclusion

We have therefore proposed in this paper a technique to effectively teach mathematics and science via multimedia and the M*A*S*T*E*R formula during a television transmission (or a traditional lecture). An individualized tutoring strategy is then recommended for each learner that he or she could use on his or her own in combination with a multimedia based tutoring system or purely as advice on which study habits to pursue. More information on the usage of the fuzzy expert and fuzzy decision making systems (Du Plessis, 1998), Gardner's theory of multiple intelligences (Rose & Nicholl, 1997; Dickinson, 1996) and a domain and motivational based tutoring system (Del Soldato & du Boulay, 1995) will be made available on our website during the first part of 1999 (URL: *http://mzone.mweb.co.za/residents/dupcpss/concepts.html)*. We plan to demonstrate our complete system at the conference and will apply it to our pilot project on linear and exponential functions.

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Models Of Computer Application In Education

Dr. Ivan Gerli , assistant profesor
Centre for Computers, Informatics and Multimedia in Education
Faculty of Education Maribor, University of Maribor
Koroška 160, 2000 Maribor, Slovenia
E-mail: ivan.gerlic@uni-mb.si

Abstract: This article basically deals with the model of computer application within the educational system of Slovenia. Its introductory part depicts the most distinct periods and trends in the historical development of computer application in the Slovene educational system, followed by a detailed analysis of individual segments of the entire computer application model.

Instruction

The process of introducing computer into the Slovene educational system started in the year 1970, when the project of equipping secondary, - or more precisely, - grammar schools with computers was launched. At that stage, however, a computer was still a device which, for some time, was still not available to students and which the latter knew merely from their teachers' descriptions, or which they saw perchance only in the course of excursions where they visited the computer centres. The then lessons in computer science were executed mostly without any virtual contact with computers (since the schools had none), and hence the lessons in computer science turned gradually into a typically routine school subject, where the students were made familiar with the theory of computer science and solving logarithms. If we throw a brief glance at the typical historical periods of computer application in education (Figure 1), we see that the characteristics of computer application just mentioned were actually the characteristics of the early period of computer application in education, or - more precisely, - the period before the emergence of microcomputers. With the emergence of microcomputers the situation was changed.

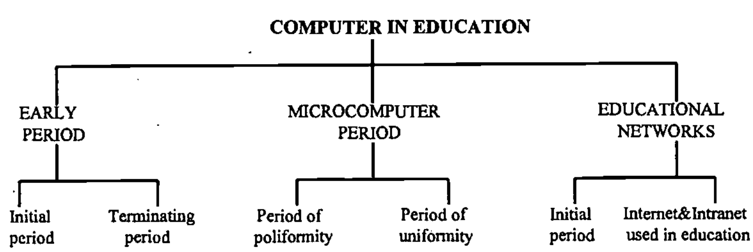

Figure 1. Characteristic periods in the history of computer application in education

Due to their prices getting low, the computers became accessible for schools. The students could use computers directly and interactively for the first time. The teachers and students now dealt with real computer science which gradually made itself felt in all other spheres of school, and extended its range of activities upon all segments of school life and work. Some projects were launched first on the regional level (projects launched by some of the regions) (e.g. Sinclair, Commodore, etc. 1985-89), these projects were then followed by some projects funded by means provided by the state aiming at equipping schools with computers ("RACEK 89" and "RACEK 90"), which provided computer equipment for all elementary schools and for the majority of secondary schools. One of the characteristics these projects shared, was the organised approach to the purchase and fabrication of educational software, especially to the process of educating teachers. In the year 1994 the amount of such-like projects increased strongly, and the projects themselves became more intensive and more affluent in the qualitative and in

the quantitative sense, since this very year saw the birth of the state-funded project labelled as "ACHIEVING COMPUTER LITERACY" - that is, the systematic equipping of Slovene schools with information technology.

Computer application model in education

In modelling computer application in the Slovene educational system, we proceed from the definitions of computer application, various Slovene and foreign authors have put forward in their works; yet, we basically proceed from the actual position and actual possibilities offered within the Slovene educational system. Among the points that concern the definition of computer's function and role in education, we considered those where the authors stuck to the *informal determination* (of computer's function and role in education); the authors show differences in the number of these possibilities of computer application they deal with, what naturally results in differences among these authors in the level of generalisation of individual possibilities. In our model, we distinguish globally among the following three fields of computer application in education (Figure 2):

The *primary field*, - the field of computer science education; it comprises activities the aim of which is to make the participants in the educational process (the students), as future users of computers, familiar with the functioning and the use of computers (the field of general education), or to make them enthusiastic about work with computers, so that they decide for a professional career dealing with computers (special professional field).

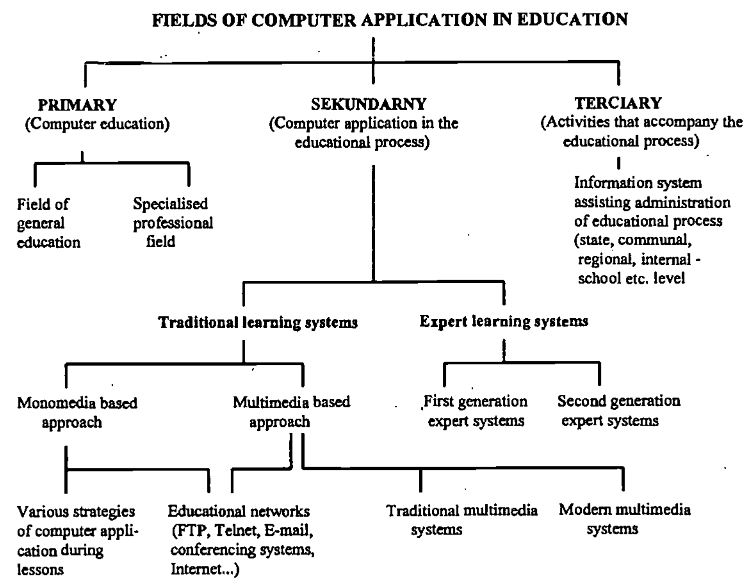

Figure 2: General computer application model in education

- The *secondary field*, - the field of computer application in the educational process; here belong all the activities that are closely related to the frontal (direct) educational process in any subject area in elementary schools. In this case the computer serves as a teaching tool or aid in the traditional forms of computer-assisted earning systems (monomedia- or multimedia systems) on one hand, or in the systems supported by artificial intelligence (AI), - the so called expert learning systems.
- The *tertiary field*, - the field of activities that accompany the educational process; here belong various research activities, as well as school administration and management of the educational system, the latter thus being integrated into the educational informational system at the school, communal, regional, and state level, or at the international co-operation level.

The education benefits mostly from the *secondary field*; here belong the use of computer in e.g. teaching mathematics, physics, Slovene, science, sociology, music, etc. In all these cases computer serves as a teaching aid or tool, which is fully or partially involved in the teaching and learning course. If computer is fully involved, this means that it is part of every single phase of the teaching and learning process and that it interferes with the entire regulative teaching course, and that it is actively involved in all procedures - students' preparation for educational work, learning and work with new learning contents, practice, revision, checking what and how the students have learned in order to ascertain their knowledge and plan further work, etc. In the second case, computer is part of only some of the phases of the teaching and learning process (course), such as practice, revision, checking the students' knowledge, presentations of new learning contents in individual steps or in the form of whole activities as units, etc.

Regardless of whether computer is fully or only partially involved in the phases of teaching and learning process, the secondary field of computer application in education can be divided into two major groups of systems that differ from one another structurally and as far as their development is concerned:

- traditional learning systems;
- expert learning systems.

The major characteristic of the traditional learning systems is that they are based on the use of educational software which is the result of programmed procedures that can be depicted in the form of more or less complex models - algorithms, so the traditional learning systems represent the *algorithmically approach* (precisely defined linear or branched procedures that are thought in advance, following exactly determined rules in anticipated situations) in the preparation of software and didactic outfit. To say it a little more simply, - these models - algorithms make a fixed hypothetical construction which gives us an authentic (real) idea of what operations are carried out in a student's head during the process of learning or solving problems respectively. The desire to equip schools with best possible educational software available and therefore enrich the systems mentioned above with the newest ideas in pedagogy, didactics, and especially psychology, showed that there were several problems in this field which were not of algorithmically character and proved therefore difficult (or quite impossible) to be solved. So the pedagogic circles, too, started to explore the possibilities of the use of artificial intelligence in education, which we define in our model as *the expert learning system.*

But in everyday situations the traditional learning systems of computer application are unfortunately still most widely used. Traditional learning systems are usually divided into the following two main types of approach:

- monomedia-based approach,
- multimedia-based approach.

Our depiction of monomedia-based approach in the computer application in education is based didactically on the so called didactic quadrangle in which the relations or communication channels can vary, which makes us bear in mind various *strategies* of computer being applied to education (Figure 3).

As it can be seen from the model, we distinguish between low-complexity strategies on one hand, and high-complexity strategies on the other. High-complexity strategies represent a kind of a shift from the situation where "the computer teaches the student" to the situation where, at least apparently; "the student teaches the computer" by programming it, solving problems following his/her ideas and decisions in an interaction with the stimulating and responsive environment. Thus the computer is gradually abandoning its function of direct teaching (it is no longer a simulation of a teacher), and is becoming a tool for stimulating the students' thinking processes, fantasy, and creativity.

The *multimedia-assisted computer application* in education represents the integration of text, sound, graphics, static and dynamic picture in the computer-assisted multimedia system; or, - if we put it another way round, - a multimedia system uses the computer as a tool for exerting control over various (several) media. In the multimedia-based approach we distinguish between two terms: *multimedia and hypermedia*. Multimedia systems, these two terms describe, differ in their level of technological development of the media, but especially in the interaction level between their elements. Under "multimedia" we understand the combination of the computer and the traditional low interactivity level media, whereas the term "hypermedia" comprises the combination of the computer and the modern up-to-date high interactivity level media. With regard to this we too distinguish in our own model between the traditional multimedia systems (multimedia) and more complex multimedia systems (hypermedia). Great attention, in the didactical as well as in productive sense, is being paid to this field in Slovenia.

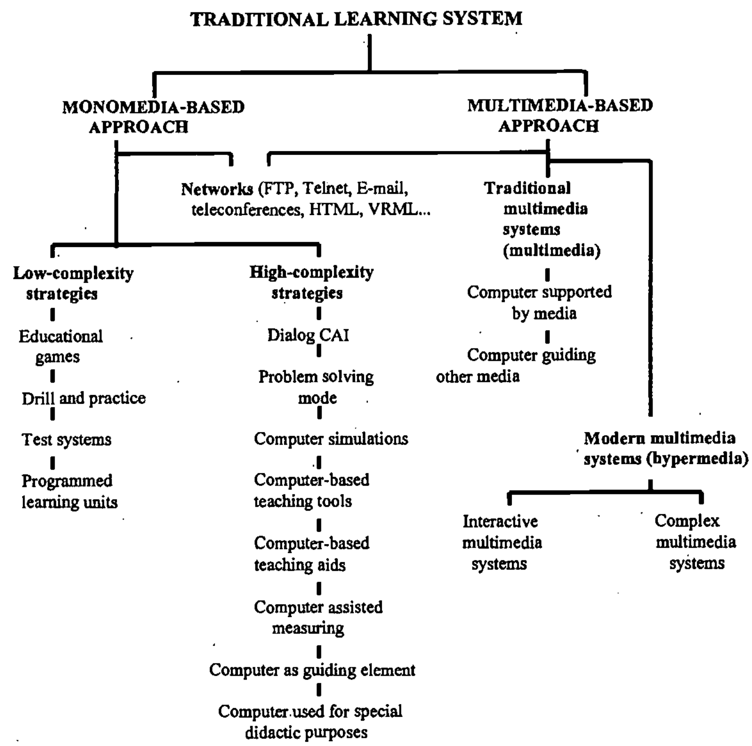

Figure 3: Traditional learning systems in the secondary field of computer application model

As we can see in figures 2 and 3, *educational networks* are increasingly making their influence felt in the lessons in monomedia- as well as multimedia-based approach (e.g. taking the form of capturing and exploring FTP files, TELNET, e-mail, WWW-systems, teleconferences, distance learning, etc.) The educational networks bear all the characteristics of monomedia and multimedia systems (HTML texts, JAVA educational applets, VRML, etc.) In the year 1995 we established in Slovenia the Slovene Educational Network, where an increasing number of our schools have access through Internet and Intranet to various projects home and abroad.

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Arthur: An Adaptive Instruction System Based on Learning Styles

Juan E. Gilbert
University of Cincinnati
Department of ECECS
United States
juan.gilbert@uc.edu

C. Y. Han
University of Cincinnati
Department of ECECS
United States
chia.han@uc.edu

Abstract: The theory of learning styles states that people have different approaches to learning and studying (Dunn 1987 & Dunn 1978). Given a specific instruction method or environment, some people will learn more effectively than others due to their individual learning style and the grade distribution of the learning would be bell shaped, with the majority of the learners appearing in the middle of thc distribution curve. Several studies show that there is "No Significant Difference" when technology is applied to instruction (Crump 1928, Gerhing 1994, Goldberg 1996, Moore 1996, Schlosser 1994, & Wilson 1996), since either in traditional classrooms or in any of the technological environments, there is only one form of instruction, and usually from one source, yielding the familiar bell shaped grade distribution. This explains the "No Significant Difference" results and indicates that another instruction method needs to be investigated. An approach to achieve "A Significant Difference" is to provide several different instruction methods. This paper describes Arthur, which is a web based instruction system that provides adaptive instruction to achieve "A Significant Difference".

Introduction

Learning styles are approaches to learning and studying (Dunn, 1987). We all have learning preferences, which enable us to learn more effectively. When introduced into a learning environment that supports our learning style(s), learners have a higher level of understanding the material. The learning styles theory implies that how much individuals learn has more to do with whether the educational experience is geared toward their particular style of learning. In a traditional classroom environment, there is one instructor and several learners, which is an one-to-many relationship. The instructor presents information with his/her personal style of instruction. The instructor may use technology such as overhead slides, computer animations, videos, or simply chalk and talk lectures. If the instructor's style of instruction is conducive with the majority of the learner's learning style, then the class as a whole will perform well. In the general case, the instructor's style is conducive with most of the learner's, but not a perfect match. In this case, the majority of the class will have an average performance with fewer people doing either very well or very bad, which establishes a bell shaped grade distribution.

There are several different learning styles and combinations of styles. Sarasin (1998) discusses auditory, visual, and tactile learning styles. Inquiry-Based Learning (Pasch 1991), Discovery Learning (Bruner 1966), and Expository Teaching (Ausubel 1977) are just a few other learning styles. There are several other learning styles and instruction methods. In fact, learning styles or instruction methods can overlap or be used in combination with other methods. When considering all the possibilities of instruction, it becomes clear why there is a bell shaped grade distribution in the traditional classroom. It becomes an impossible task to accommodate everyone's learning style. Therefore, instructors generally use what works best for them and on the average, most people get it, yielding a bell shaped grade distribution.

In the tutoring environment there is one instructor and one learner, which is an one-to-one relationship. This environment would appear to be an improvement on the traditional classroom because of the personalized attention. This may be so, but there is still the limitation of the tutor's ability to adapt to the learner's learning style. If the tutor can not adapt to the learner's learning style, then the learner does not gain very much of an advantage over the traditional classroom.

Imagine a classroom full of instructors and only one learner, which is a many-to-one relationship. Each instructor is an expert in the same field of study, but each uses a different style of instruction. Hence, the learner's chances of doing well in this classroom would appear to be significantly better than in a classroom with one instructor because each learner would adapt to the instructor(s) that would facilitate his/her learning style. In the sections that follow, we will introduce an implementation of the many-to-one relationship.

Arthur: An Adaptive Instruction System Based on Learning Styles

We have developed a web based instruction system that provides adaptive instruction, Arthur. Arthur takes several different styles of instruction from several different instructors and makes them available to each learner, which defines a many-to-one relationship. A group of instructors from the same field collaborate to create a course map, which is similar to a syllabus, for the course content. The course map is divided into small sections that are called concepts. A concept is a basic unit of instruction or a fundamental concept that must be covered within the course. After creating the course map/syllabus, each instructor will create a web deliverable course module that adheres to the course map. Web deliverable includes, but is not limited to, text, images, audio, animations, video, multimedia, etc. For example, five instructors are gathered together to create a Calculus 101 course. The instructors create a course map that contains forty concepts. Each instructor will create their own web deliverable course module containing forty concepts using a different instruction style. Upon completion of their individual course modules, each instructor will add their course information into Arthur. This creates an instruction pool of course modules. The instruction pool is a collection of course modules entered by the instructors. In the Calculus 101 example, the instruction pool would contain five different course modules, one from each instructor. Before course modules can be added to Arthur, instructors and their different instruction style(s) have to be identified.

Identifying Instructors

In the beginning of a course, instructors have to be selected to participate in the course creation process. In this process, the selection of the instruction styles has to be established as well. Ideally, the instruction styles would be selected before the selection of instructors. This is a difficult task because most instructors use more than one style when delivering instruction. Therefore, the instructors are selected before the styles. This process involves observing instructors during their delivery of instruction, reviewing their lecture notes and other media used during instruction. After reviewing the various styles used by different instructors, each instructor will be categorized as to their dominant instruction style(s). After assigning instruction styles to instructors, each instructor will develop their own course modules in a web deliverable form. The next step in course creation involves adding individual course modules to Arthur.

Submitting Content

After the selection of the instructors and the instruction styles has been completed, each instructor will add their course module to the system. Arthur provides several web based forms that allow the instructors to add their course module to the system. The first step to adding a course module to Arthur involves adding information about the course. For example, one of the instructors will be identified as the course coordinator. The coordinator will add Calculus 101 to the system along with the predefined concepts within each course module. When the other instructors login into Arthur to submit their individual course modules, Calculus 101 will appear as a course available to them. Instructors will identify

their course materials by URL. They will add the URL for the first page associated with each concept within a course. This will allow each instructor to maintain his/her own course materials on their own web servers. Instructors will also add their personal information into Arthur as well. This includes their name, affiliation(s), email address, etc. Finally, the instructors will submit quiz questions that will appear at the end of each concept. The quiz questions appear in the form of multiple choice or written answer. Once instructors have submitted their course materials and quiz questions to Arthur, the system is ready for learner use.

Learning Experience

When a learner enters Arthur using a login and password, Arthur will deliver the first concept of one of the course modules from the instruction pool. The courses are initially selected at random. Therefore, each student will be assigned their first course module by chance. Each concept is terminated by a short evaluation quiz entered by the instructor. For example, John Smith logs into Arthur. John is assigned the first concept for Calculus 101 using an Auditory (Sarasin 1998) Expository Teaching (Ausubel 1977) style, which was developed by instructor Carl Gilbert. This style uses audio to present a general explanation of each concept followed by examples. When John completes the first concept, he will be given a short quiz. The quiz is delivered through the web using Arthur. The quiz will be graded by the instructor, Carl Gilbert, or automatically by Arthur, i.e. multiple choice. Instructor Gilbert will be notified via email that a quiz has been taken. After notification, instructor Gilbert will log into Arthur where the quiz questions and answers will be presented. The learner's name, John Smith, is never revealed to instructor Gilbert only the question and answers. After grading the quiz, instructor Gilbert will report a score for the learner. The student must pass each section with a score of eighty percent or better in order to continue within the current course module. This evaluation method introduces the term *Mastery Learning*, which is used by Arthur to adapt the instruction style.

Adapting Instruction

Mastery Learning is based on the assumption that, given enough time and proper instruction, most students can master any learning objective (Bloom 1968 & Guskey 1986). The normal distribution of scores learners exhibit on any performance test arise from the use of one instruction style given by one instructor and the practice of holding instructional time constant for all students and allowing learning to vary. Bloom (1976) suggest that learning should be held constant and time allowed to vary. To use the mastery approach, an instructor must break a course down into small units of study, which correspond to concepts within Arthur. Each unit might involve mastering several specific concepts or objectives. Mastery usually means a score of 80 to 100 percent on a test or other assessment (Woolfolk 1998).

Arthur uses mastery learning to adapt instruction for each learner. When a learner completes a quiz at the end of a concept, Arthur employs mastery learning to adapt the instruction based upon the learner's score for each quiz. If the learner scores 80 percent or better, Arthur will allow the learner to move onto the next concept using the current course module. In the Calculus 101 example, assume John Smith passes the first concept of Carl Gilbert's course module with a score of 90 percent. Arthur will present John Smith with the second concept of instructor Gilbert's course module. John Smith scores a 75 percent on the quiz following the second concept. Arthur presents John Smith with the second concept of Frank Howard's Calculus 101 course module, which uses a different instruction style from Carl Gilbert's course module. Therefore, when learners pass the quiz at the end of a section, Arthur assumes that the instruction style used in that section matches the learner's learning style.

In some cases, learners may require multiple instruction methods. These learners may require that a concept is explained using an audio method followed by a visual method. In this case, Arthur cycles the learner back through their learning experience. For example, John Smith started Calculus 101 using instructor Gilbert's course module. When John fails the quiz following the second concept, he is moved to instructor Howard's course module. John passes the second concept using Howard's course module. If John fails the quiz following the third concept of Howard's course module, John will be reassigned the third concept using Gilbert's course module. This will allow John to use both methods to support his learning in

the case that John is a multiple method instruction learner and requires both Gilbert's and Howard's form of instruction.

When a learner successfully completes a course using Arthur, the system creates a learning map of the learner's learning experience. This map can be used to identify the learner's learning style(s). The learning map can also be viewed as a model of the learner's behavior while using the system. The learning map will be used in data collection and analysis. The data collected by Arthur can be used later when the learner returns to the system to take a new, yet similar course, i.e. Calculus 201. The models that are created when the learner completes a course may be used as a classification tool. In the following sections, we will describe the system implementation of Arthur.

System Implementation

Client Side

Each learner will use Netscape Navigator 4.x or Internet Explorer 4.x to use Arthur. Once the learner goes to the web site that hosts Arthur, the learner will be forced to authenticate using his/her preassigned login and password. The interface to Arthur uses a Java applet in a html frame to provide all the navigation information from the web server. Special client side software requirements may be necessary for particular courses upon the demand of the instructor. For example, an instructor may require that the learner have a particular programming language installed on their computer in order to compile and test programs. Another instructor may require that the learner's computer have a particular database package or word processor. These requirements depend on the individual instructors and the tools needed to successfully complete their course.

Server Side

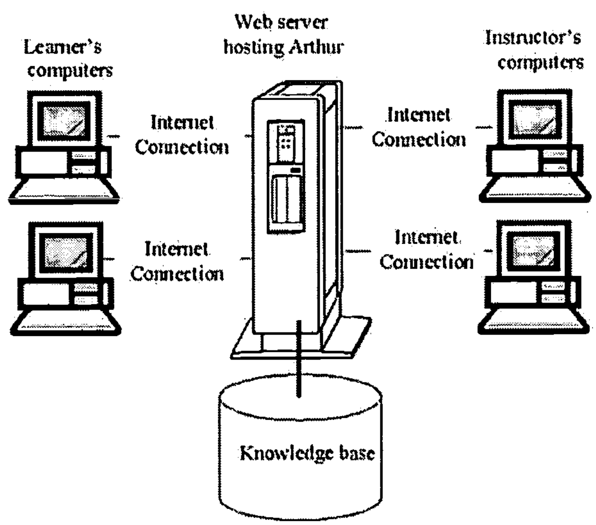

Figure 1. System Architecture

Intelligent FAQ

Arthur will also make use of Intelligent FAQ. This is a feature that will be used to answer frequently asked questions. When the learners are going through the course modules, questions will arise about the concept being learned. In order to answer those questions quickly and effectively, Arthur implements Intelligent FAQ. Intelligent FAQ is an information retrieval (Salton 1989) system used to answer frequently asked questions. Intelligent FAQ accepts a question from the learner and creates a query string as seen in information retrieval systems. The query string is created by removing the stop words (Britanica 1998). When a question appears for the first time, it is sent directly to the instructor via email.

The instructor will log into Arthur and answer the question. Once the question has been answered, the learner will receive an email notification that an answer has been submitted. The learner will log into Arthur and pick up the answer to the question. Arthur will store the query string and answer in the knowledge base for later use. When a different learner asks a similar question, Arthur will retrieve the answer from the previously asked query string and answer stored in the knowledge base. Intelligent FAQ is being developed as part of Arthur, but can be used on any web site.

Conclusions

The theory of learning styles states that people have different approaches to learning and studying (Dunn 1987 & Dunn 1978). Several studies show that there is "No Significant Difference" when technology is applied to instruction (Crump 1928, Gerhing 1994, Goldberg 1996, Moore 1996, Schlosser 1994, & Wilson 1996). The most commonly used instruction environments use an one-to-many or one-to-one instructor/learner relationship. We have developed an environment that utilizes technology to deliver a many-to-one instructor/learner relationship. Before the recent use of technology, this type of education experience would have been too expensive to implement. Using the world wide web and supporting technologies, we can deliver a many-to-one instructor/learner relationship such that individual learning styles can be accommodated.

Arthur will be initially tested using Physics 101 and CS 1, computer science programming with C++. It is expected that other domains will work as well. In the future, Arthur will add new domains of instruction. For example, the arts, sciences, languages, mathematics and other engineering disciplines will be added to Arthur. In the short term, Physics 101, which is currently being taught to various degree tracks, and CS 1 will be used to gather initial data results.

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OWL: An Integrated Web-based Learning Environment

David Hart, Beverly Woolf
Center for Computer-Based Instructional Technology
Department of Computer Science
University of Massachusetts, Amherst
United States
{dhart,bev}@cs.umass.edu

Roberta Day, Beatrice Botch, William Vining
Department of Chemistry
University of Massachusetts, Amherst
United States
{rday,bbotch,vining}@chem.umass.edu

Abstract: OWL (Online Web-based Learning) is an electronic learning environment developed for General Chemistry and currently being adopted by other disciplines. Basic OWL provides a powerful, web-based electronic homework model used by thousands of students each semester. OWL's open architecture allows for extensions that expand its scope from the delivery of straightforward electronic quizzing to the offering of a richer interactive learning environment. Such extensions include guided discovery exercises and intelligent tutors, numerous examples of which are currently being created and tested in large enrollment General Chemistry courses. In this paper we describe OWL and its use on campus. We also report on a number of OWL evaluation studies underway, including some preliminary findings from formative evaluations of OWL's use in classes and of some of Owl's extensions, and the first large-scale evaluation of a Stoichiometry Tutor that is integrated into OWL and that shows significant increases in student performance.

Developing a New Model for Homework in Large-enrollment Classes

Electronic homework has been used in the General Chemistry Program at the University of Massachusetts for 12 years. The first version was implemented using the Plato system, a commercial courseware creation package used by many universities in a variety of disciplines. The two primary General Chemistry service classes enroll between 1200 and 1400 students each semester from 35 different majors. As with any large service course, methods to encourage students to keep up with current assignments are important factors in the success of these courses. Before the introduction of electronic homework eleven years ago, General Chemistry students attended weekly recitation sections lead by faculty members, and took a quiz at the end of each section. Quizzes were graded by instructors and results were distributed one week later. While this system created the desired motivation for students to stay current with the curriculum, it was extremely labor intensive – 72 faculty contact hours each week, plus an even greater amount of TA time spent on grading. A serious pedagogical drawback was the lack of immediate feedback to the students about their work; getting a quiz back a week later provided little opportunity for students to learn from their mistakes.

The Chemistry Department's adoption of electronic homework was motivated in large part by a looming increase in the number of faculty retirements. As is the case nationally, the University was unwilling to replace these retiring faculty members on a one-for-one basis, which meant that faculty resources were under increasing pressure to cover the large contact-hour commitments required by the recitation sections. Electronic homework was seen as a way to cover these commitments with fewer faculty contact hours while maintaining the motivation factor for students to keep up with their coursework.

Adoption of electronic homework afforded the opportunity to change the quiz/homework model at the same time. Because the computer grades automatically, students could take and retake "quizzes"

repeatedly until they demonstrated mastery of each topic. Random selection from a large pool of questions for each quiz meant students would seldom see a question repeated, so that instructors could build in an immediate feedback cycle – after a student submitted an answer, the correct answer and a body of informative feedback was displayed that allowed the student to learn from his or her mistake immediately and apply that knowledge to the next question(s) seen. A large part of the success of this model came from the creation of a Chemistry Resource Center, a large room filled with computers that students use for their electronic homework assignments. This room was (and still is) staffed with TAs and faculty who can give help and feedback to students while they are doing their electronic homework. Instructors, TAs and students all felt that this was a better use of their time than recitation sections.

The Chemistry Department was keenly interested in the results of this new model. Several of the authors carefully compared student performance in the years previous to the model's adoption and in the years immediately after. While there was no improvement in grades, the real gains were seen in students' affective responses – surveys showed that students overwhelmingly preferred the new approach. There were of course big gains in the cost efficiency of delivering the course. Given that the new model saved resources, was preferred by students, and did not negatively impact student performance, it was wholeheartedly embraced.

Online Web-based Learning for General Chemistry

The Chemistry Department began a collaboration in 1996 with the University's Center for Computer-Based Instructional Technology (CCBIT) to replace the by-then antiquated Plato system with a Web-based version, OWL. By adopting Web technology, OWL provides a platform-independent delivery system that is available all day from any web-linked computer a student or instructor can work. It also allows developers to incorporate large off-the-shelf software components for web service, databases and middleware. The OWL system was used by the full Chemistry courses for the first time in the spring of 1997, and has been used successfully ever since. In a typical semester over 50,000 Chemistry quizzes are taken, with more than 5000 in one day during peak usage periods. 60-70% of these quizzes are taken outside the Chemistry Resource Center (i.e. in students' rooms or other labs on campus). Student surveys administered each semester show a high degree of satisfaction with OWL, including a recognition that OWL helps students learn the material and keep up with the class.

A host of similar systems have been created in recent years, such WebAssign at North Carolina State University [[1]], both CyberProf [[2]] and Mallard [[3]] at the University of Illinois at Urbana-Champaign, and even commercial versions such as EBSCO's CyberExam. Most of the commercial web-based courseware development packages (e.g. Web-CT, Web-in-a-Box and TopClass) provide online quizzing capabilities. OWL, though developed independently, shares many important features with these systems. In addition, OWL has advanced features such as parameterized questions, user-defined multimedia and Java tags, and sophisticated course management tools. It is also missing some useful features found in one or more of the other systems (e.g. essay submission, audio support) that will be added soon. One feature of OWL that sets it apart from others is that, by design, its architecture is open for the addition of new learning modalities such as guided discovery modules and intelligent tutors, and for the incorporation of curriculum content materials whose use by students can be tracked by the system. These extensions to OWL are described below.

OWL is now used in five Physics & Astronomy classes with almost 1000 students each semester. Like Chemistry, Physics has been able to eliminate discussion sections and TA time spent on grading. In one class, TA requirements were halved while the amount of graded homework for each student increased nine times over the previous, non-OWL semester. In this particular class, the instructor was able to measure a significant increase in student performance over the previous semester (a 6-8 point increase in mean scores

[1][] See http://wwwassign.physics.ncsu.edu/.

[2][] See http://ntx2.cso.uiuc.edu/wss/services/cyberprof/.

[3][] See http://www.ews.uiuc.edu/Mallard/Overview/.

for each of three midterms and one final exam), some of which can be attributed to the increased time spent on homework assignments – students reported a doubling of the time spent weekly on homework assignments from one semester to the next [4].

In the coming year (1999) OWL will be used in a wide variety of departments, including Geosciences, Engineering, Microbiology, Education, Spanish & Portuguese, Art History, Mathematics, Biochemistry and Entomology. These departments have been selected by the University to participate in disseminating OWL throughout the campus. In future years OWL will be provided as a service to users from all departments, with support from the University's academic computing facility. OWL is also being tested on other campuses. The Chemistry Department is supporting classes at UMass/Dartmouth and at Tuskegee Institute.

Basic OWL runs in Windows NT and uses straightforward Common Gateway Interface programming written in C++. It uses the Netscape's Enterprise Webserver and Microsoft's SQL Server database program. Students and content authors (instructors, teaching assistants) can access OWL using the latest versions of Netscape Navigator and Internet Explorer.

Using OWL's Open Architecture to Integrate Interactive Learning Activities

The basic OWL system has been created with funding from the University. External funding has been obtained to extend OWL from an online quizzing system to an interactive learning environment through the incorporation of such resources as guided discovery exercises and intelligent tutoring – all web-based. OWL's open architecture allows the incorporation of these new resources by simply treating them as additional quizzes or homework assignments, all delivered over the Web. Students are assigned to work with a guided discovery exercise or intelligent tutor that is embedded in OWL, using it to engage in a learning activity much like an online laboratory. Once the student finishes the exercise, control is returned to OWL and the exercise results are stored with the student's permanent record in OWL's database. This allows instructors to assign active learning tasks in addition to quizzes and track students' progress in completing them.

Discovery Exercises

Guided discovery exercises allow students to interact with a multimedia simulation or visualization activity, using leading questions to guide them to the "discovery" of basic laws and concepts such as gas laws or electromagnetic radiation. This technique has been used successfully in the classroom for many years by one of the authors, Vining. He has created a library of 40 or more such exercises, collectively called *Chemland* [5], that are being recoded in Java to run under OWL's control. 33 of these have been ported to Java, and they are now being fully integrated into OWL [6].

An example of a guided discovery exercise embedded in OWL is shown in (Fig. 1). This Java applet (lower right window), designed to guide the student through an exploration of the physical laws governing the electromagnetic spectrum, allows the student to run the mouse over a bar representing the visible light spectrum (shaded bar at top of small window). As the mouse moves over points in the spectrum, the corresponding values for wavelength, frequency and photon energy are displayed. A click of the mouse at any point shows the waveform for that point in the graph (lower left). The student's task is to answer a series of OWL questions (see top window) that start with the basic mechanics of moving the mouse and noting the resulting parameter value changes (as we see in the three questions shown), but will lead through

[4] Personal communication with the instructor, Prof. Jose Mestre.

[5] For the full set of Chemland exercises see http://soulcatcher.chem.umass.edu/web/projects.html.

[6] For Java recodings of Chemland exercises for use in OWL see http://owl.cs.umass.edu/chemland/chemland.html. 25 of the exercises have been licensed to a major Chemistry textbook publisher, to be used in a website accessible to users of their textbook.

a careful progression that first familiarizes the student with individual parameters (e.g. changes in wavelength up and down the spectrum), then examines the relationships between parameters (e.g. how does frequency change as a function of wavelength?), and finally requires that the student generalize these observations in order to answer questions about the basic laws governing the behavior of electromagnetic radiation. All question responses are stored in the OWL database so that instructors can track students' progress.

For each of the 33 Chemland exercises integrated into OWL a set of guiding OWL questions must be authored that effectively simulate the guidance provided when a skilled instructor uses that Chemland exercise in the classroom. We have currently completed question sets for 21 exercises, and have just begun testing them with small groups of students (results are not yet available). Full scale testing of these exercises will begin in the Spring 1999 semester as they are integrated into the normal cycle of general chemistry homework assignments.

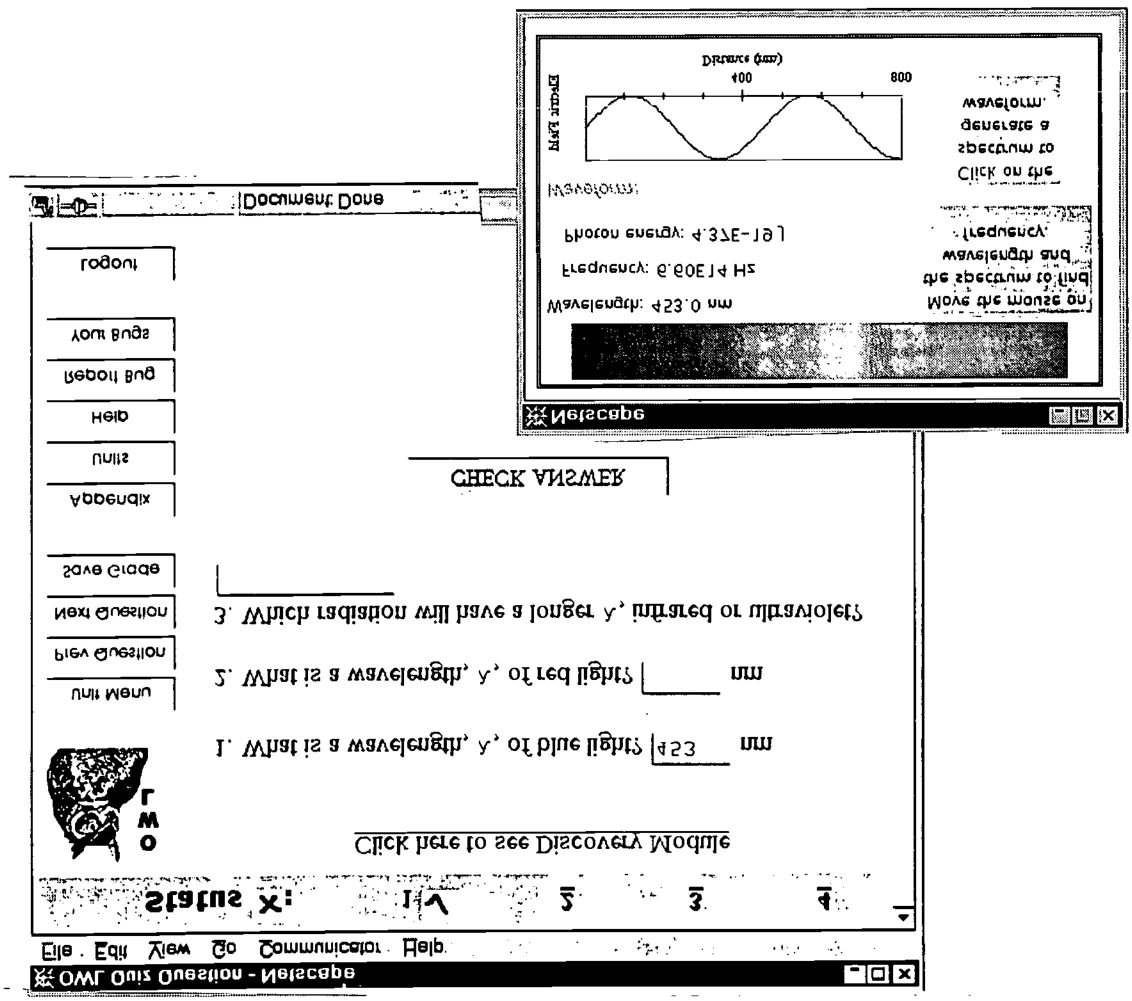

Figure 1: Electromagnetic Spectrum Discovery Exercise from Chemland integrated into OWL

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Intelligent Tutors

Intelligent tutors customize their instructional strategies to the needs of the individual student. They vary the pace of instruction, presenting problems in such a way as to challenge the student at the appropriate level. Students are required by the tutor to interact with the instructional material to demonstrate facility with it. OWL is being extended to incorporate intelligent tutors including two already developed. A Stoichiometry Tutor has just undergone large scale evaluation during the fall semester. Results, which were very positive, are reported below. A Lewis Structures Tutor has also been developed and undergone initial formative evaluation. Results suggest it can be effective but has several small, correctable flaws that will make it more so. Large scale testing of this tutor will occur in the spring. Tutor development for OWL is supported by external funding (see Acknowledgments): 15-20 tutors will be created and incorporated into OWL in the next two years.

Stoichiometry Tutor

Stoichiometry is one of the basic curriculum units in first semester general chemistry, though approaches to teaching it vary. Several years ago it was decided that the General Chemistry Program would move teaching of Stoichiometry from lectures to labs. The labs were reorganized to cover the various topics in Stoichiometry over the semester. However, after several semesters trying this approach, the consensus was that students needed additional help – they weren't learning Stoichiometry as well as they had before. Rather than move it back to the lecture (and bumping some other important topic), an intelligent tutor already under development for OWL was made a requirement for all beginning general chemistry students (859 in Fall 1998).

The tutor presents each student with problems in Stoichiometry that start with basics and gradually increase in difficulty, varying this increase according to the perceived ability of each student. If the student can solve the given problem, the tutor generates another, slightly more difficult one. If the student makes a mistake, the tutor gives hints by breaking down the problem into its constituent subproblems. If mistakes are still made, the tutor provides additional, more fundamental hints in a recursive manner, until it bottoms out in the most basic chemistry (e.g. "the atomic weight of Oxygen is 16"). Stoichiometry by its nature lends itself to this kind of approach, and the tutor leverages this problem structure to great effect. Students who use the tutor log into OWL and select the tutor as their current assignment. The tutor tracks the student very carefully and forms an assessment that it passes back for storage in OWL's database. Work with the tutor was broken into three separate assignments spread over six weeks, so students spent considerable time working with it. Each student had to solve a minimum of 29 problems over this time.

Roughly 30 students used the tutor in the summer school of 1998. In preparation for assessment of the tutor a series of three Stoichiometry questions were added to the final exam in many sections in the Fall of 1997. These questions were repeated on exams in the summer and fall finals in 1998. This provides a baseline of performance we can use to assess whether students working with the tutor know more about Stoichiometry as a result. The 30 students who used the tutor last summer showed impressive improvement: they scored 5-10% better than students in the previous fall, but the sample size too small for these results to generalize.

During the past fall the 859 students using the tutor provided a large experimental population. Pretests of these students using the same three exam questions showed that their knowledge of Stoichiometry was minimal (in the best case, only 14% of students could answer a question correctly). The same 3 questions were included in the finals for three of the five course sections, giving us an experimental group of 438 whose scores could be compared to the students from the previous fall (who didn't use the tutor). Results are summarized in (Tab. 1).

Final Exam		**FALL 97**			**FALL 98**		**%Gain**	**Asymp.**

Questions	N	#Correct	%Correct	N	#Correct	%Correct		Signific.
Question 1	622	464	74.6%	438	353	80.6%	6.0%	.022
Question 2	777	413	53.2%	438	269	61.4%	8.2%	.005
Question 3	776	569	73.3%	438	369	84.2%	10.9%	.000

Table 1: Data from large-scale evaluation of the OWL Stoichiometry Tutor shows that students who used the tutor in the Fall of 1998 performed significantly better on a series of three Final Exam questions than did students in the Fall of 1997 who didn't use the tutor.

Each table row records the results on one of the three exam questions, first for the Fall of 1997 and then Fall 1998. **N** shows the sample sizes, the number of students who responded to each of the three questions on the respective exams. **#Correct** is the number of correct answers and **%Correct** the ratio of the first two. **%Gain** shows the increase in **%Correct** from the non-tutor group to the tutor group, which range from 6% to almost 11%. While these gains are consistent with those from the small summer sample group, the final column (**Asymptotic Significance**), taken from a 2-Way Chi-Square test on the data from each of the exam questions, shows these results to be highly significant.

We also conducted surveys to assess the affective responses of students who used the tutor. Students were asked to respond to 11 questions by selecting one of five options ranging from "Strongly Agree" to "Strongly Disagree". Of 578 respondents, 58% agreed or strongly agreed that the tutor was a good use of their time, 72% that it improved their understanding of Stoichiometry, and 71% that the tutor helped them learn from their mistakes. On the flip side, only 10% felt the tutor was hard to learn how to use, though 38% said they had experienced some frustration when the tutor had problems (several performance problems with the tutor only surfaced when it had 859 regular users!). Only 22% felt more help should have been provided in how to use the tutor.

Lewis Structures Tutor

A second tutor has been developed to teach Lewis Structures, a systematic method for drawing molecules in two dimensions that is used to infer molecular geometries. This tutor is very interactive, allowing students to drag icons representing atoms, bonds and electron pairs into proper alignment and get coaching when they encounter difficulties. As with the Stoichiometry Tutor, students log into OWL and choose the Lewis Structures assignment, from which point OWL passes the student ID and assignment information to the Tutor. To complete the assignment, the student must draw one or two Lewis Structures at each of seven difficulty levels. OWL stores the student's assignment progress (whether partially or fully completed) whenever a session is closed. The Lewis Structure Tutor runs as Java program and uses Java server-side technology to manage each student's session. The Lewis Structures Tutor has been evaluated formatively with one section of 164 students. The students scores on two midterm exam questions were compared to scores on the same questions from two sections who did not use the tutor. The results were ambiguous – better on one question and worse on the other – leading the authors to suspect that several hinting techniques used in the tutor actually allowed students to find shortcuts to solving the problems rather than work them out to completion. These shortcuts will be eliminated for full scale testing in the Spring of 1999.

Support for Building Tutors Within OWL

Up to this point tutors we have developed for integration into OWL have been treated as external modules that are programs in their own right and communicate with OWL via message passing. However, we are considering the benefits of building simple tutoring capabilities directly into OWL. While the current external-module approach is good for tutor developers who need a clean interface to OWL's inner workings, it prevents faculty instructors (who are not intelligent tutor programmers) from using their questions in a tutoring context. This is creating a situation where information is being duplicated, as in Stoichiometry, where the Tutor uses its own database of information that is distinct from OWL's question set. Such a tutoring facility, if built into OWL, will not have the sophistication of standalone tutors, but

will provide an avenue for instructors to make good dual-use of the knowledge they put into OWL. Both tutoring models will be supported in the long run.

Adding Curriculum Content to OWL

OWL will soon provide the capability to present new curriculum content. The first user of this facility will be the University's Office of Environmental Health and Safety (EH&S), which has tremendous training and certification responsibilities for the campus. For example, over 3000 faculty, staff and student employees must be certified or re-certified annually for Hazardous Materials management. Once this capability is built in, OWL will be able to track the student's or trainee's use of such materials, much as it tracks the results of homework activities now. In order to do this, OWL will be interfaced with the University's employee database, allowing it to track EH&S training requirements and progress for each department on campus.

Acknowledgments

Internal development of OWL has been funded by the University of Massachusetts at Amherst, including the offices of the Provost and of the Dean of Natural Sciences & Mathematics, and the departments of Chemistry, Physics & Astronomy and Computer Science. Extensions to OWL for discovery exercises and intelligent tutors are funded by the National Science Foundation (NSF DUE-9653064), the U.S. Department of Education (FIPSE P116A70834), and Fivc Colleges, Inc. While the development of OWL has drawn on the talents and support of more people than we can mention here, we gratefully acknowledge the tremendous backing provided by the Dean of Natural Sciences & Mathematics, Linda Slakey, and the chairs of Chemistry and Computer Science, Lila Gierasch and David Stemple. The work would not get done without the expertise and programming skills of OWL developers Steve Battisti and Cindy Stein and discovery exercise/tutor developers Matt Cornell and Chris Eliot. Finally, we thank Prof. Arthur Swift of the Physics & Astronomy Department for helping us stretch the OWL model for use outside Chemistry.

The Comparative Evaluation of Classroom and Distance Sections of a Industrial Software Engineering Graduate Course

D. Michele Jacobsen
Niek J.E. Wijngaards
Rob Kremer
Mildred L.G. Shaw
Brian Gaines

Software Engineering Research Network (SERN)
Department of Computer Science
University of Calgary, Calgary, Alberta, Canada
{jacobsen, niek, kremer, mildred, gaines} @cpsc.ucalgary.ca

Abstract: This paper describes the extent to which we achieved our original objectives with a distance-based learning model for a graduate course in software engineering. The approach taken to compare concurrent local and distance learning environments includes evaluations from three perspectives: 1) the teachers, 2) the learners, and 3) technical support. As a result of the current experiment, our next experiment will be focussed on a distance-only offering of a graduate course.

Introduction

The Software Engineering Research Network (SERN) is funded by industry and administered by the Industrial Software Engineering Chair at the University of Calgary to support the dissemination of good practice in software engineering. One component of SERN's activities is a research-based masters program with a specialization in software engineering targeted at students with industrial experience in full-time employment (Shaw & Gaines, 1998). This program has dual objectives: 1) to develop highly qualified personnel, and 2) to encourage industry-based software engineering research with a focus on good practice. The coursework component of the M.Sc. includes required courses that have been developed in consultation with the industry partners. The learning environment for these required courses is unconventional and reflects the industrial experience of the students. After the first background lecture, students take over much of the responsibility for presentations on various topics in each course. The instructors' role is that of facilitator managing a process of debate and exploration rather than attempting to be an authority in the domain. The overall aim of the M.Sc. program is to provide a supportive and nurturing learning environment in which experience and knowledge can be constructed and shared, ignorance displayed and errors made without censure and with ready access to diagnostic help. It becomes clear to students that, while there are no easy answers to the core questions of industrial practice in software engineering, there are many useful perspectives and that simplistic, surface level answers generally have very limited applicability. Students make their coursework accessible to others by posting assignments on the World Wide Web. An e-mail list server is used for continuing discussion of the course topics outside the class environment. These two features have made it possible for students whose companies relocate them, or who change jobs to companies in other locations world wide, to continue to participate in the courses. Remote students who have already come to know their colleagues can continue to present and share material through the web and participate in discussion through the list server.

Towards A Distance Model

We are currently addressing the challenge of making the M.Sc. program formally available to remote students while maintaining effective ongoing participation. A first step has been to develop and offer parallel sections of SENG611, a team-taught, six-week Requirements Engineering graduate course. One section of SENG611 was delivered on campus, and the other delivered at a distance using facilities provided by WebCT (Goldberg, Salari, and Swoboda, 1996). The option of participating in the course using a distance model was offered to students during the first of six lectures. Of the 21 students in the course, 7 participated in the distance section,

and 14 on campus in a conventional face-to-face learning environment. In addition to individual assignments, all students collaborated on a major group project that they presented during the final lecture. This paper describes the extent to which we achieved our original objectives with a distance-based learning model. The approach taken to compare and analyze the two learning environments includes evaluations from three perspectives: 1) the teachers, 2) the learners, and 3) technical support. First, an analysis of the instructors' experience with the two sections of the course includes a description of pedagogical requirements before and throughout the course, and a retrospective consideration of lessons learned. Second, an exploratory analysis of information collected from students, both throughout and at the completion of the course, is presented. The third perspective taken is that of technical support. WebCT was customized in order to meet the requirements of SENG611; a report is provided on the efficacy of this tool for a graduate course in software engineering. The results of the current experiment have implications for the design and delivery of subsequent software engineering courses offered at a distance.

Pedagogical Requirements

The original pedagogical requirements for the local and distance sections of SENG611 included the following:

1. The existing course structure of SENG611 was to be maintained during the experiment, which includes publicly available student work and collaboration on group projects.
2. Existing web-based course materials were to be re-purposed for use in WebCT.
3. Both local and distance students were to be actively engaged in the course.
4. Differences between local and distance student participation in the course were to be minimized by providing: a) the same course content, assignments and deadlines, b) access to in-class interactions (instructor & students), and c) insight into the personalities of the two instructors.
5. Neither group was to be disadvantaged by the experiment with concurrent sections of SENG611.

Subsequent discussion focuses on the impact, implementation, and an assessment of each of these requirements from each of the three perspectives.

Instructor's Experience

Prior research has found that faculty spend **more time** preparing materials and resources for instruction when integrating computers into their teaching and learning on campus (Jacobsen, 1998). Instructor workload increases, at least initially, for teaching and learning online (Harasim, Hiltz, Teles, & Turoff, 1997). Our results are consistent with these findings. To meet student needs in concurrent local and distance sections of the course, one instructor spent additional time on the following distance-related tasks: 1) "repurposing" existing course web pages for use within WebCT, 2) creating detailed web materials for the distance group, and 3) locating and organizing online references and links to additional materials. In addition, both instructors felt they spent more time fielding e-mail and telephone inquiries from distance students than would have been spent for these questions in an exclusively face-to-face offering of the course. Time spent on these tasks was over and above the time required for conventional classroom instruction. The instructors were participant observers in the list server, rather than active and directive moderators (except when students appear to be involved in a non-productive debate or require expert advice). The instructors assessed list server participation during the course, and found the sheer volume of discussion was greater than in previous, classroom-only offerings of the course. There are a number of possible explanations for this trend. First, a large proportion of the local students speak and write English as their second language, and seemed to prefer to participate more in the list server than in the lectures. It may be that these students are more confident when they have time to reflect and respond to a written discussion, rather than speaking out in class. Second, distance students actively participated in list server discussions, possibly because they were not present for the classroom discussions. A third possibility is that students actively participated because this was a graded expectation for the course, although this expectation was unchanged from previous classroom-only offerings of the course.

Pedagogical Lessons Learned

We discovered that it is important to carefully structure the entire course before it starts and to be faithful to that structure throughout the course to provide distance students with a stable context in which to learn. While this

finding may seem rather obvious from an instructional design standpoint, it is not the typical approach in SERN's graduate course offerings. Instead, *flexibility* to change course material and follow "excursions", as dictated by student interests, experiences, and current situations, is favored over rigid structure. This constructivist approach may be at odds with the need for more structure in a distance model. This is worrisome because this approach is highly valued by both students and instructors. We are currently investigating instructional strategies that provide a balance between carefully structured and defined course design, and responsive, flexible learning environments. It may be that our distance students felt they needed more structure because the distance model of learning was new to them. The distance students monitored what the local students were doing in the course, and were fearful of falling behind or missing important information. We will continue to evaluate student learning experiences and concerns with subsequent distance course offerings.

We learned that although the course has always included extensive web-based notes, considerable effort had to be invested to reconsider and repurpose the online materials to make them useful for the distance students. For example, overhead slides that presented point-form information were insufficient instructional supports for distance students who did not have the benefit of the lecture context, presentation, and related discussion and interaction. We also found that descriptions and instructions for assignments and "in-class" exercises had to be made more explicit for distance students.

The instructors believed that the quality of assignments and amount of effort invested in participatory activities varied much more in the distance than in the local groups. One possible explanation is that the face-to-face interaction among and between students and instructors in the classroom allowed them to arrive at a common understanding of expectations. This finding suggests to us that instructors must find a way to be very explicit about discussing and arriving at a common understanding of expectations with their distance students. It is our hope that we find an innovative way to achieve this goal without stifling the creativity and individual style of student's knowledge construction. A related finding, which may be an artifact of this comparative study, was the instructors' belief that distance students' contributions to the list server varied more than discussion by local students. Again, a possible explanation for this difference is that distance students were participating in the course without the benefit of the shared context created in collective face-to-face discussion and interaction. We attempted to capture this context by appointing local student groups to record and post summaries of class discussions. However, the posting of summaries was often not timely enough to be of significant benefit.

Comparison of Two Learning Environments

Two unconventional data collection procedures, along with a conventional end-of-course evaluation, were used to explore and evaluate the two learning environments offered in SENG 611. Students e-mailed weekly *learning logs* and a final *Biography of Learning* to a distance education researcher (who took no part in the grading of student achievement in the course). Students recorded three types of information for their *learning log*:

1) *reflections on the outcomes of lecture/sessions* (main objectives, what was important new learning, what was confirmed, what changed for the student, value of topics discussed to student's work life or future career goals),
2) *what worked particularly well, and what did not* (according to preferred learning methods, individual learning styles or personality types), and
3) *time spent on various course-related tasks*, such as reading the textbook, writing responses, participating in project work and group meetings, reading and contributing to the course list server, and constructing and uploading HTML documents.

The learning logs proved to be a rich data source from which students could conduct a comprehensive review and analysis of their personal learning experience in SENG611. The *Biography of Learning* was a retrospective narrative account through which the student questioned and reflected upon their own educational biographies and learning experience throughout the course.

What Worked Well, and What Did Not

Both local and distance students regarded the list server discussions as an important extension of classroom discussions, and all students agreed that group work was a valuable component of the course. Students in the local section of the course were assigned the task of summarizing the in-class discussion and interaction, and

posting this information on the course web page for the benefit of the distance students. Unfortunately, this did not work well for distance students because of the variable quality of the transcripts and the delayed posting times. Also, according to local students, summarizing the lecture reduced the quality of their participation because their attention was focused on "catching every word" rather than on contributing to discussion. Students criticized some technical aspects of the current experiment. In particular, unreliable accessibility to the course material, which was related to network access issues that were beyond our immediate control. Students also experienced difficulties generating and transferring their assignments as HTML documents; some lacked prior experience with HTML, and others encountered problems accessing the server.

Time Spent On Course-Related Tasks

Weekly time estimates for course-related tasks were collated for each of the five weekly learning logs. An aggregate summary of the total and average number of hours per week per task, and the average number of hours spent on each task per student is presented in Figure 1. Surprisingly, local and distance students spent a similar number of hours per week on average for course-related tasks. This finding contradicts the distance students' perception that they spent more time overall than local students on course-related requirements. An explanation for this difference in perception may be found in how local and distance students spent their time on various tasks (Figure 2).

Figure 1. Average Hours Per Task Per Student, Local versus Distance Cohorts

Figure 2. Percent of Total Time Local and Distance Students Spent on Various Tasks (including class time).

Distance students did spend **more** time on certain tasks; participating through email and the list server, creating and transferring HTML documents, and collaborating on group projects. Distance students reported they spent a great deal of time coordinating group work over the network, creating, exchanging and editing HTML files, and meeting for group work. Local students were able to meet before and after class for group work tasks. Distance students attempted to mediate some of these activities using the network; perhaps their initial unfamiliarity with this type of electronic exchange cost them additional time. Conversely, local students appeared to spend more time reading course materials. Given the additional amount of time required for the distance group exercises, the distance students reported that they read the absolute minimum to complete their work.

Improvements to Evaluation Procedures

The Learning Logs and Biography of Learning proved to be a successful data collection technique. Students provided rich and extensive qualitative and quantitative information about their participation in and perceptions of the course, types of tasks and time spent completing them, and reflections on their learning styles and preferences. Students were guaranteed that the learning logs and biographies of learning submitted to the researcher would not be made available to the instructors during the course, and that only group reports would be made available after the course. This step was taken to preserve the anonymity of students, and to promote an open and honest evaluation of the strengths and weaknesses of our distance model. This data collection procedure yielded 5 learning logs and 1 biography of learning per student, and with 21 students, the researcher's task included organizing, sorting, and recording 126 documents. Use of this data collection procedure in future courses will be greatly facilitated by employing a web-based, fill-in form that would automatically save student information to one file which can then be imported seamlessly into a statistical application for analysis. A web-based form will also provide a standardized format for incoming data, and enable the researcher to provide group responses to the instructor as an on-going, formative evaluation of the course. The course evaluation survey was administered using conventional paper-and-pencil forms. This data collection procedure has been automated by constructing a web-based form that students can use to submit their course evaluations on-line.

Technical Support of WebCT

The technical support requirements for SENG611 were concerned with two main issues: 1) supporting the organization and delivery of the course, and 2) minimizing the differences in student engagement. Although the course material already existed as web pages, WebCT was chosen as the web-based software tool to support the dissemination of course related information in this experiment. WebCT offered encapsulation and paths through the existing course content, student presentation areas for groups of students, individual student tools for note-making, and a chat facility for synchronous, online discussions. It was the preferred choice for a number of reasons, including free testing of WebCT with full functionality, inexpensive licenses, a large customer base, proximity of developers, ease of access via common web-browsers, and ease of customization (if needed).

In Spring 1998, WebCT was installed on a local server so we could experiment with many of its features. This led to enough confidence in WebCT for its use with the graduate course in Fall 1998. The technical support person and a course instructor were well versed in HTML, scripting, and other computer-related activities which influenced the evaluation and usage of WebCT. Based on the current experiment using WebCT, we have made the following observations:

6. Support by developers of WebCT is **very good**. Queries and requests were dealt with quickly and to our satisfaction.
7. It is **easy** to (a) install WebCT (beta 1.3 on Windows NT took slightly more time than 1.2 on Unix), (b) create courses as an administrator, and (c) encapsulate existing course material.
8. It is **moderately difficult** to get used to all of the WebCT concepts and develop a mental map of the course structures, and to keep information up-to-date in a course, because the tool imposes a certain approach to structuring on-line course materials. One must become familiar with the affordances and constraints inherent in WebCT's design in order to construct well-organized course materials.
9. It was **difficult** to customize WebCT to add connections to the external list server; Perl scripts had to be modified to add a mailto: hyperlink (referring to the list server) to WebCT's common button bar.

WebCT is geared to non-technical course designers. It was our experience that the WebCT designer interface often hampered the HTML-knowledgeable instructor's efficiency in building and maintaining the course material. For example, sequencing course materials requires the designer to set up a "path", which involves a number of intermediate steps that would not be required if the designer was using only HTML. However, for an instructor who is new to creating web-based documents, the structure and tool set offered by WebCT provide valuable supports as they construct course materials. We found that WebCT was not completely applicable to the current offering of the SENG611 course. However, based upon research that compared WebCT to other web-based course tools (e.g., Kristapiazzi, 1998), we expect that other web-based course tools are also not completely applicable and would require customization for SENG courses. Courses in the research-based M.Sc. program have been developed within an *open architecture* philosophy and the belief that there should be public access to past and present SENG course materials and student work. Inherent to the design of WebCT is a *closed architecture* philosophy -- courses are password protected, and information in courses is not easily accessible to the general public. WebCT's student tools, in particular note making and group presentation areas, offer useful tools for online courses. The e-mail and chat facilities in WebCT were not used for the current experiment; an external, publicly accessible list server remained in use. WebCT's quizzes, which employ selected response and open-ended questions, and so on, were not useful for this graduate-level course.

Future Investigations

As a result of what we have learned in this experiment, we plan to improve the design of our distance model in a number of ways. In this experiment we offered concurrent sections of the Requirements Engineering course for the purpose of directly comparing the two learning environments. In future, we plan to offer courses either at a distance or locally, but not concurrently. First, it is a conservative estimate to suggest that instructor workload is doubled because they are, in effect, teaching two courses to two different classes of students with different needs. Second, if the "distance" students are not truly at a distance (students in our graduate program tend to be located in Calgary), they tend to gravitate towards campus to meet anyway. It was difficult to keep the distance students at a distance to increase the authenticity of the experiment. We discovered that students in both sections wanted to meet face-to-face to work on assignments, and usually met on campus prior to and after the lecture. Third, our experience was that students felt somehow disadvantaged no matter which group they were in -- the local groups felt that allocating attention to creating a lecture summary reduced their opportunity to fully participate in the classroom discussion. The distance group felt they were missing vital information by not

being present for classroom discussions and the face-to-face contact with instructors. Fourth, both local and distance students perceived that they spent more time per week on course-related activities, although the average time spent by each group per week was not significantly different. Our second experiment with a distance learning model will be with a graduate course in Design Patterns, and we will offer only a distance section for all students. The first and last lecture will be face-to-face, and all other classes will be at a distance. The course will be project-based; students will "present" their projects (as a web document), then lead web-based discussions about their work for the subsequent week. We will also experiment with real-time, synchronous class discussions at designated "lecture times" employing a computer-based conferencing tool with video, audio, and application sharing features. The final lecture of the course will be a face-to-face seminar, where students will present and discuss their work in a conference-like setting.

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Educational Opportunities Using VRML in the AI Classroom

by

Paul Juell, Computer Science, North Dakota State University, Fargo, ND 58105-5164, USA
juell@plains.nodak.edu

Abstract

This paper presents some results from the Visual Program project. The goal of the Visual Program project is to provide an environment in which students can study and learn AI techniques. We provide tools to support active learning using visualizations of AI programs. These visualizations include animation, fly-through models and more interactive information models. The visualizations are distributed as VRML virtual worlds. The distribution of the visualizations on the Web allows the student to explore the data or the model.

OVERVIEW

This paper presents some results from the Visual Program (VP) project. The goal of the Visual Program project is to provide an environment in which students can study and learn AI techniques. We provide tools to support active learning using visualizations of AI programs. These visualizations include animation, fly-through models and more interactive information models. The visualizations are distributed as VRML virtual worlds. The distribution of the visualizations on the Web allows the student to explore the data or the model. Some of our models allow the students build their own virtual world to provide a visualization of programs they are developing. These then would allow the student to explore the operations and characteristics of her/his program. Some examples of the various systems are: (1) For a presentations unit, we have animations showing various searches. (2) For explorations of data/process we have 3D fly-through models of the points searched by a Genetic Algorithm (GA). (3) For the student building a visualization we have tools to allow them to build virtual worlds modeling the states in a state space search.

New technology presents opportunities to do new and hopefully useful things. We emphasize visualizations of data and process using VRML as the delivery platform. These visualizations are intended for a graduate level course in Artificial Intelligence. We felt it would be a good problem domain because the course content can be very complex, but may be characterized by compact descriptions. This is, in part, because of the symbolic nature of much of AI. The symbolic notation offers the possibility of creating small but informative visualizations. This project has developed a number of these visualizations.

The VP project is one of several projects part of NDSU's World Wide Web Instructional Committee (WWWIC) (McClean 1999). WWWIC is partially funded by a NSF grant. WWWIC is sponsoring projects in cell biology, geology (Slator et al. 98) (Schwert, Slator & Saini-Eidukat 99), computer science (Hill & Slator 98), AI, and anthropology. WWWIC as a whole and each of the parts are developing tools to allow students to interact with knowledge in the particular discipline. Although the vision driving each of these project differs, the projects all have a commonality in the visions. All of the projects are developing Web based products. Many of these products use VRML and Java to provide 3D worlds and student interaction with the underlining models. The pedagogical force driving all of these efforts to provide a way for the student to actively interact with the information in the specific discipline.

VRML and Java as a development environment

To an extent, VRML directly supplies the tools to produce and and deliver the author's vision to the student. In HTML the unit of information is a page, in VRML is called a world. A world is a 3D collection of objects and possibly related actions and Java code. VRML is a standard (Hartman, Wernecke 1996) for specification of worlds and for programming the worlds. The specifications are written in ASCII. The worlds can be displayed by a Cosmos plugin for Netscape. Using the plugin, the worlds can be navigated in real time, can include complex objects, and can interact with normal web information in HTML based pages. In addition, VRML directly supports animation and also supports real time interaction with Java. This combination of features allows building ranges of virtual worlds. These can vary from simple static worlds, to worlds with preprogrammed interactions, to worlds with complex interactions using programs to provide the model driving the interactions. WWWIC purchased some world building tools such as Bryce 3D and Cosmos Worlds. These were useful in developing realistic type models needed by the other projects. However, they were of limited use in developing our visualizations. Most of our products were prototyped by directly writing VRML code. In some cases code generators were then developed to build similar worlds directly from data.

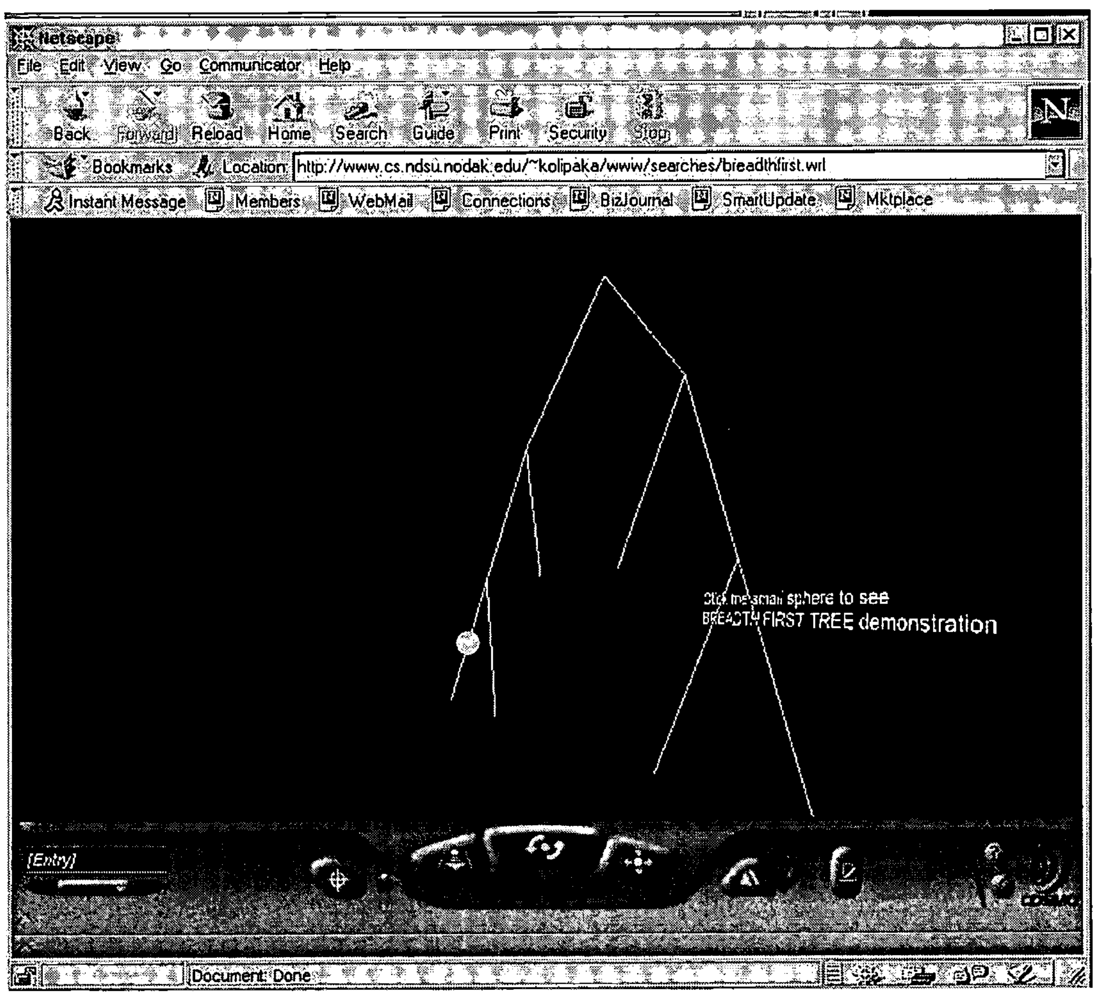

Figure 1: Movie of breadthfirst search

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We developed a number of these presentation tools. An example is a set of visualizations of the searching process. We have images of search trees with the search shown by a animation of a ball following the search path (Fig. 1). We have examples showing depth first, breadth first and hill climbing searches.

Visualizations for the classroom

All of the products developed for this project started with an individual having a vision of an image, world or movie. Then the job became to find a way to get the technology to provide an instantiation of the concept. Once that was done, we needed to determine quality and usability of the product. This evaluation lead to redesigns and rebuilding the images, worlds and the interactions. The projects were demonstrated and evaluated by the programming team and a larger group of faculty and students working on the umbrella grant project (McClean 99). (See http://www.ndsu.nodak.edu/wwwic). This process has lead to a number of innovative visualizations. All of the visualizations can be used in the classroom to present a single example or concept. Many of these visualizations can be used with more examples.

Another example of this class of visualization is a nice pictorial of what is known as a crossing problem (Fig. 2). Our example is the problem of a father and his two sons trying to get across a river. There is a boat that can take only 200 pounds. The solution to this problem requires a number of steps of loading the boat, crossing the river, unloading load the boat repeating these processes. One of our visualizations shows pictures of the father, the two sons, and a stylized boat. A movie is shown of the appropriate individuals getting into the boat, and they and the boat crossing the river. This movie then shows the full process.

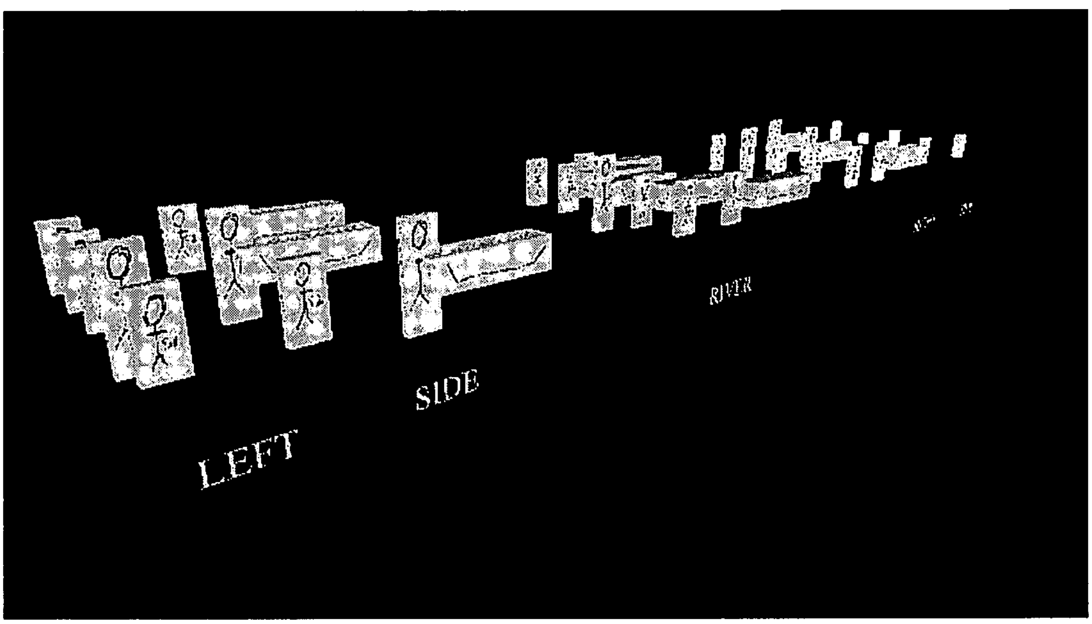

Figure 2: All the steps of the crossing problem

These presentation tools can be shown in the classroom. This assumes availability of the computer, projector and web access. A VRML plug-in and Java support are also required. The author is using the Web for most lecture material, so it is a trivial matter to include these examples in the lecture. The visualizations can also be used by the student outside the classroom. The visualizations are distributed to the students over the web.

We provide a second level of visualization which we refer to as an explorative visualization. The basic information, process or data is pre-packaged and does not change. However, the student has various options and can control the process of examining the information. This process of examination serves as an aid in

understanding the interactions of the data and process. An example of this is a multi paned window showing the execution of a rule based program. One pane shows the working memory (the current variable values), one pane show the rule to act on the working memory and a third pane shows the sequence steps. Mousing over the step will show the appropriate information in the other panes. This visualization allows the student to inspect the operation of the process at their own speed and order.

Examples of Visualizations

A common example used in AI is a blocks world. A set of rules cause changes in the blocks world over time, causing the configuration of a stack of blocks to change. One of our visualizations shows the full running of a blocks worlds program. All of the steps are shown in one image. Each point in time is shown further back in the image. Each layer shows the stack of blocks as it would be at that point in time. Next to the stack is the rule that will effect the blocks next and the current values of variables in the working memory. This fly-through 3D image will allow the user to inspect the changes in states, the effects of the states on the blocks world and to see patterns in the execution of the program. At this time, we have hand coded this blocks example. We hope to allow building these types of worlds from data later.

Another version of an exploration visualization is an active diagram. By delivering a Data Flow diagram in VRML, we allow user control of the presentation of the diagram. The user can select how much, and which types of information to display. Animations clarify the flows of data, and navigational tools allowing focusing on parts of the information. Descriptions of the nodes are hidden until a mouse over turns on the text. Navigation aids are built into the diagram. These will step the view to the next selected point of interest. Clicking on a connector will change the view to the next node. Some nodes will have full diagrams inside them. Clicking on these nodes will take you into an embedded world. The embedded world is the next level of detail in the diagram. We plan on later developing a notation to allow the user to build these active diagrams.

The highest level of visualization we support allows the student to build his/her own visualization. This allows the student to explore the data or process of their own programs. A command or data interface is provided that allows the student to build the visualization. An example of this is a visualization tool for state space search. The student will instrument their program and obtain a sequence of state descriptions. Another file specifies how to display the states, including which images to attach to the items. The tools will then produce a VRML file that can be inspected to see the progress of the program. The VRML file will either show the states over time, with the later states farther back in the 3 dimensional image or will display a user controllable movie.

Another example shows the searching done by a Genetic algorithm (GA). The student has the GA program create a file describing the points searched. The file has the 3 space location of the searched point, the generation of the search and the quality of answer the location represents, the time of the search and the goodness of the value. These values will then be displayed in 3 dimensions with the points represented by a sphere and the color showing approximately when the search occurred. The answer quality can also be shown by the shape of the point representing the search. The user can also select that this be shown as a movie rather than a single image.

Conclusions

This project has developed a number of visualizations to aid a student in understanding of AI techniques. These visualizations can be used in various ways, from presentations to aids in debugging of programs. The development process is continuing, with new visualization and improvements in the current tools. We have been very pleased with VRML as a development environment and with some of the visualization we have developed. We are in the process of fielding the visualizations and assessing the results.

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Acknowledgments

These development efforts are funded by the National Science Foundation under grants DUE-9752548 and EAR-9809761.

Research Projects and Journal Article Case Studies with Asynchronous Computer Groupware

W. R. Klemm, D.V.M., Ph.D.
Professor, Dept. VAPH
Texas A&M University
College Station, TX 77843-4458

E-mail: wklemm@cvm.tamu.edu
Web site: www.cvm.tamu.edu/wklemm

Abstract. This paper describes the use of a web-like computer conferencing environment with undergraduate students to organize and support individual research projects or group-based case studies of original research literature. Rather than a collection of e-mail messages, the on-line environment allowed teacher and students to annotate with in-context hyperlinks, either to pop-up "sticky notes," links to graphics or new documents, bookmarks within a document, or to Web site addresses. Use for research projects made it easier for the teacher to keep track of each student's work in progress and reduced the need for many face-to-face meetings and associated scheduling problems. Use for case studies included a systematic model of an analytical process, helped students to gain confidence, and improved the quality of student work.

Introduction

This paper presents examples of how undergraduate students used asynchronous ("just-in-time") computer conferencing software to conduct undergraduate research projects and case studies of scientific journal articles.

The students were upper-division undergraduates in various life-science majors. This computer environment allowed both students and professor to work at our own time and place of convenience. Students accessed the computer environment from various computers on the university campus or from modem dial-up connections in their dorm rooms. No schedule conflicts interfered with our work, and work time was flexible. Other advantages were specific to the respective activities, as explained below.

The client/server-based software (FORUM98®) allowed professor and students to share the same documents, including allowing everyone to make pop-up "sticky notes" or make hyperlink annotations of text, graphics, or Web sites. These notes and annotations were not simply attached e-mail messages, but rather were integrated in context with statements made within a document - much like World Wide Web documents.

Student Research Projects

Every semester, I supervise two or more undergraduates in research projects, plus graduate students. I have always had problems in scheduling frequent meetings with the various students and in remembering what all of us said and agreed to in those meetings. It is difficult recalling all the different details in each project. We needed a "paper trail" to track where we were in each project. Why not, I thought, create that paper trail in a way that would expedite creation of the final project report or even a publishable manuscript?

So, I opted for assigning individual work space in FORUM and created a home page for each project according to the following outline (Figure 1):

- Working title
- Background and Context for the Research (to become Introduction in a manuscript)
- Hypothesis and Rationale (to be included in manuscript Introduction)
- Experimental Design and Methods
- Results
- Discussion
- Key References (basis for a final bibliography)
- Miscellaneous Information (for material that might be needed later)

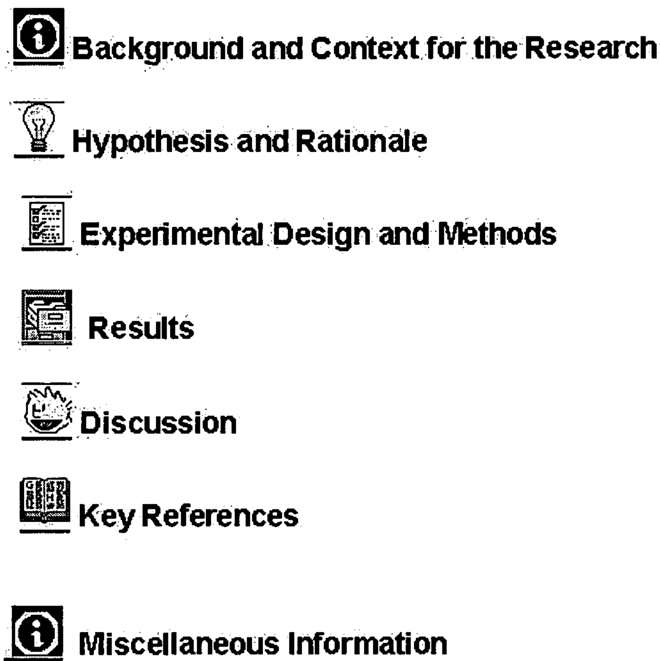

Figure 1. Appearance of the “home page” showing link anchors (icons) to various components of the student project.

The similarity to the format of a scientific research paper was intended. This format organized relevant information in the way it would appear in the final report or manuscript and helped to ingrain in students the scientific process.

Students came to me with vague ideas of what they wanted to work on. To help them crystallize their thinking, I required them to create a draft treatise on the background and context for what they wanted to do. This gave me opportunities to respond with specific, in-context suggestions. After this section became heavily annotated with sticky notes and linked items, the student created another draft of this section that accommodated the ideas that emerged during the on-line evaluation. New drafts occurred as needed until we had all the key ideas organized and thought through.

Early on, students were guided to develop specific, testable hypotheses. These, along with associated rationale, became the basis for a draft in the "Hypothesis and Rationale" section. Annotation of this section led to successive drafts.

Students next constructed an experimental design and specified the appropriate methods. These descriptions went through several drafts until we had a game plan that was ready to implement on experimental subjects.

Results and Discussions sections developed as they would in writing a scientific paper. However, the software allowed me to annotate and correct the student's work as it developed.

Summary. This approach was convenient and, more importantly, students thought more carefully about their work. Perusal of the various drafts provided a good learning experience in itself. Also, by the time we finished the work in the computer environment, a rough draft of a publishable manuscript already existed.

Journal Article Case Studies.

A neuroscience principles course that I teach included as one of its goals the objective of helping students gain confidence and skill in reading primary scientific literature. Normally, scientific papers intimidate undergraduates. The class was divided into groups of four or five, and each group used a systematic analytical model to conduct a case study of assigned scientific papers. The model provided a sequence of steps that guided students through the key steps of analysis and critique (Figure 2).

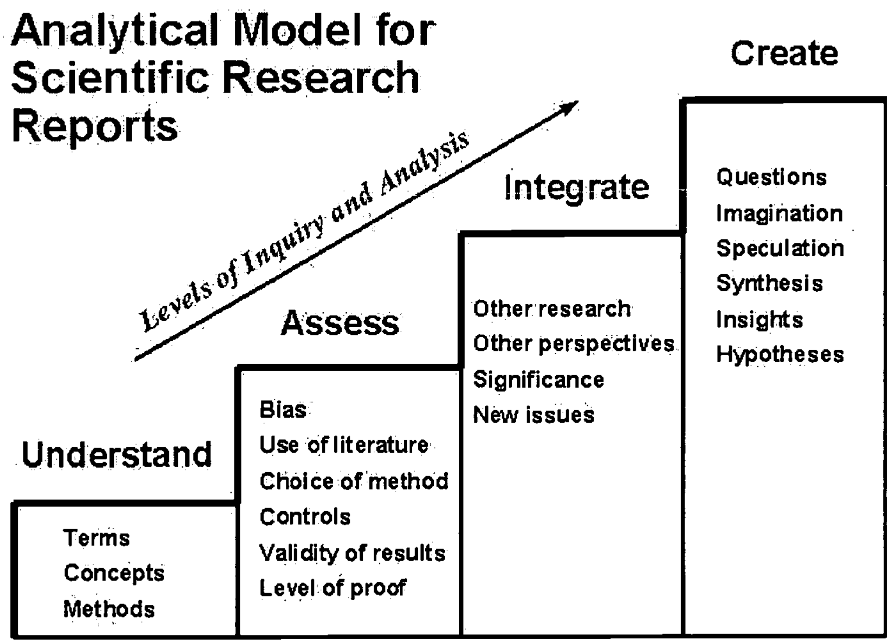

Figure 2. Analytical model for using original scientific research reports for case studies.

The essential steps became separately linked documents in the computer work space. The instructions for each step, as shown below, seemed to provide sufficient guidance.

- **Understand** - Define or explain terms, concepts, and methods. Identify the learning issues and assign team members to supply needed information and understanding.

- **Assess** - (1) Identify the core principles of the course that are pertinent to this journal article. Explain why they are pertinent. (2) Critique methods and results (bias, level of proof, statistical rigor, controls, appropriateness of methods, quality of the data, validity of interpretations and discussion, consideration of alternatives).

- **Integrate** - Relate to common knowledge and other research. Provide other interpretations, points of view. Evaluate significance.

- **Create** - Raise original insights and questions. Posit new hypotheses and experimental designs.

In each area, I added annotations that clarified and corrected as needed. In each section, students made individual observations and insights according to the stated expectations. They also annotated each other's input with questions, answers, and other ideas. The level of group cooperativity was especially high in the "Understand" section of the exercise. Here students identified for each other various learning issues. When a question was raised, anyone who knew the answer shared it with the others. For information that needed to be acquired, each student volunteered to get information of personal interest. Remaining chores were assigned by group consensus.

At first, students were a little unsure about how to go about this exercise. But with my prompting and feedback and with the group support, they became progressively more adept at making sophisticated critiques of journal articles.

Summary. Students gained important experience in learning how to comprehend scientific papers in this field. Moreover, they gained confidence in their ability to read primary literature. Heretofore, they had relied only on textbooks and popular-science articles. This experience seems especially valuable as preparation for graduate or professional school.

General Conclusions.

Both kinds of learning activities help undergraduates experience the educational and aesthetic value of research. The asynchronous computer environment can make these experiences more convenient and rigorous than might be the case if all of the interaction among students and teacher were done in face-to-face conversations.

How to Enhance Students' Conceptual Understanding Related to a New Topic Using Computer-Based Presentations

Athula Kulatunga
Department of Industrial Technology
Southeast Missouri State University
United States of America
akulatunga@semovm.semo.edu

Abstract: This paper is a report on the findings of a study conducted over two years on electronics technology majors. A quasi-experimental study was designed using the Nonequivalent Control Group Design method. Computer-based review sessions were developed and presented at the begging of each lecture for five to ten minutes. These presentations reviewed the essential concepts learned in previous lectures. The effectiveness of computer-based review sessions was examined in four different courses using t-tests. The results show that the review sessions had increased the students' conceptual understanding of electrical circuits in three out of four courses. This paper also presents a general model that can be used to develop computer-based review session for other subject matter.

Introduction

Review of prior knowledge before introducing new knowledge enhances learners' understanding of subject matter. Verbal information learning and psychomotor skill learning seem to require the most review. Introductory courses in science and technology present learners with verbal information and psychomotor skills from start to finish. As technology advances, the amount of information to be presented, and the number of skills to be mastered increases, leaving instructors little time for preparing and presenting a review session. However, advancement in computer software and information-presentation technologies may provide some answers to the above challenges.

Purpose

The objective of this study was to improve students' conceptual understanding of electrical circuits via computer-based review sessions. Researchers have identified that students who have good conceptual understanding of electrical circuits will be able to troubleshoot circuit problems effectively and efficiently. The study was repeated with different groups of students over two years (De Kleer, 1984; White & Frederiksen, 1990).

It was hypothesized that if students are exposed to interactive review sessions pertinent to previously learned concepts before new concepts are presented, the student would be able to apply the conceptual understanding to solve complex circuit problems more effectively.

Significance

Computer-based instruction and evaluation have been used for many years in the field of electrical technology for pedagogical purposes (Pudlowski & Rados, 1987; Dobson, 1995). Most computer-based

instructions are designed as stand-alone units or as tutorials that require learner-initiatives, extensive time, and dedicated computers.

The study described in this report incorporated presentation software (Microsoft PowerPoint™) and an overhead projection system for presenting review sessions. The instructor has designed all his lecture outlines and review sessions for each lecture using Microsoft PowerPoint. Students had the chance to participate in the review sessions during the first five to ten minutes of the class. A computer was programmed to start the review sessions and the display was projected on a screen via an LCD projector. The review sessions continued in a cyclic fashion until the instructor arrives. The above process required only one computer setup but will present the review session to all students and provided students with the resources to recall prior knowledge and prepare for the upcoming class.

Methods

A quasi-experimental design was used for the study. Since random assignment was not possible due to the classroom environment, a research design known as the Nonequivalent Control Group Design. The population of the study consisted of students who enrolled in Electronic Circuit Design Analysis I, Electronic Circuit Design Analysis II, DC Circuit Principles, and AC Circuit Principles offered in 1996 and 1997, by the Department of Industrial Technology, at Southeast Missouri State University. In those four courses, electronics majors learn the most important and fundamental concepts that are the pillars of the study of electronics.

Educational research requires repetition with varying body of population to verify their effectiveness (Smith & Ragan, 1993). By conducting the study over two years including four different courses, the researcher expected to identify statistically significant outcome of this study.

The classes offered in 1996 were selected as the control group and the classes offered in 1997 were used as the experimental group. At the beginning of the semester, a pretest was administered to both groups of each course to measure similarities between the two groups. The pretests were used to identify significant differences between the groups on their conceptual understanding of electrical and electronic circuits. A t-test was used to find significant difference between the treatment group and the control group at 0.05 alpha level.

The computer-based review sessions were shown only to the students in the experimental group. The equipment purchased from the funding provided by the Funding For Results (FFR) program at Southeast Missouri State University. A laptop computer and a color projection system were among the equipment. Both groups completed same classroom instruction pertinent to each class, received the same amount of homework and other assignments, and took the same exams pertinent to each course. The researcher tried to minimize the effects of other variable such as variation of instruction in order to identify the effects of the review sessions.

The researcher designed all his lecture outlines and review sessions for each lecture using Microsoft PowerPoint™. The review sessions served two purposes: a) allow student to recall previously learned concepts and their inter-relationships, and b) activate students' attention to prepare for the upcoming lecture (Smith & Ragan, 1993, p.140-144). Students had the chance to participate in the review sessions during the first five to ten minutes of the class. Each review session consisted of major concepts of the previous lecture. The concepts were lined-up so that one concept ties to the preceded concept. All interrelated concepts were presented as a group. Based on a pilot study, a presentations development model was developed as shown in Figure 1

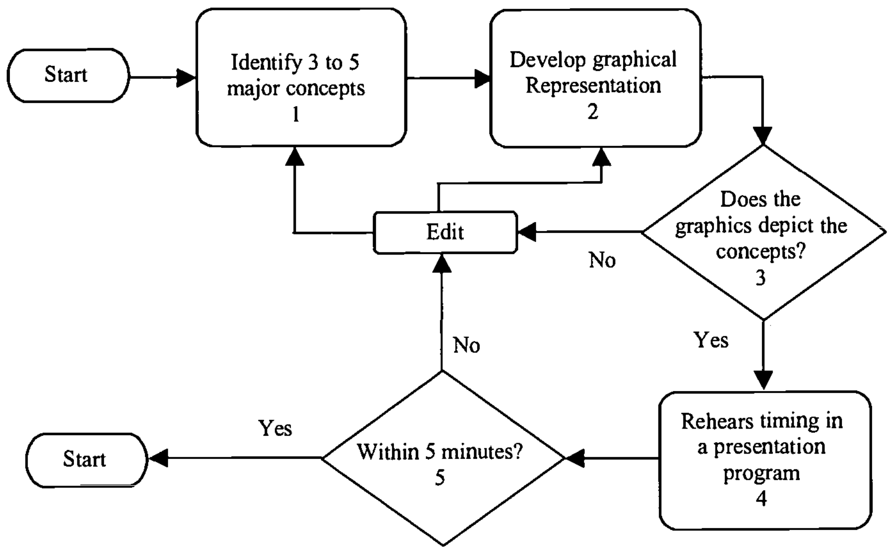

Figure 1: Computer-based review session development model.

The presentation should limit to maximum of five major concept due to time limitations. These concepts should reflect the subject matter learned in the previous lecture. When developing the graphical representations, arrows can be used to represent relationships among different variables. If possible, minimize the text to describe the concepts and their relationships. .Moderate use of animation seems appropriate when the concepts related to formulas are presented. Large text -- size 36 -- and consistent color patterns were used in slide construction. Figure 2 illustrates an example.

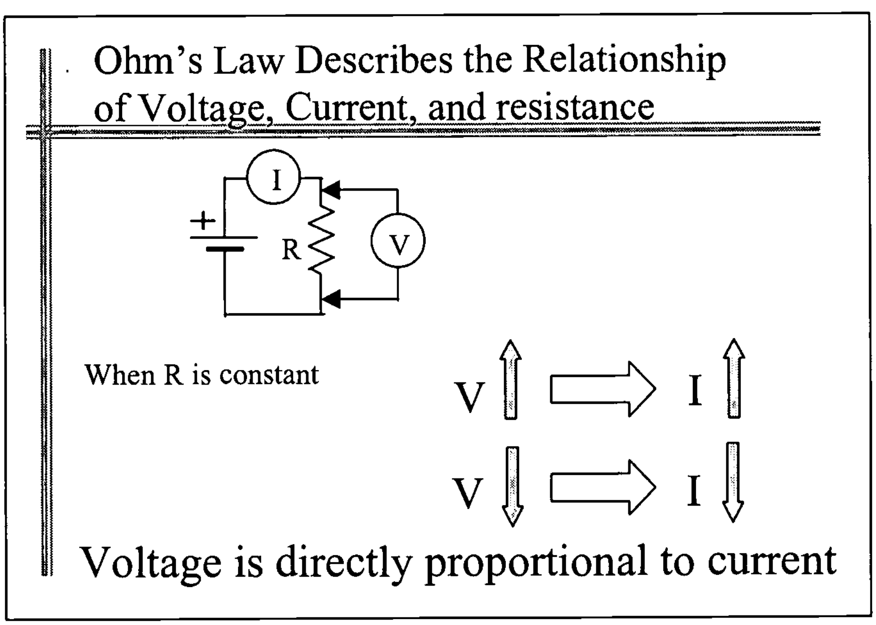

Figure 2: An example of a review session slide

Any commercially available presentation software can be used to implement the presentations. In this study, Microsoft PowerPoint™ was selected because: a) it is widely available, b) generate file format that can be easily transmit via telecommunication mediums, and c) viewer do not require the same program to view presentations. The viewing software is available to any computer user at no cost. These features were important because: a) the student who choose to copy the lesson outlines or the review sessions may not own the PowerPoint™ program and b) the student have the option to download or view the material over internet from the instructors homepage.

The review sessions should be limited to about five minutes so that the material can be displayed twice within ten minutes. A computer was programmed to start the review sessions five minutes before class begins. The display was projected on a screen via an LCD projector. The display time was limited to maximum of ten minutes while running in a cyclic fashion.

At the end of semester each semester, both groups were administered a posttest to examine the students' mastery level of concepts taught in that class. The control group and the experimental group of each course received the same posttest.

Findings.

The effectiveness of computer-based review sessions was examined in four different courses using t-tests. According to the pretest results, thcrc were no statistically significant difference (alpha = 0.1)between control and experimental groups of Electronics Circuit design Analysis I, Electronics Circuit Design Analysis II, and AC circuits. The control and experimental groups of DC Circuit course were not similar (alpha = 0.1) at the start of the study. Table 1 summarizes the t-test for the posttests.

		Students	Mean	Variance	P(T<=t) one tail
Electronic circuit Design Analysis I	Control	16	60.31	1036.76	0.0611
	Experimental	10	78.22	323.06	
Electronic Circuit Design Analysis II	Control	18	59.33	589.88	0.0123
	Experimental	9	79.33	56.75	
DC Circuits	Control	16	77.12	117.85	0.659
	Experimental	34	73.12	126.35	
AC Circuits	Control	14	73.14	205.82	0.0092
	Experimental	28	82.5	101.67	

Table 1: Posttest results analysis for Control and Experimental groups of the four courses.

The results show that the review sessions had increased the students' conceptual understanding of electrical circuits in three out of four courses (alpha = 0.1).

Conclusions

The study revealed that computer-based review sessions can be used to improve conceptual understanding in certain electronics courses. Further studies should be done in the other fields to validate the findings. Using a simple model, one can transfer lecture outlines into computer-based presentations. An effective review session should include graphical representation of concepts when possible. A consistent presentation in terms of font size, highlighting colors, and design may attract students' attention. It is also important to tie similar concepts together while showing the relationships among them.

Though it takes additional time to prepare computer-based lesson outlines and review sessions, the benefits outweigh the apparent drawbacks. Some observed benefits are:

1. Easy to upgrade -- as the course content change, individual slides can be modified or added to the presentation. This may not be possible with regular transparency based presentations.

2. Telecommunication ready -- Students are able to download the presentations from a web-site to review missed lesson and notes. Computer-based material are fully compatible with telecommunication mediums and can be used in distant education activities.

3. Supplement to slow-learners -- Students who have learning difficulties may be able to copy the material into their personnel computers for additional review.

4. Multimedia Presentations -- The computer-based nature allow easy integration of the content in multimedia presentation with sound and animation.

5. Activated attention -- The review sessions focus students' attention to the topic being discussed.

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A Comparison of Students' Beliefs and Attitude Towards Statistics Between Technology-rich Environment and Traditional Lecture

Carl Lee
Department of Mathematics, Central Michigan University
Mt. Pleasant, MI 48859 USA
e-mail: Carl.M.Lee@cmich.edu

Abstract: For a long time period, statistics has been considered by students one of the most boring subjects in their college course experience. Many reasons are attributed to this attitude. These may include cognitive factors as well as non-cognitive factors. This study is aimed at the investigation of the non-cognitive factors related to students' belief and attitude before and after taking an introductory statistics using an interview methodology. Of particular interest is to compare students' belief and attitude between students from a technology-rich class and from a traditional class. The purposes are (a) to investigate if students' attitude has changed after taking a technology-rich statistics class and their experience about technology, (b) to compare if there is a dramatic difference between the technology-rich class and a traditional class before and after taking the course.

Introduction

In the recent decade, statistics educators began to pay attention to the issues of teaching and learning of statistics (e.g., Hogg, et al, 1992). For a long time period, statistics has been considered by students one of the most boring subjects in their college course experience. Many reasons are attributed to this attitude. These may include cognitive factors as well as non-cognitive factors. Cognitive factors are related to how students learn the subject and how to logically transmit knowledge to students using various pedagogical approaches. Non-cognitive factors are related to belief and attitude expressed by students before and after taking the course. While these two issues are equally important in the process of learning, statistics educators have paid overwhelm attention to the cognitive factors by implementing more activities, more real world data and more projects using technology as part of the new pedagogical innovation (e.g., Gnanadesikan, Scheaffer, Watkins, & Witmer (1998), Bradstreet (1996), Giraud (1997)). One may refer to Becker (1996) and Moore (1997) for a review of literature and a discussion of new pedagogy for teaching statistics.

There are many literatures about pedagogical models for teaching statistics. However, little studies have been conducted to investigate cognitive factors associated with the process and outcome of knowledge learned other than the typical tools such as quiz, test, homework or projects. It was even more rare that the non-cognitive factors were investigated (e.g., Shaughnessy (1992), Gal & Ginsburg (1994)). This study is aimed at the investigation of the non-cognitive factors related to students' belief and attitude before and after taking an introductory statistics using an interview methodology. Of particular interest is to compare students' belief and attitude between students from a technology-rich class and from a traditional class. The purposes are (a) to investigate if students' attitude has changed after taking a technology-rich statistics class and their experience about technology, (b) to compare if there is a dramatic difference between the technology-rich class and a traditional class before and after taking the course.

Background

Two classes of students with at least pre-calculus background participated in the study. The class sizes were about 30 in each class. One class was taught by an instructor using traditional note taking approach without using any technology except scientific calculators. The other was taught by using the PACE model developed by Lee (1997, 1998). PACE stands for Projects, hands-on Activities, cooperative learning in a computer classroom, and Exercises. Students collected their own data in class based on the pre-designed hands-on activities, then two students were paired to conduct data analysis in the computer class room, and summarized their results for presentation. Instructor's role was a facilitator who guided students through the process of discovering and constructing statistical knowledge. Technology was an essential part of the process. Instructor spent more time on concepts related to data collection, measurement, sampling errors, and the interpretation of results, much less time on the computations.

Both instructors had more than ten years of teaching experience in statistics and were trained in statistics. Students were mostly from the college of science and technology.

Brief Review

A typical assessment tool for assessing belief and attitude is by the use of likert scale instrument. In the literature, there are only a few instruments that are designed for assessing attitudes towards statistics. Roberts and Bilderback (1980) designed an instrument of Statistics Attitude Survey. Wise (1985) modified this survey and designed the survey of Attitudes Toward Statistics. Sutarso (1992) also developed an instrument, Students' Attitude Toward Statistics. The drawbacks of these likert scale instruments are discussed in detail by Gal and Ginsburg (1994). These difficulties include (a) it is unable to distinguish if the observed attitudes are actually toward math or toward statistics, (b) it is unable to gather information about motivation behind the attitudes without some degree of comments, (c) the diverse attitudes can not be identified using an instrument that measures only one or two dimension of the attitudes. Viewing these difficulties for assessing students' belief and attitude, we designed an interview study, in addition to a survey, to investigate students' attitude change before and after the class from students in a traditional class and students in a technology-rich class.

The Interview Design

In addition to the likert scale survey, which was conducted at the end of the semester (see Lee, 1998), an interview study was conducted to investigate students' belief, attitude, learning style, motivation and their understanding of statistical knowledge. Three students who received A's, 3 students who received B's, and 3 students who received C or lower were selected, and invited for the interview study from each class three months after the classes ended. These students did not know in advance they would be selected for the interview. Neither the instructors knew that there would be an interview study during the semester when they taught the course. Seven students from the PACE model class and six students from the traditional class participated the interview. Each interview lasted for about two hours. There were two parts in the interview. The first part was related to background, reasons for taking the course, attitude and belief before and after taking the course, learning styles and motivations. It took about 30 minutes for the first part. The rest of the interview related to statistical concepts. A typical interview started with the questions such as

Why did you take this course? How can statistics help you? If this is not a required course, would you take it, why?

Gradually, the conversation went into

What was your impression about statistics before you took the course, how and where did you received such impressions? After taking the course, what is your impression about statistics? Why or why not your impression differ from that before taking the class? What do you think about the difference between statistics and mathematics before and after taking this course?. What would be the best way for you to learn quantitative-oriented subjects? How can technology make the difference in teaching and learning statistics? What factors motivate you to spend time studying a subject, not necessary statistics?

As discussed in Gal and Ginsburg (1994), these questions are very difficult to be answered using any likert-type instrument. Only through a face-to-face interview, one can have a deeper understanding. For example, a likert-type instrument may be able to cover several dimensions of attitude, but would not be possible to find out reasons behind their answers. Learning styles and motivations are two other important factors for understanding how and why students learn statistics. Likert-type instruments are not be able to provide in-depth thinking behind students' answers.

Results and Findings

This article focuses on how technology changes students' belief and attitude. We analyzed and compared students' belief and attitude between the technology-rich class and the traditional class before and after taking the course. Four aspects about students' belief and attitude are analyzed. The first aspect is related to feeling, attitude, and impression, the second aspect is related to belief, the third is related the level of difficulty, and the forth one is related to the use of technology.

Table One summarizes students' attitude, impression and feeling about introductory statistics course before and after taking the course for both technology-rich and the traditional classes. When question about how they felt or what was their impression about statistics, as expected, the words such as *'boring, scared, negative, confusing, horrible'* were found in the interview regardless in which class they were. These unpleasant attitudes towards statistics are the accumulated experience from students who had statistics courses, and passed down to their friends and peers. As Peterson (1991) indicated that students remember the pain but not the substance. These students have a great deal of influences of other students' attitudes and impression even way before they took their own statistics course. Such negative attitudes are extremely difficult to reverse, let alone the subtle concepts in statistics that instructors try to transmit to students.

The technology-rich approach, the PACE model was designed in mind to ease the anxiety of computation and to actively involve students in class activities. It was hypothesized that this model will have positive impact on students' attitude and belief, in addition to the content itself. Table One also summarizes and compares students' attitude and impression towards statistics after taking the course between the technology-rich approach and the traditional approach. These words from students themselves clearly indicate there is a dramatic difference between technology-rich class and the traditional class.

Table 1: Students' Attitude and Impression About Introductory Statistics Before and After Taking the Course

Before Taking the Course	**After Taking the Course** (n): n is the # of occurrences found	
	Technology-Rich Class - PACE Model Approach	**Traditional Note-taking Class**
Boring (2)	Not boring (4)	Boring, not interesting (3)
Little scared	Expect to fall asleep, but did not	How you would know which one is which for a problem. They all seemed the same to me.
Nervous	Can see the value.	Actually, I liked it more before I took the course.
Confusing	It was not bad at all. Learned a lot more than I thought.	Hard to pay attention when it was just a regular writing on the board.
Very negative	Glad I took it.	It was not boring, just very concentrated.
Do not know much(4)	More involve than I thought.	It was interesting. If you like math, you like playing with numbers
Horrible		If I have straight forward problems, I can do it. But, I would not be able to derive anything from a word problem. I had problems with stat because of this.
		So much information and a lot of details. I had hard time understanding it. It was a new kind of learning, and it was a lot of information.
		I was used to seeing a formula and seeing an example and how it plugs in, but there are a lot more variables than just an equation or something.

The impression of *'boring'* no longer exists in the technology-rich class. In contrast, it was still boring in the traditional class. The comment by one student from the traditional class *'Actually, I liked it more before I took the course'* suggests the difficulty of teaching introductory statistics using a traditional lecture and note taking approach.

The words of formula and plugging-in formula did not occur from students in the technology-rich class. In contrast, they have occurred often in the traditional class. This is the natural consequence of traditional class. Instructors must

spend time on formulae, application of formulae and practice using formulae. Due to the amount of topics that are covered in an introductory course, it usually ends up with a lot of formulae of view, and how to find which formulae to plug into a given problem. However, these so-called formulae may be originated from only a few concepts. If students would have understood the concepts, the formulae would have been meaningful, and become useful statistical tools for solving problems.

Table Two analyzes students' belief of statistics in terms of similarity between statistics and mathematics. Before taking the course, students' belief of statistics was that statistics is *'Number crunching'*, *'whole bunch of equations'*, *'Abstract concepts'*, *'Just like mathematics'*, and so on. Considering how introductory statistics has been taught, these beliefs were not surprising. It is another clear evidence that different teaching pedagogy is in a great need.

Students' beliefs from the class of traditional approach after taking the course have changed from thinking statistics is *'whole munch of equations, abstract concepts'* to *'It was different from math'*, *'Applications are different from math'*, *'It has different thinking process, It was concepts, math part was straight forward'*. On the other hand, students in the traditional class believed that statistics is mathematical oriented such as *'It was a math course, just with the direction toward statistics'*, *'In this course, I had hard time building on some basic principles'*, *'It could be very interesting if that was more relative to life'*.

Students' beliefs from the class using the technology-rich approach were different in many ways. These students related statistics more with problem solving, benefiting for research and so on. In particular, there was a clear belief of the value of statistics. The computer technology and hands-on activities were pointed out as surprising and helpful, while a student from the traditional class pointed out that if technology would have been used with some group work, more would have been learned.

The similarity of beliefs between the technology-rich class and the traditional class was that they all agreed that statistics is not just pure mathematics and formulae. It has different applications, different thinking process. The biggest difference of the beliefs between the technology-rich class and the traditional class is that the belief in the technology-rich class was positively related to values and benefits, while the traditional class seemed to stay at the same negative attitude in their belief.

Table 2: Students' Belief of Introductory Statistics Comparing with Mathematics Courses Before and After Taking the Course

Before	**After**	
Before Taking the Course	**Technology-rich PACE Model Approach**	**Traditional Lecture & Note-taking Approach**
Number crunchy	Can see how it benefit me for my research	It was a math course, just with the direction toward statistics.
Abstract concepts (2)	Statistics deals with numbers, which represent real world. Math deals with numbers and formulas	It was different from math. In math, you built upon some basics and go farther. In this, I had hard time building on some basic principles.
Putting numbers to things,	Realize what is behind these numbers	It could be very interesting if that was more relative to life.
Odds and probability	It is more problem solving, not just plugging numbers	If we would have used technology, maybe some class discussion, or group work, I think I would have learned more.
A bunch of equations	Like math better, it is easier.	Applications are different from math.
Use numbers to predict (2)	The amount of computer and hands-on activities were surprising and helpful.	It is different thinking process. It is not like this is number One, and that is number Two. It is like this is number One, then trying to figure out what to do with number Two.
Just like math (2)	It is just an application of mathematics	It was concepts. The mathematics part was straight forward.

	You have to think about information more and put it into perspective, and compare different things. Not just multiplying and adding things together.	Relating to Physics, not just plugging in variables and numbers, but also what you would apply to.
		I always thought I would really love stat because I love math. But, it was not pure formula.

Table Three analyzes students' beliefs of the difficulty level associated with their learning experience from each class. There are several noticeable differences between technology-rich class and the traditional class. Students from the traditional class experienced difficulty of *'putting so many parts together', 'understanding different probabilities and equations', 'how to set up problems properly'*. Students from the technology-rich class rarely using words such as *formulae, putting parts together* and so on. In stead, they expressed their experience as *'You have to think, it is not easy', 'not as abstract, more applied oriented', 'when start thinking more, understanding more'.*

Table 3: Students' Belief of the Level of Difficulty Before and After Taking the Course

Before	**After Taking the Course**	
	Technology-rich Class Using the PACE Model	**Traditional Lecture & Note-taking Approach**
Did not know much (3)	You have to think, it is not easy.	Some stuff were more in-depth than I was thinking at the end.
Common sense	When start thinking more, understanding more.	There were so many different parts. I had hard time putting them together.
Easy (4)	Very easy, interesting in the beginning, then gets more difficult. (4)	I had hard time understanding different probabilities and equations.
Did not expect to be easy (2)	The last three weeks were very difficult	It was not easy. Had to work really hard.
Hard (3)	Not as abstract, more applied oriented	I had real difficult time on how to set certain things up in a logical way.
	I could do computations, but I did not think I understood why	The most difficult part was trying to set up problems properly.
		I could take the formula and plug things in. But trying to initially set up a problem, that where the difficult was.
		The second half was very difficult.
		A lot of different ways to figure out so many different kind of situations.

Hands-on activities and Computer were used throughout the entire semester in the class using the PACE model. These students had some further comments with regards to the use of computer. The following were a list of comments summarized from those students:

1. When doing computer, I know how to do it, but feel like did not know why I was doing it. To me, it was too much computer.
2. I knew computer can help. But, I did not realize it has graphs and stuff like that.
3. The amount of time using computer instead of formula was a surprise.
4. If you do not use computer, you are not going to see the applications of statistics.
5. From application point of view, computer is helpful. Because if you do not see where you are going to apply, you kind of lose interest, you do not see where you are going with it.
6. We used too much computer, not enough lecture.

These comments suggest that use of computer can be overwhelmed for some students. In general, students commented the value and benefit of hands-on activities and the use of computer for data analysis and report writing.

One needs to be careful of mixing technology and lectures. On the other hand, *the surprise of using computer and hands-on activities* indicates that the traditional approach has occupied students' mind before taking the class. One needs a careful planning before class starts, in order to make the process more organized and smoother. It is no doubt that the technology-rich class has improved students' attitude and belief towards statistics. This interview study provides some insight about students' belief and attitude towards statistics by comparing their changes of belief and attitude between students in technology-rich class and students in the traditional class. Much more research on the impact of technology to students' learning is needed. This includes both learning process and outcome assessing. In particular, further research is needed in the area of how students learn statistical concepts, and how these concepts and knowledge affect their problem solving strategies. In addition, the unlimited opportunity of technology for teaching and learning quantitative skills such as the use of Internet and multimedia is waiting for instructors and researchers to explore.

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Encouraging Computing Diversity and Persistence through Research

Sandra Madison, Ph.D., Associate Professor
Department of Mathematics and Computing
University of Wisconsin-Stevens Point
Stevens Point, WI 54481 USA
email: smadison@uwsp.edu

James Gifford, Ph.D., Professor
Department of Mathematics and Computing
University of Wisconsin-Stevens Point
Stevens Point, WI 54481 USA
email: jgifford@uwsp.edu

Abstract: This study explored the parameter-related misconceptions of two college students enrolled in an introductory programming course. Both students appeared to conceive a direct procedure-to-procedure linkage, with the connection being made by identically named formal parameters. Throughout the semester, both students were able—by making apparently innocuous adjustments to formal parameter lists—to construct correctly functioning modular programs. They were also able to correctly answer parameter-related test questions. As a result, the misconceptions were hidden from the instructor and perhaps from the students themselves. The paper discusses the results of the study within the constructivist framework and suggests implications for instruction.

Introduction

National studies show increasing numbers of female students in higher education. However, despite increased college enrollment, women nationwide continue to be under-represented in the sciences (Frenkel, 1990; Scragg & Smith, 1998). Moreover, recent studies show that the percentage of females receiving computing degrees dwindled from approximately 37% in 1984 to 28% in 1994, in contrast to other science and engineering fields where the percentages of females are increasing (Edupage, August 6, 1998). Given the high percentage of Caucasian males currently employed in the field, national concern with affirmative action, and ample opportunity, businesses continue to seek out qualified women and minorities.

The lack of diversity among the existing pool is a problem; however, the current and expected shortfall of needed programmers of any gender or from any ethnic group is an equally significant problem. Few people doubt that technological skills will become increasingly important as our country enters the 21st century. Mid-1990s Department of Labor statistics indicated that the demand for qualified computing professionals already exceeded the supply and was expected to double in the next decade. The monumental problems created by the millenium bug, problems that only recently gained the public attention, are already intensifying that demand. The national and societal demand will go unmet unless we can find a way to increase the supply of trained programmers.

Faced with the dual problem of too few programmers and too little diversity, the educational community must ask ourselves: Why is it that—despite acknowledged career opportunities and known financial advantages—interest, especially female interest, in the computing discipline remains tepid? What is it about computing—or the way we teach it—that drives students away? How can we better cultivate the heretofore untapped (or under-tapped) pool of computing talent?

Computer programming is the foundation of all the computing sciences; large doses of programming permeate any computing curriculum, particularly at the introductory level. Unfortunately it is also the component of computing that is most inimical to females; it is the area where they are least likely to persist (Lockheed &

Mandinach, 1986). In truth, the literature attests that students in general find college-level computer programming courses demanding, and that attrition rates in those courses are high. The situation is not new, nor is it unique to a few institutions. For example, in 1983, Deimal and associates observed students' invariable lack of intuition about the nature of programming. In 1986, Greer described the attrition in introductory programming courses as "an unfortunate but inevitable consequence of the nature of university introductory computer science courses" (p. 219). As concerned educators, we need to question the assumption that attrition is inevitable. More productive questions might be: How can we alleviate the difficulties novice programmers experience? What can we do to facilitate their success? In 1986, authors Spohrer and Soloway counseled, "The more we know about what students know, the better we can teach them" (p.624). Their message is unmistakable. Programming instructors need research that informs the instructional and curricular decisions over which we have control.

The study reported in this paper addresses the challenge of student success and persistence in an introductory computing course by exploring the misconceptions of two novice programmers. It assumes that teachers who understand their students' misconceptions should be better able to meet their students' instructional needs and facilitate their success.

Methodology

The study is a subset of a larger study that attempted to describe novice programmers' understanding of the simple parameter-passing construct. The current study specifically addressed the following question: What misconceptions do novices possess regarding the concept of simple parameters? It provides part of the answer by pursuing an in-depth analysis of two students' misconceptions. It will be shown that the two harbored essentially the same flawed conception of the parameter process. The topic of simple parameters was selected because the literature reveals a virtual absence of attention to the construct. Moreover, the topic is pivotal since it is precisely the feature that gives modern programming languages their power. Pedagogical understanding of the topic is made even more important by the fact that many instructors and students attest to the fact that parameter passing is the most challenging concept covered in the introductory programming course.

The study assumes a constructivist perspective. It presumes that people construct knowledge through a "process of building intellectual structures that change and interact and combine" (Papert, 1988, p. 3) rather than being empty vessels to whom knowledge can be transmitted. Specifically, the theoretical framework for this study builds on the Linn and Songer (1991) model for conceptual change originally posed for students learning science. The three stages of the model include action knowledge, intuitive conceptions, and scientific principles. Action knowledge is the understanding learners bring to a learning situation, understanding that is based on personal experience. Intuitive conceptions are the conjectures learners construct to explain events they observe as they attempt to make sense of the world they perceive. Intuitive conceptions, since they are derived solely from unexamined experience, are often incorrect and might well be called "misconceptions." Finally, learners acquire scientific principles, organizing their intuitive conceptions into principles consistent with those held by experts. Characteristic of the intuitive conception stage of the Linn and Songer model, researchers studying novice programmers have found that, rather than resulting from slips in mechanics of program construction, most faulty answers arise from systematic application of knowledge the student already has. The answers make sense when interpreted in terms of the student's current understanding (Pea, Soloway, & Spohrer, 1987).

Teachers who view learning in terms of the Linn and Songer (1991) model for conceptual change within a constructivist framework should not be surprised that students construct their own meanings. More importantly, they should not be surprised that some students harbor misconceptions despite instruction to the contrary.

The current study was theory-driven, drawing upon several methodologies traditionally employed in qualitative educational research. In harmony with recent research in education, the study focused on detailed analyses of individual subjects' responses. Data sources included observation of the classroom instruction, semi-structured interviews, protocol analysis, and document examination.

The bulk of the data for the larger exploratory study was collected from students enrolled in one section of an introductory programming course at a regional university during a fall semester. The study described here focused on two of the students (with self-selected pseudonyms Jason and Steve) who participated in the larger study. Neither had any previous exposure to the parameter process although Steve had taken a one-credit Introduction to Pascal course prior to his enrollment in the course that was the first course in the Computer Information Systems major.

One interview task proved especially helpful in uncovering the misconceptions. Subjects were given the program listing for a partially completed program designed to calculate the volume of one rectangular solid. (See Figure 1.) To complete the task, subjects were to complete the procedure heading lines so that the program would compile and behave as advertised.

```
PROGRAM CalculateVolumeOfARectangularSolid;

PROCEDURE ______________________
BEGIN
  Volume := Len * Wid * Dep
END;

PROCEDURE ______________________
BEGIN
  WriteLn ('The volume of the solid is ', Answer: 8:2)
END;

PROCEDURE ______________________
BEGIN
  Write ('Please enter a dimension ==> ');
  ReadLn (Dimension)
END;
```

```
{main}
VAR
   Volume,
   Length,
   Width,
   Depth:   Real;

BEGIN
  GetInput (Depth);
  GetInput (Width);
  GetInput (Length);
  CalculateVolume (Length, Width, Depth, Volume);
  DisplayOutput (Volume)
END.
```

Figure 1. Partially Completed Modular Program.

Results and Discussion

Jason and Steve both exhibited problem-solving behaviors that could be attributed to a fundamental misconception of the parameter process. Errors they made suggested a systematic application of a parameter process that involved a direct procedure-to-procedure communication link, a link that was forged by identically named formal parameters. Consistent with the literature on misconceptions, some oral and written responses that initially appeared capricious—and even bizarre—proved to be logical and appropriate choices when interpreted in terms of the learners' hypothesized misconceptions. Importantly, both students were able, despite their fundamental misconceptions, to repeat the textbook and instructor's language, to correctly answer parameter-related test questions, and to construct modular programs that produced the correct answer. In these ways, the students' lack of understanding was concealed from the instructor and possibly from the students themselves.

Jason

During the hand-construction task (See Figure 1) in which the formal parameter name choice was constrained, Jason failed to consistently choose appropriate parameter names. For example, Jason first correctly constructed the procedure heading line: *PROCEDURE CalculateVolume (Len: Real; Wid: Real; Dep: Real; VAR Volume: Real)*. He named the formal parameters *Len*, *Wid*, and *Dep* "because of their use in the assignment statement," the procedure's only executable statement. He next wrote: *PROCEDURE DisplayOutput (Volume: Real)*, incorrectly naming the single parameter *Volume* rather than *Answer*, the only identifier used in the procedure's only executable statement because "it has to come from the above procedure. Volume was used as a variable

parameter up there [*Volume* in *CalculateVolume*], so it has to be sent down to this procedure *DisplayOutput*." Finally Jason constructed the procedure heading line for *GetInput* thus: *PROCEDURE GetInput (VAR Len: Real; VAR Wid: Real; VAR Dep: Real)*. He incorrectly gave the procedure three formal parameters—*Len*, *Wid*, and *Dep*—which he correctly identified as variable parameters "so they can be sent to the procedure to perform the calculation."

Interpreted from the perspective of Jason's hypothesized name-controlled, direct-connection link, his parameter choices were appropriate and his reasoning cogent and coherent. CalculateVolume provided a *Volume* to *DisplayOutput*; thus *DisplayOutput* needed a *Volume* to receive it. *CalculateVolume* needed *Len*, *Wid*, and *Dep*; thus *GetInput* needed to supply them. It is noteworthy that Jason examined the procedures in the order of their physical appearance on the page, rather than the logical order of their execution. Apparently that order determined the name choices.

Jason repeated the words of the text and lecture, he wrote correctly-functioning modular programs as long as he could choose matching parameter names, and he correctly answered multiple choice test questions related to the number of parameters in corresponding actual and formal parameter lists and other facts. As long as the task did not conflict with his misconception, he succeeded. However, when Jason's conception of the parameter process clashed with rules he had memorized but whose purpose he perhaps did not understand, his naive conception prevailed.

Steve

Just as the hand construction task in which the parameter names were constrained (See Figure 1) revealed Jason's misconception, so did it Steve's. After experiencing some confusion with the *GetInput* module, Steve turned to the parameter list of *CalculateVolume*, constructing it as follows: *PROCEDURE CalculateVolume (Num1: Real; Num2: Real; Num3: Real; VAR Num4: Real)*. Although the number of parameters and the value-variable choices were correct, the parameter names were not. Steve offered that he had not chosen the names for any particular reason, that "the actual parameter list just needs something to match up with." *Num4*, he offered, needed to be a variable parameter because "it has to get passed between procedures to *DisplayOutput* after it's calculated." His phrase "passed between procedures" first suggested the direct link. Steve next wrote: *PROCEDURE DisplayOutput (Answer: Real)*, correctly naming the single parameter *Answer* "because the *WriteLn* calls it up as *Answer*." But then he changed the *Num4* parameter in the *CalculateVolume* procedure to *Answer*. The other procedure heading lines completed, Steve returned to *GetInput*. He alleged that the parameters needed to be *VARs* because "they have to go to other procedures." Steve eventually constructed the following: *PROCEDURE GetInput (VAR Num1: Real; VAR Num2: Real; VAR Num3: Real);*. Next, recognizing that the GetInput procedure needed a declaration to match the *ReadLn (Dimension)* statement, Steve added *Dimension* as a local variable. Referring to the *GetInput* procedure, he claimed, "That's the only one that is going to use the *Dimension* in that form because it's not used anywhere throughout, so it's not going to be put in the *VAR* parameter. It's a local variable."

It appears Steve was imagining a direct procedure-to-procedure connection between the parameters, a connection that was established through identical parameter names. *CalculateVolume* needed *Num1*, *Num2*, and *Num3*; thus *GetInput* needed to provide them. *DisplayOutput* needed an *Answer*, *CalculateVolume* needed to provide one. No other procedure had a parameter named *Dimension;* thus *GetInput* did not need one either. As Steve constructed numerous correctly functioning procedures over the course of the semester, one must assume he knew that the number of actual and formal parameters must match. However, the conflict provoked by the seemingly novel input procedure (Actually, it was conceptually identical to one used in a previous laboratory exercise.) caused Steve to abandon or distort the procedure heading line construction rules—rules whose purpose he perhaps did not understand—to allow him to build a procedure heading line consistent with his understanding.

Many of Steve's problem-solving decisions and behaviors approximated Jason's. As Steve constructed numerous correctly functioning procedures over the course of the semester and correctly answered multiple choice test questions, he presumably knew the parameter rules. However, when his choices were constrained, he—like Jason—did not consistently choose names compatible with the procedure's executable statements or construct

formal parameter lists with the correct number of parameters. He chose instead identical formal parameter names for all procedures that referred to the same data element.

Summary

A footnote in Joni and Soloway's (1986) article on novice programmer misconceptions speculated: "We suspect that many novice programmers have difficulty with VARing variables because they have misconceptions about argument passing in general" (p.115). Fleury (1991) found that important percentages of subjects harbored significant misconceptions regarding the parameter process. She, too, found that students could construct correctly working original programs despite their misconceptions. Mayer (1985) theorized that learning a programming language involves acquiring several types of knowledge. Novices must learn syntax, must know how to generate a program, and a must develop a mental model of the computer system. The novices in this and in Fleury's study knew the syntax, and they could generate programs. What they lacked was an accurate mental model of the Pascal computer system.

Significance

Steve and Jason exhibited problem-solving behaviors and verbalizations that could be attributed to a fundamental misconception of the parameter process, a process that involved a direct procedure-to-procedure link. This finding suggests first that teachers stress carefully that variable parameters are necessary when the value of the parameter is changed within a module and the changed value needs to be communicated back to the calling module. Although subsequent modules typically use those values, that situation is not necessarily the case.

Upon reflection of their instruction, the authors have concluded that, in their zeal to force students to learn to use parameters, they likely over stressed the non-use of simple (e.g., Readln, Writeln, assignment) statements in the main module. The practice may have fostered the misconception; it surely camouflaged it. Students need to be exposed to multiple instances of situations where the values associated with variable parameters are used by subsequent modules and situations where they are not.

Both students made program construction errors that at first seemed capricious, but made sense when interpreted in terms of the hypothesized misconception. Thus, programming teachers should refrain from interpreting program errors as simply carelessness or lack of attention or lack of concern on the student's part. It is also important to note that, during the interviews, both subjects verbalized their inability to understand. This fact suggests that students can provide helpful information about their understandings and misunderstandings if they are provided an opportunity. If improving the success rates in introductory programming courses is a legitimate goal, then instructors must fashion opportunities for students to say, "I do not understand."

Despite their fundamental misunderstanding, both Jason and Steve could write original programs that produced the correct answers—as long as the parameter name choice was not constrained. If understanding of the programming language constructs is a legitimate and important goal of programming instruction, then instructors of introductory courses must craft opportunities whereby learners construct criteria for programming success that are more comprehensive than merely "finding the right answer." The instructor who relies heavily or solely on original program construction has no assurance that students understand the fundamental language constructs.

An introductory programming course is traditionally taught as a skill development course. Programmers are, after all, ultimately judged by the skill with which they construct programs. Accordingly, traditional instruction has been designed to develop skills, perhaps at the expense of understanding. The course in which the participants were enrolled was no exception. The results of this study suggest that educators may wish to rethink the goals, assessment, and methods of instruction of the parameter topic. Doing so may enable more students to construct an understanding that moves beyond the stage of intuitive conception to the stage of principled understanding of the parameter process.

Given the migration from Pascal to C++ as the language of choice for introductory programming courses, the unaware might conclude that the current study adds little of importance to the research base. However, the literature reveals a dearth of parameter-related research in *any* programming language. Moreover, the C++ mechanism for simple parameter passing is conceptually identical to that of Pascal; only the syntax changed. Anecdotal evidence suggests that the misconception persists.

Principled understanding of parameters and other programming constructs should promote success and therefore persistence in the computing discipline. Instructional reforms such as those suggested here could help women and other under-represented groups--indeed all groups--take their rightful place in a well-educated, skilled work force for the 21st century.

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Acknowledgments

The research reported in this paper was a portion of Sandra Madison's dissertation, completed at the University of Wisconsin-Milwaukee under the supervision of Henry S. Kepner, Jr.

Integrating Math, Science and Technology: Teaching Problem-Solving Skills Through Robotics

Anneliese Payne, Ph.D.
Dept. of Curriculum & Teaching
Hofstra University, Hempstead, NY 11549
E-mail: cataxp@hofstra.edu

Abstract: This paper focuses on one aspect of the math, science and technology program within the School of Education and Allied Human Services at Hofstra University. Hofstra's M.A.-MST degree program for in-service teachers has been cited by the New York State Dept. of Education as a model for integrating math/science/technology in the elementary schools. This paper describes a computer technology in education course in which students learn to become problem-solvers and self-learners through an introduction to a hands-on, self-paced, individualized program. Robotics is introduced through the use of a binary interface that is plugged into the printer port of an IBM or compatible computer. Students learn the binary number system and learn to manipulate remote control toys, trains, doll houses or any invention they have created.

The M.A.-MST Program

The Master of Arts degree in Elementary Education with a Specialization in Mathematics, Science and Technology at Hofstra University in Hempstead, New York is designed for elementary school teachers who seek the skills, knowledge, and dispositions to integrate the teaching of mathematics, science and technology. Within this program, technology is defined in two ways: design and construction technology and computer technology. There is one required course in design technology (taught by the Department of Engineering) and a computer technology in elementary education course. One of the many strengths of this program is that the instructors who teach within the M.A.-MST program model a constructivist philosophy and conduct classes as facilitators of learning and strive to promote problem-solving skills. This paper focuses in particular on the computer technology course and the problem-solving skills and higher order thinking skills learned by the students through the integration of math, science, technology and the use of robotics. (The "students" referred to in this paper are the in-service teachers enrolled in the M.A.-MST program.)

In the computer technology course, students are introduced to a hands-on, self-paced, individualized program which includes instructional materials from Creative Learning Association (1995). These materials allow students to work independently and at their own pace. The students use BASIC programming to develop responsibility, creativity, higher order thinking skills such as analysis, synthesis, evaluation, along with cooperative learning, independence, problem-solving, communication, self-directed learning, mastery of subject matter, ability to learn from others and, most importantly, a love for learning. All of these skills are important for the in-service teachers to experience and learn during the course so that they can effectively model and integrate this style of teaching in their own classroom. Comments from the mid-term examination explain the extent of the students' understanding of these skills (the students' names have been omitted):

Responsibility: "I believe that this course seeks to engender a highly responsible approach to learning, with the ultimate goal of self-accomplishment. By making the student totally responsible for the completion of the individual assignments and adhering to due dates, the aim is to encourage the student to unlock his or her initiative. The students encounter problems and solutions are not given. What is given is merely a clarifying, supportive question which allows the student to *discover* for him/herself. There is a built-in sense of accountability for one's personal learning and progress. It is an internal pressure which is stronger than an external one. I believe that only by sparking this internal learning mechanism can we really enjoy the fruits of our labor. Confidence in one's ability is the ultimate result."

Creativity: "Creativity is also a way of allowing each student to be involved and excited about their own learning. Students can embellish their projects and presentations with their own originality. Creative teaching units allows a wide scope of personal use and interest to feed the students' progress. Once a student begins, he or she is hooked and not even aware of the work involved. The PowerPoint and Robotics are other levels which entice individual creativity for both fun and purpose."

Analysis: " Analysis comes into play when we try to break down parts of our program to try to find and fix our own problems. This also occurs when we are trying to help others. In each case we must try to find out what we want the computer to do, how we will accomplish that goal, and then analyze when the commands we entered did not work the way we wanted them to."

Synthesis: "This computer class allows us to develop the skills to synthesize knowledge because so many of the assignments require taking tidbits of information that we have learned from tasks that we have already completed and combine them in different ways so that a new problem in a unique situation can be solved. With each progressively difficult assignment we complete, more and more information becomes easier to use and manipulate, which allows us to ultimately conclude all of the work for the semester. We also learn to synthesize each other's ideas and solutions into our own, giving us a larger knowledge base to use when trying to solve a problem."

Evaluation: "We are asked to evaluate our own performance when we are 'teacher of the day'. We also use this skill when we use the robotics system. Evaluation teaches us to learn from our own mistakes and discover ways to be more effective. We evaluate our own progress through this self-paced environment. By developing this skill in class, we will become better teachers because many times we are the only ones that would be able to evaluate our performance and determine what areas need to be improved."

Cooperative Learning: "Cooperative learning is defined as 'an arrangement in which students work in mixed-ability groups and are rewarded on the basis of the success of the group'. Since no two persons have exactly the same ability, our whole classroom is a giant mixed-ability group. Even though each individual is not rewarded on the success of the whole group in general, during at least one exercise (developing robotics skills), we are rewarded for working effectively in groups."

Independence: "Acquiring the skill of independence in terms of learning goes hand in hand with developing responsibility and creativity skills in our class. We learn to become independent because we are not constantly reminded to keep up with our work, therefore we have to pace our progress in completing assignments. The combination of being creative in solving problems that are presented in class, being responsible for completing the assignments in a timely fashion, and the freedom to acquire knowledge in our own unique way allows us to become independent learners."

Problem-solving: "Every assignment involves figuring out how to accomplish its objectives. We learn how to solve problems when our neighbor asks for help with their projects, and when we are 'teacher of the day' and we must go around the room trying to help the class as needed. In both cases we hate to determine what the other person wants to accomplish, how they have tried to reach their goal, realize how they can repair their mistakes, and search for a way to help them see the solution without giving them the answer. Each part needs mini-solutions to solve the overall problem."

Communication: "As learners, we must develop communication skills in this class in order to acquire knowledge that is useful in our prospective careers. As teachers, we must develop communication skills in order to be fully able to assist our students in their pursuit of knowledge. Therefore, during every class session there is always an element that involves learning how to communicate with one another."

Self-directed Learning: "We have the opportunity to work on our assignments in any order we chose. Also, the way we accomplish our goals for each task can take any form that we wish (creativity). There are also no mandated ways to finish each piece of assigned work, therefore we can assimilate our new and old knowledge to allow us to complete our work in the most comfortable and efficient way possible. The combination of the information provided from our own and other's mistakes allow us to become better self-learners."

Mastery of the Subject Matter: "Because we are responsible for our own learning and we can be creative in terms of how we solve and approach solving problems, the actual integration of the subject matter becomes much easier and enjoyable for each of us. Also, because we are not only learner, but are teachers of this new information, the information is more easily synthesized in our knowledge schemata."

Ability to Learn from Others: "This class is not based on the 'sage on the stage' philosophy of teaching. Instead, it is grounded in the 'guide on the side' philosophy of teaching. We have been trained to learn for ourselves and from each other since the first class. Except for some words of guidance here and there from our professor, mostly we have to depend on each other for new perspectives on how to attack a problem, words of support when we fail, and words of praise when we finally achieve our goals. This support from our peers comes from either our neighbors from whom you ask for assistance, or from the 'teacher of the day' whose responsibility it is to assist those students who are in need."

Love of Learning: "One area of my knowledge insecurity was computers. However, I have been able to apply my natural zest for learning to computers. I have mastered the fear and can allow my love of learning to flow. We must all become self-learners! It is the ultimate tool for success. Fear gets in the way of learning. This course has demonstrated the fact that if one hangs in there, the problem can be solved either alone or with assistance. The freedom of security in this classroom has helped me to go back to *my* classroom and re-ignite my learning spark. I am internalizing my computer learning by *thinking*."

It is satisfying and exciting that the students have learned these skills in one semester and in turn will be able to model these skills for their own students in their elementary classrooms. According to Dusick (1998), our job as educators is more than just to educate. It is to prepare students to be capable, productive citizens when they graduate. As far back as the early 1980', researchers were predicting that many jobs in the 21st century would require computer knowledge (p.11). In the executive summary of the Report to the President on the Use of Technology to Strengthen K-12 Education in the United States (by the Panel of Educational Technology organized in 1995), it is stated that "it is widely believed that workers in the next century will require not just a larger set of facts or a larger repertoire of specific skill, but the capacity to readily acquire new knowledge, solve new problems, and to employ creativity and critical thinking in the design of new approaches to existing problems".

The Robotics

In order to further the conceptual understanding of technology as a problem-solving tool, students are introduced to robotics through the use of a binary interface that is plugged into the printer port of an IBM or compatible computer. What is a binary interface? In order to communicate with a printer or other peripheral, the computer has to send a one or zero on each of eight wires in the printer cable). The binary interface detects these ones and zeros and displays them on Light Emitting Diodes (LEDs). Then a transistor switch is used to turn on and off any toy or invention that is wired to the switch. An optical isolator is included to prevent electrical feedback that might damage the computer.

The students are challenged to find the right printer port of their computer by testing the address of LPT 1, LPT 2, LPT 3, etc. Once the connection is made, the students communicate with the binary interface by turning the LEDs on or off. In doing so, they learn the binary number system and are challenged to find the numbers between 0 and 255 which will turn each of the lights on or off in sequence. The next challenge is to control a battery-powered motor with the computer. Students occasionally find this challenge difficult because they want to rely on their memories from their own elementary school days when they learned about electricity, rather than the problem-solving skills they have so recently acquired. Since the students are engaged in this process as part of a small cooperative learning group, each one of them not only masters this task, but also shares a feeling of excitement and accomplishment. Once that challenge is completed, the students then write a very simple program in BASIC that will manipulate a toy train that will move in a rectangular path. What makes these challenges unique, is that the students have no prior knowledge of robotics, yet teach themselves how to maneuver any battery-powered object that they may want to create.

The Elementary Classroom

According to Puk (1996), students need to move past the level of functionality of technology and develop what might be called the "art of" engaging a particular technology. By "playing around" with the technology, they learn, through trial and error, how to utilize the technology in a more fulfilling manner. a. 13) One of the goals of the computers in education course is to encourage students to "play around" with the technology and go beyond the every day uses of drill and practice software. The students in this course are teachers who are presently teaching children who will graduate from high school and college in the 21st century. It is not possible to teach all of the technology skills that children will need when they are grown because technology is changing so rapidly. Therefore, it is extremely important that children learn to become problem-solvers and self-learners so that they can teach themselves the skills needed in the 21st century.

Teachers can set up an individual, self-paced program in their own classroom regardless of the number and age of computers available to them. An elementary school classroom, starting in 4th grade could be set up with a program very similar to how it was set up at the college level. One slight difference would be a more formalized way of keeping track of the individual student progress through the program. Once the students reach a certain level of expertise, problem-solving and self-learning skills, robotics can be introduced. Children learn easily through concepts that apply to their lived experiences.

Conclusion

Within the M.A.-MST program at Hofstra University, the computer technology course encourages in-service teachers to develop skills that are needed by students in the 21st century. The in-service teachers have the opportunity to work in a learning community where they learn from each other, use higher order thinking skills, be creative, independent and develop a love for learning. Robotics is introduced as a means to develop problem-solving skills and integrating math, science and technology. After completion of the program, teachers will be prepared to model for their children the type of learning that will be necessary to their success. In the classroom of today, every teacher should be a learner and every learner should be a teacher.

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Cooperative Learning In Web Courses: A Framework Based On Cognitive, Social And Technological Aspects

Luiziana Rezende
Mathematical And Natural Science Center
Federal University Of Rio De Janeiro
Brasil
Luiziana@Lci.Ufrj.Br

Abstract: This paper presents a project to distributed learning environment mediated by informatics and network systems, used now by students of Graduated Courses in Chemistry and Eletronic Enginnering, in the Mathematical and Natural Science Center / Federal University of Rio de Janeiro (UFRJ) - Brazil. This work has been developed in the M.Sc. Course of Informatic (NCE/IM - UFRJ). This project proposes a framework for learning of the subject-matter *Computation I* , atending a greet critical mass of students, based on the *Learning Cycle Paradigm*, under a pedagogical focus of *Social-Interactionism*, having telematics resources like mediator technology and whose main purpouse the cooperative learning carried out from projects situated on the student's context, through the conjugation of presencial and non-presencial activities.

Introduction

The Computation Science Departament, offers the subject-matter Computation I to various classes at the University, it's proposition is an introductoty view in programming, through Pascal languages. Many are the problems that happen with this form of work, and the most important remarkable are: the great number of students, unmotivated teachers, teaching and not learning perspective, distant concepts of the student's reality and disconected his study area, students with differents knowledge levels and class evasion after first evaluation. Teachers and students agree that is really necessary a reformulation.

The framework for this course was structured with the cognitive, social and technological aspects needed and possible for a distributed learning environment. The various aspects of the elaborating process are described below.

The Epistemological Perspective

The structure of the knowledge of the subject-matter "Computation I" was set on a cooperative basis, by the construction of a *Conceptual Map* (Fig.1).

The conceptual map (Novak, 1981; Gaines, 1997), on the scope of the educational hypermedia, has a system of concepts in the grounds of knowledge, serving as a conceptual model that give to the educator a capable instrument of representation of knowledge, that will help on the process of teach and learning. They make clear the relation between the concepts the professor wishes to establish, and, in the other hand, allow the student to have a clear vision of this concepts.

The methods and techniques involved in the acquisition of knowledge on Computation I in this project are: identification of a key problem in the students area, bibliographic research, construction of the conceptual structure diagram, formal and informal discussion in a virtual computer web environment, construction and utilization of a collective virtual library, software and tutorial utilization, critical evaluation of computer programs in the Pascal language, design implementation of individual and collective prototypes.

MAPA CONCEITUAL DO CURSO DE COMPUTAÇÃO I

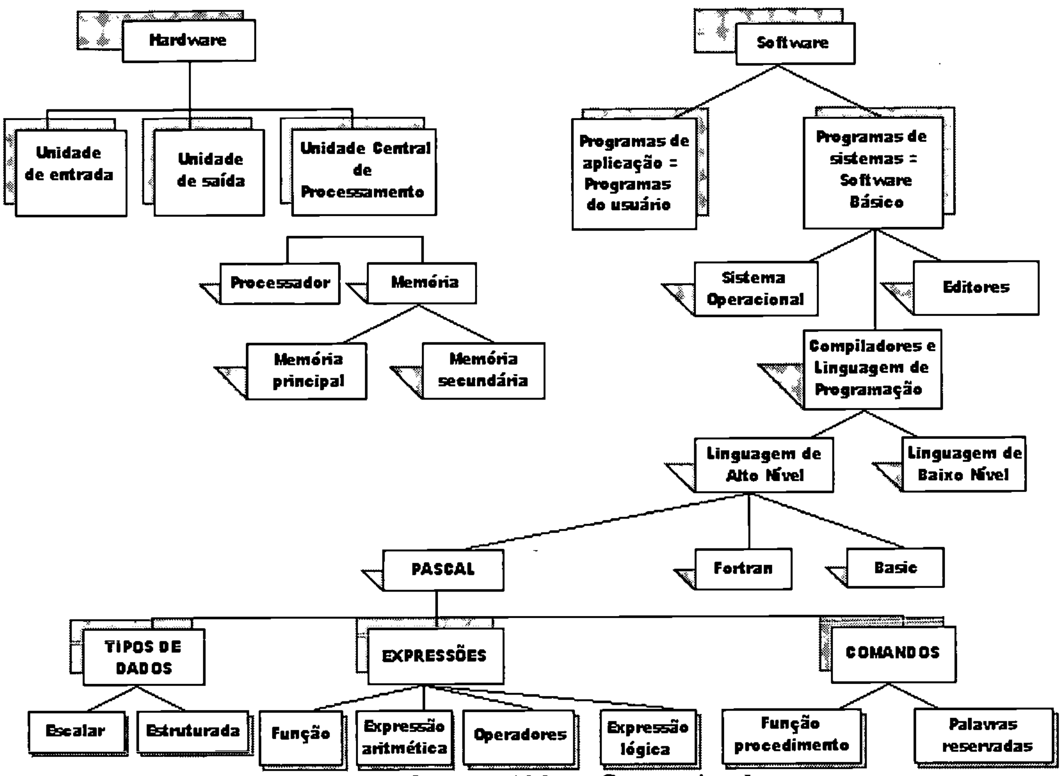

Fig.1 - Conceptual Map - Computation I

Psychopedagogical Perspective

The psychopedagogical perspective refers to pedagogical and psychological theories that give support to the educational process, and according to Bell (1996), can be associated to two visions of this process:

- Traditional view that reinforces the teaching and implies in a linear system of education structured from a hierarchic organizational relationship, based in inductive deductive scientific models.
- Contemporary view that reinforce the learning and imply a system based on *learning cycle* (Kolb, 1984), structured from concrete and abstract activities, based on reflections, mental connections, decision taking, action and reflection from the consequences of the action itself (Fig.2) .

Nowadays, the Computation I course is developed with the teaching perspective, showing a variety of problems. It's necessary to improve for the learning perspective.

Fig.2 – Kolb's Leaning Cycle

The cooperative learning in web courses demands a new pedagogic view. With the potentiality of the new technology and the communication webs it can be easier and have a distributive cooperative learning character. Many factors are implicit in this process and must be analised from a learning Social-Interactionism Perspective.

According to Vygotsky (1984/1988), the main representative of the Social-Interactionism, every student is an active organism, whose thoughts are constructed slowly in a historical environment, and in essence social. The social interaction, measured buy the language, has an essential role in the cognitive development. According to Perkins (1993), in a distributed environment is considered the person plus the environment (including the culture in which it is placed and the objects and people it has contact). Nowadays the notion of cognition is losing the aspect of a central process of the mind to assume

also a perspective of *distributive cognition*. We consider the individual and his environment as one. We also considers his artifacts creating an interactive environment highly complex, with rules, principles etc.

The *theory of learning cycle* (Bell, 1996) says that every student has a potential of learning from raising questions about his daily problems, through creative activities that allow the exploration of all the potential according to their abilities.

Due to the different level of knowledge between the students of Computation I, the interaction is essential for the personal development of each student, as well as the social development of the group. This way, the student, will be able to search cooperatively with his pairs the solution for the problems.

Such problems are identified on the student area, according to the course, with the help of his pairs and teachers and using the programming language as a tool that will take to the solution. When the student find meaning and relevance on the context that will be object of knowledge, it is known as situated learning, meaning that it happens on the context in which the student is placed and the learning is result of an activity.

The environment of cooperative learning sustained by the telematics, in a distributed environment, can offer a diversity of situations that allow the student the development of this abilities, which in the heterogeneous universe of the student of the Computation I course is essential.

The situations in the university are highly specialized, in the real life that doesn't happen, demanding an enormous capacity of putting into context, critical analyzes, knowledge integration and utilization of the proper tools.

Nowadays in the discipline of Computation I has been a presencial development. This project goal is the introduction of non-presencials activities in the context as a way to solve some of the problems spoken before.

Didactic Perspective

A distributed learning environment supposes the distributed representation of the knowledge. It can be conceived in an Open Education System through virtual environments, interactive characteristics of the hypermedia system and the computer network. This environment is near of the student's real world and is constituted based on non-linear navigation characteristics and interactivity, that allow the student control of the educational process, autonomy, freedom, communication and cooperation. According to Feijó (1997) "the riches of an interactive environment constitutes on the variety of interactive tools that he can dispose and also the on intrinsic characteristics, like active, experiential, multisensorial, collaborative, etc; of each tool and what they can give to the learning process.

Knew and used for a long time in education, the learning based in projects seems to be the fundamental point in Computation I, as make possible to students build the knowledge from problems in their specific study area. This position, in front of the environment and knowledge, must be supported for some attitudes; like continuos arguing, research cooperating and a self-methodology to solve problems.

The students of Computation I are the own designers of their learning, since the problem identify stage, passing by the possible alternatives inferences, testing them from programs using , till get definitely to the pertinent alternatives to that specific situation. All this process, however, is inserted in a cooperative work, in a continuous integration between pairs and groups and in the language use through different channels of communication, mainly the computers webs.

The projects based learning give the student the possibility of link his culture and the scientific established knowledge, pondering about the world and himself. Freire (1977) affirms that "when men discover themselves like a culture product, they see themselves like subjects and not like learning objects, going from the common sense to the scientific knowledge sense in a continuum of respect"

The Computation I Learning Environment

The virtual environment built to the Computation I has different spaces, making possible an active richness, interacting and communication.

The Student starts his travel through the site (Fig. 3) of the subject that makes possible the following environments:

Curriculum - In this space the student identify himself to the others participants, inserting a photograph, and writing his interests, his activities, his course and all he finds important.

Fig.3 – Computation I Learning Environment

Module - This space constitute in a hypermedia system, where the student can navigate when he wants. It is composed by hypertexts about program languages. Its model is based in the Computation I Concept Map. The system is open and dynamic, in this way professor and student can insert new texts if they find necessity.

Tutorial - Here the student is in contact with a tutorial about computer architectures and Pascal Programming Language, and also with other tutorial's address that can be accessed through the web.

Virtual Library - Space built in a cooperative way by students and professors during the course, to constitute in a database having reusable programs with descritores, interesting sites on the web and bibliographic reference.

Projects Bank - In this space, the student purposes projects related to his study area that need the program language to be solved. He can also be placed in a project that has already been proposed and which is of his interest. All students regardless matriculated in Computation I have a determined timetable inserted in on of the projects, making up different research groups.

MOO - This is an object oriented virtual ambient and constitutes in a space which the student can interact with other students, the professor and monitor(s), in accord to the activities and to the different purposes. There are, in the world, virtual classes with specific characteristics textually described.

Consultation - Here the students have access to the electronic mail to ask advice for the professor or monitor without have to access the MOO.

FAQ - In this space there are the manly doubts that students have, related to concepts already worked, in this way the search for monitors and students decrease and they develop more autonomy and independence.

Portfolio - Each integrand of the course has his individual portfolio for the documentation of his activities and self-evaluation. There is also a group portfolio to the documentation of the activities developed in projects and group evaluation.

Discussion List - In this space, specific issue discussions are achieved through on line messages that are placed in a decreasing send list order, registered in memory, which can be accessed whenever it is necessary. The student has also the possibility to select only the desired messages.

Support and Tutoria

The Computation Course I is promoted by a Teaching Institute that has the task of, during all the teach-learning process, to attend, support and monitorate the students, to facilitate and evaluating, in a continuous way, the learning. This responsibility relation is set since the student's enroll in the course.

So, the tutor is an essential and indispensable person in the communication web that connects the students with the subject. He must have enough knowledge about the subject and manage the technique of integration and motivation of the group, in the various forms and styles. The ideal tutor must have some basic qualities like authenticity, emotional stability, ripening, self-knowledge, emphatic, intelligence, mental quickness, social culture, trust in the others, cultural unrest, extensive interests, leadership, cordiality and capacity to listen.

In Computation Course I the process of tutoria is made through the professor and monitors role. The monitor are the students with a differential knowledge level allowing them to pass for self learning and reflection process when they help other students. It is also important to motivate them to revise contents already known and reach different learning levels.

Learning Evaluation

The main function of evaluation, that is not always emphasized, is get better, to improve. Is not the amount of knowledge that improve a person but the quality and what in her that can make an interior change, open horizons, lead to new positions and new desires, to encourage the continue of learning to make it continuous.

For Landim (1997) the evaluation can't be considered like an isolate stage and even less like the last stage of the learning process, because integrate the process like a substantial element. The evaluation must be like a continuous conscience of the whole learning process, with the finality to take it to the reach of proposed purpose, not being interested only in remind moments.

The learning evaluation understood as a process, must be continuous, to offer enough information about the performance in each stage of the learning building journey, to orient and get over the difficulties.

The evaluation is a substantial element in the open learning system, mainly in pilot-projects like Computation I, because the result must lead to a deep knowledge of the course operation, in all the basic aspects: organization, didactics, structure, tutoria and student's learning evaluation. Their knowledge must be changed in different informers of sent evaluation, suggestions and recommendations, leading the course's responsible to continuous decisions or affect elements changes; contributing to the optimization of the learning process.

From the framework created to the Computation I course we can conclude that the evaluation must be concentrated in strategies that emphasizes the process: analyzes, reflection, cooperation and communication, above all in the learning context.

Will be used structure observation methods, from the students task group and established points list to guide the register telematic, in a certain way, can both make easy and difficult the evaluation process. If in one hand, through the computer programs memories it can make automatically the register of student's incursion in the different ambient and his participation in the discussion list, in the portfolio, in the library building, in the virtual ambient intercourse. In other hand it is difficult the direct observation, the confrontation that happens in the indetermination and in the unforeseeable behavior of the student and in the emotional demonstration.

The open evaluation will use the following data:

- The *portfolio*, that have registers of the student's activities, both individual and cooperative, making possible that the evaluation and self-evaluation be achieved in any moment, during the whole learning process, both by students and professors.
- *Projects bank* - Through it we can have an idea of the suitability, the richness and the functionality of the project to the students and to the institution. We have also to emphasize the investigations, the hypothesis tested, summarizing the project development, working in a prescriptive way.
- The *consultation*, it reflect if the student relation the contents of computation I to the projects in the content, making possible to the professor have a direct and closely contact with the student, and do also, in time, some observations, give orientation and ask the student about confuse issues that are inserted in his universe, in a teaching way, helping him to reach his goals.
- *Virtual space* (Moo) it can be reflected if the learning had been pleasing and if the moments was rich, through the students participation in the conferences and bugs room, reflecting specially the contributions and cooperation grade in the resolution of problems, and also the quality and pertinence of his suggestions.

Considerations

The inter activity, the co-operative work, the not linearity and the learning through projects that are inserted in student's context are tools that make possible to professors and students a enormous range of situations for the formative evaluation. In this way we work harder than in conventional methods, however it makes possible the analysis of the data, gotten in a qualitative form, and also the student's vision and his learning in different moments and activities.

The Computation I subject is being developed in a public teaching institution, like a pilot-project, involving in a first moment, a small universe of students. In this way, there is the necessity of an addition evaluation instrument, to make possible to the student a single and individual moment of reflection about the learned concepts and its applicability, restructuring the knowledge and put it in a cognitive hierarchic form, to don't lose time. The addiction evaluation instrument had been created based on the Computation I Conceptual Map making possible to professors and students verify if had a restructuration of the knowledge, and, if it became confirmed, give to the student the opportunity to reflect about his own way of thinking and organizing his concepts, leading to the metacognicion.

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Educational Software Components of Tomorrow (ESCOT)

Jeremy Roschelle, Chris Digiano, Roy Pea
SRI International

Jim Kaput
University of Massachusetts, Dartmouth

jeremy @ unix.sri.com

Abstract: Prior research and development demonstrates that dynamic notations and multiply-linked representations can enable ordinary students to achieve extraordinary learning of scientific and mathematical concepts (Kaput, 1992). However, prior techniques for building such software have resulted in expensive, incompatible, and inflexible products (Roschelle & Kaput, 1996). The vast majority of educational software projects, many of which are funded by the public sector, show promising results in small tests but never reach a larger market (OTA, 1988; PCAST, 1997). How can sustainable and scalable production of high quality math and science software be achieved?

The Educational Software Components of Tomorrow (ESCOT) project is exploring one promising direction of innovation: assembling math education software from components rather than hand-crafting new programs or applications for each curricular need. Typical components include graphs, tables, simulations as well as tools for manipulating geometry and algebra. Using capabilities of the Java language and associated frameworks, it is possible to construct individual educational components so that non-technical authors can flexibly combine them, composing new activities and lessons.

One way to understand the potential of this approach is by analogy. Only a very few people can build their own stereo system by wiring together transistors and other components at the circuit level, but many people can assemble a stereo system to meet their needs by attaching cables to their preferred amplifier, receiver, disc player, turntable and speakers. The move to higher level components has created a much larger marketplace of compatible products that yield flexible arrangements for particular needs. Similarly, ESCOT is raising the level of components for educational software from the programming language level to the pedagogic/curricular level. In this paper, we report some of the early results from our testbed for developing interoperable components for middle school mathematics, as well as some of the difficult challenges that lie ahead.

Introduction

Systemic reform of K-12 mathematics education is now firmly under way, with reform-based curricular and pedagogical objectives that embody high national standards being implemented at increasing numbers of sites. The National Science Foundation (NSF) catalyzed these reforms by funding standards-based materials development. As intended, these ambitious materials development projects, most of which are reaching publication and implementation stage during the 1997-98 academic year, are now setting the pattern for reformed practice in all grade levels.NSF's investment in materials development not only instantiates the best thinking and research on student learning of mathematics, it also serves as the basis for widespread teacher development work and as a focus for systemic programmatic reform across the nation:statewide, urban, local, and rural.

This remarkably productive national materials development effort did not involve substantial technology, for three reasons: (1) neither practitioners nor facilities embodied sufficient capacity to support everyday technology use by mainstream teachers; (2) consequently, materials requiring substantial technology use could not be commercially viable; and (3) the innovative software products resulting from NSF research lacked interoperability, and thus could not accumulate, integrate, or scale to meet the needs of reformed practice. The net result is that the powerful curricular materials foundation for reform lacks a technological

parallel, despite the wealth of research showing that technology can be a powerful catalyst for reform (see review in SPA, 1997).

The Educational Software Components of Tomorrow Project (ESCOT) is a response to this technological shortfall, beginning with a middle school mathematics testbed and creating a basis for a more extended response spanning all school mathematics and science.Our approach builds on the concept of an "Educational Object Economy" (EOE) (Spohrer, 1997), which combines a digital library of reusable, interoperable software resources with a knowledge network that facilitates distributed, collaborative effort to improve the quality and quantity of resources. By "reusable," we mean that the software can be adapted without the help of the original developers to meet unforeseen needs (Basset, 1996). By "interoperable," we mean that software modules can be mixed and matched (Orfali, Harkey, & Edwards, 1996) to provide more flexible support for learning than can be provided by one module alone. By a "knowledge network," we mean a diverse Internet-based community of experts-- teachers, researchers, developers, and others-- that self-organizes to publish, share, find, critique, and improve software resources and associated materials such as activities and assessment rubrics.

The ESCOT hypothesis is that a knowledge network & digital library of components for K-12 math and science learning can lead to a much more sustainable and scalable approach to developing educational software (Roschelle, Kaput, Stroup & Kahn, 1998). Our grounding for this argument builds upon economic analysis of the potential of reusable software & widespread networking to introduce new business models. In particular, reusable software can lead to a supply chain is longer, more modularized, and more differentiated, which in turn, presages much greater productivity for educational authors (Baetjer, 1998). In addition, the Internet enables the creation of knowledge networks by supporting the formation of communities that share expertise and exchange "objects" (software modules and contextualizing information) at extremely low transaction cost, resulting in "increasing returns" (Hagel & Armstrong, 1997). Under these conditions, economists argue, a "network economy" can emerge and provide exponential growth with only linear initial costs (McKnight & Bailey, 1997).

We are exploring these hypothesis through a testbed of shared software components for middle school mathematics and a community of developers, curriculum experts, authors, and web facilitators. In this article, we report on early progress ESCOT is making in three areas:

1. Interoperability: enabling modules for graphing, geometry, and simulation to be incorporated into a single activity document, and used as one composite tool.
2. Mapping Curriculum & Technology: constructing a database of the technology needs of 5 modern curricula for middle school mathematics, and a related database of existing technologies that meet those needs.
3. Integration Teams: developing an approach to composing classroom lessons that relies on short-term, focussed teams comprised of a master teacher, software developer, and web facilitator.

Interoperability

Our ESCOT testbed initially includes three anchor technologies, as shown in Table 1 below.

Table 1: ESCOT Anchor Technologies

Technology	Description
SimCalc http://www.simcalc.umassd.edu/	dynamic graphing and animation tools for understanding calculus ideas
Java Sketchpad http://www.keypress.com/sketchpad/java_gsp/	dynamic geometry, based on the top-selling "Geometer's Sketchpad"
AgentSheets http://www.cs.colorado.edu/~l3d/systems/agentsheets	student and teacher constructable simulations

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Each of these tools was previously a stand-alone application in a low-level programming language such as C++ or Lisp, with very limited capabilities to coordinate with other tools in the context of a classroom lesson. Prior to ESCOT, each independent author had developed a Java version of their software, opening the possibility of interoperability. Within ESCOT, we have begun to realize this possibility through three steps:

1. Adapting each component to the JavaBeans and InfoBus specifications. JavaSoft, the organization controlling Java technology, supports these specifications as generic mechanisms for components to shared data and coordinate behaviors.
2. Defining interfaces between components specific to middle school mathematics needs. In particular, we have defined interfaces for some of the mathematical data types that appear in middle school mathematics curriculum, such as a measurement, a time-series of measurements, and a continuous mathematical function. In addition, we have defined some interfaces for pedagogical control of the display, for example, selectively hiding information from the student, and gradually revealing it. These interfaces allow separate components act as linked representations of the same mathematical object, and support dynamic updating as the mathematical object changes.
3. Creating an prototype authoring tool, the MathKit Designer, that allows a non-technical author to choose a combination of components from a set of templates, customize those to the needs of a particular lesson, and publish the combination as a new "applet" on a web page.

The results have been successful; we can now combine these components into a single applet, where they act as if they were a single educational tool tuned to the needs of a particular lesson. For example, Figure 1 shows a tool for exploring the relationship of the area of a circle and a square. This tool combines two separate components, the sketchpad component (from Key Curriculum Press) and the table component (from SRI International). The data in these components is interlinked: as a student drags a red hotspot in the sketch, the geometric figure changes shape and the rightmost column of the data table updates its values. The table reports the area of the circle and the square, and their ratio, which not surprisingly, is always *pi*.

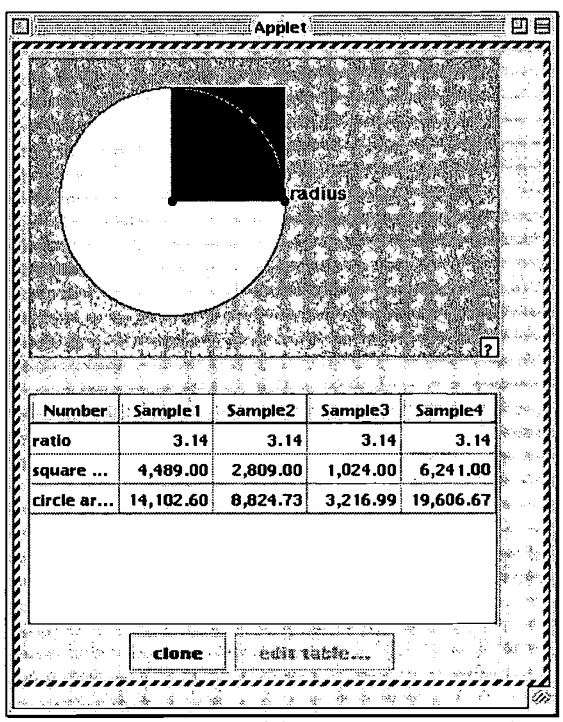

Figure 1: An activity comprised of the sketchpad and a table component

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Efforts at expanding interoperability are on-going. We have plans to add additional anchor technologies to our suite. For example, NIH Image, a powerful tool for measuring and analyzing digital images is available in open source version. We will attempt to adapt this version to ESCOT interfaces. In addition, we plan to expand the testbed through new volunteer members from other research projects which are developing complementary components such as the E-Slate project in Greece. We will also encourage contributors to the Educational Object Economy to use ESCOT components and interfaces. Interested developers and authors of middle school math software are invited to contact ESCOT for information on how to join the testbed.

Interoperability is a challenging problem with many dimensions, of which ESCOT is just addressing a few. Related and complementary efforts include the IMS Project, which is creating specifications for courseware authoring tools and repositories of components, and the IEEE Learning Technology Standards group, which is working on issues such as recording assessment information, linking to intelligent tutors, and defining an overall architecture for learning tools.

Mapping

Another crucial aspect of the ESCOT approach is coordinating the supply of components with the demand (needs) created by new curricula. In particular, we are addressing the needs of five NSF-supported curriculum projects in coordination with their associated implementation group, the Show-Me Center at the University of Missouri directed by Barbara Reys. The curriculum projects are:

- Connected Mathematics published by Dale Seymour/Addison Wesley, development centered at Michigan State University.
- Mathematics in Context published by Encyclopaedia Britannica (under renegotiation), development centered at the University of Wisconsin-Madison.
- Middle School Math through Applications Project (MMAP) unpublished, development centered at the Institute for Research on Learning.
- Seeing and Thinking Mathematically published as MathScape by Creative Publications, development centered at the Education Development Center.
- Six Through Eight Mathematics (STEM) published by Houghton-Mifflin, development centered at Montana State University.

ESCOT is developing a database that describes each of the units in these curricula, and their technology needs. The database is searchable by grade level, conceptual strand, technology type, technology use, and technology functionality. For example, it is possible for a developer to identify all the units that involve graphing. From examining these units, the developer could identify the requirements of the actual curriculum, and use these as guidance in designing an effective graphing tool. Eventually the database will map from the curricular needs to existing software components. This will allow teachers to locate components useful for a particular lesson, and will allow developers to identify unmet needs by finding units with no technological support. (We expect a draft version of the database to be publically accessible by the time of the M/SET meeting. Contact the authors after March, 1999 for a URL.)

Our early explorations with this mapping database reveal an additional kind of information which needs to be mapped out: activity structures. In order to design effective components, developers need to know not just what representations will be used, but also how. For example, in a common activity structure, students have to match a target, given incomplete information. This activity structure requires that the components have the capability to provide hide information about the target, and perhaps later reveal it, so the student can confirm their answer. We are working on ways to represent activity structures in future versions of the database.

Integration Teams

If the component interoperability and curriculum mapping objectives of ESCOT are successful, we will still need a process for pulling it all together: composing new activities and lessons that utilize components to

meet the needs of the curricula. Our approach emphasizes "integration teams" rather than authoring tools. In the past, software publishers sold authoring tools (e.g., Authorware, Director, HyperCard) with the expectation that teachers would use these to produce a wealth of lessons; indeed, some teachers did so, but far too few. The vast majority of teachers have too little time, more pressing responsibilities, and not enough technical expertise to become independent multimedia authors or programmers. Our experience suggests that it will be more practical for teachers to join short-term teams that include developers who have the necessary authoring and programming experience and Internet facilitators who can support the development of on-line conversations, Web pages, and student projects. Teachers could contribute their pedagogical experience, share the work of their students, and provide field testing opportunities (Kollock & Smith, 1996) while developers contribute programming experience and debugging capabilities. Such teams will be formed by shared interest, with limited short-term objectives, for example: (a) produce a set of Web pages to introduce the Pythagorean theorem using dynamic Java sketches, then (b) present student work afforded by these tools, and (c) offer discussion areas to assist teachers who use these materials.

ESCOT's integration team approach is being developed by members of the MathForum team (the MathForum is the leading web site of teaching resources for school mathematics). Teams will include master teachers who are involved with systemic reform initiatives, as well as ESCOT component developers. We plan to investigate the integration team approach by building on a successful precedent, the "Ask Dr. Math" and "Problem of the Week" features of the Math Forum. In "Ask Dr. Math," the behind-the-scenes team responds to student math questions with suggested strategies, resources, and ideas for further investigations. The "Problem of the Week" (POW) posts challenging materials from a variety of authors for use in teachers' classrooms. Students receive replies to both correct and incorrect responses to encourage them to rethink their work. At present, these areas of Math Forum contain only pictures and text. ESCOT integration teams will connect these to the middle school math curricula (from Objective 2) and extend these by adding Java component software from our testbed such as simulations, animations, dynamic graphs, interactive notations, and other cognitively and pedagogically appropriate supports for units from the curriculum projects.

Conclusion

According to recent large-scale research studies (Education Week, 1998; Wenglinsky, 1998), technology only has a large scale effect on student learning if it is used in appropriate ways. Simulation, visualization, and exploration top the list of appropriate ways to use software, and dynamic notations and linked representations are primary attributes of these uses. However, it is much more costly to author educational software with these features than it is to produce ineffective drill and practice and page turning applications.The component approach under development by ESCOT and other projects offer a technique for lowering the cost, increasing the reuse, reducing incompatibilities, and enhancing flexibility of educational software. In the future, we look forward to extending ESCOT to a broader range of grade levels, and to include science as well as math.

ESCOT, even if it is completely successful, will only provide solutions at one level of the overall problem of enhancing the sustainability and scaleability of educational software development. Related efforts such as the Educational Object Economy are addressing related issues of community growth, intellectual property licensing and auditing, and integration of commercial and freeware marketplaces. At a lower level, companies such as Sun/JavaSoft are producing basic platform facilities that support componentware. And at a higher level, efforts such as the IMS Project and the IEEE Learning Standards Group are working towards general-purpose specifications for sharing educational objects. All these efforts will need to converge for a new educational component marketplace to emerge and thrive. Should this convergence occur, we can anticipate better quality math and science education software at much lower costs of development.

Acknowledgements

Many ESCOT partners contributed to the work reported in this article. We thank Dave Barnes, Alex Repenning, Nick Jackiw, Steve Wiemar, and Mark Chung in particular for their efforts. The work reported in this article was partially supported by the National Science Foundation's Knowledge and Distributed Intelligence (KDI) Program, Award REC-9804930. The opinions expressed are those of the authors, and may not reflect those of the funding agency.

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New Approaches to Sharing Mathematics and Science Databases

Len Simutis, Director
Eisenhower National Clearinghouse
For Mathematics and Science Education
The Ohio State University
USA
email: len@enc.org

Abstract: Prior to the emergence of the World Wide Web, descriptions of mathematics and science education resources were almost always stored in one of two formats: as structured records in databases with defined fields to describe the resources, or in structured lists, such as those used for digests or bibliographies. In both instances, there was a defined pattern or structure to the descriptions that allowed for retrieval of the information using traditional search schemes for databases, or as a formatting aid to visually scan information in list form. When the World Wide Web emerged, it appeared that structured databases had been superceded by the combination of browsing from a set of briefly-annotated links, or searching the universe of web resources from indexes built from millions of web pages. For the user, however, searching the web has been frustrating and unrewarding, particularly as the number and range of web resources have grown. Fortunately, a new database tools and descriptors have been developed to makc web search engines more effective. This paper describes these new tools, including metatagging schema adapted for use in mathematics and science education. The paper also describes emerging collaborative efforts for searches across distributed web resources to help deal with qualitative issues concerning the accuracy and appropriateness of materials for particular educational audiences and uses.

Searching the web: the current situation

The current situation for searching the World Wide Web for specific resources is not a happy one. Each person has their own favorite example of the frustrations for searching for relevant resources on the web. Six months ago, mine was to pick any of the major search engines and try to find resources to help a middle school teacher deal more effectively with equity issues in teaching mathematics. So the teacher enters "middle school mathematics equity" in the search engine window, and discovers that the list displayed includes links to pages on home mortgages near the top of the list. Recently, the situation has improved with many search engines, so that among the 25million hits returned from such a search, less than 10% have to do with mortgages or finance, and they no longer appear near the top of the list. No doubt the search engines are weighting the results based on commonality of terms in the search, with educational terms given precedence to investment or finance in this instance. Still, no one can seriously consider reviewing even more than the first 100 or so results without getting tired or dismayed by the range of resources identified. Following even these 100 links will consume considerable time, and not necessarily identify materials of immediate interest.

But what if the teacher wished to be more specific, such as 7th grade geometry concepts dealing with female gender equity issues? With a more specific search, the results are even less on target, generating returns on the first page of the result list on women's sports equity and faculty pay issues along with help wanted ads in Nebraska and a Virginia court case. Many search engines now display a hierarchical browse structure above the list of web sites in the result set with active links. An example of these hierarchical browse structures is depicted in Figure 1. The purpose of the browse structure is to help the user locate resources which may more specifically address the search terms. By inspection, however, one will see that there are a variety of paths to follow, but none which overlap the three key areas--grade level (7th), subject matter (geometry) and issue (gender equity. Many of the topics are unrelated to the search, such as Social sciences > Women's studies, and Business > Gender diversity training. Of particular interest is to note how the

Directory Topics Jump to > Web Search Results - Search Box

Sports > Sports > Gender equity in sports
Women > Education & careers > Gender equity in education
Cultures & lifestyles >
--Gender equity --Women's political issues

Education > K-12 > K-12 schools > Middle schools > Middle schools in North America
Science & nature > Mathematics > Geometry
Social sciences > Women's studies
Education problems & issues > Equity issues
Family > Kids > At school > Math > Geometry for kids
Business > At work > Training > Gender diversity training

Figure 1: browse structure returned with search for "7th grade geometry gender equity."

subject matter--geometry-- has been embedded in the browse structure Science & nature > Mathematics > Geometry. How are these browse structures created? In one of two ways--brute force classification by the cyber equivalent of library catalogers who assign attributes classifying various sites by subject or keyword, and/or by machine analysis of text to derive subject or topical attributes. In essence, additional subject or keyword terms are added to the terms indexed for the site to assure that the site will be retrieved in the browse structure. Why must this be done? Because a web site may have materials of interest concerning the topic of gender equity, but the terms may not appear explicitly at the site, and so would not show up in the list of terms gathered by the search engine indexing schemes. The search retrieval software is thus augmented to first search the terms created by the search engine's catalogers, then the indexed pages themselves.

The search engine developers--from Yahoo to Lycos to Inktomi--have now spun into diversified for-profit ventures with a variety of information products and services. Netscape and Yahoo, for example, display the hierarchical browse structures for major search categories on their home page. While education is one of the launch points, it is increasingly surrounded by searches for commercial goods and services that can generate advertising revenue (and pay fees to rise higher on the retrieval lists from searches). One can expect that more time will be spent classifying commercial sites over educational sites given the increased opportunities for revenue--a logical, though not very beneficial decision for educators and the students and parents they serve. Ideally, it is in the best interest of those who produce the information to provide the subjects and keywords which most beneficially describe a company's or organization's web resources, and not rely on others to do so. As will be seen later, software tools are being developed to accomplish this desirable objective. But first, a look at structured databases, and whether they have similar limitations from the user's perspectives.

Structured databases from a user's perspective

The most familiar front-end to structured information databases is now the online library catalog. In this environment, one can search bibliographic records by author, title or subject using preformatted search screens provided by the software vendor. Since there are a variety of vendors, with software that emphasize particular retrieval and display features, the user often has to deal with learning different software to use multiple systems. Librarians have recognized this dilemma for some time, and have developed the Z39.50 protocol to allow a single search front-end to retrieve bibliographic records from multiple databases. Thus, if a library has Z39.50 compatible software, one could search multiple distributed catalogs with a single search by title or author. The Z39.50 protocol addresses many important issues for the user searching bibliographic databases, but it falls short of dealing with the complexities of full-text documents in electronic format on the web precisely because bibliographic records are highly

structured--basically they take the same form and are displayed in the same format--author, title, publisher etc.--while electronic documents are considerably less structured. There is no consistent format, for example, for curriculum materials or lesson plans in electronic format comparable to formats consistently applied to bibliographic records.

What is the current situation for searching for curriculum materials, lesson plans or other educational resources within structured databases? Using the "7th grade geometry gender equity" example, the user must currently conduct searches using unique search and display interfaces developed by various information providers. So, for example, a user could visit the Eisenhower National Clearinghouse and search using the Resource Finder provided there, or search the AskERIC database using a variety of search and display interfaces, or visit the Math Forum at Swarthmore and search their database. Each of these databases has similar, though not overlapping content in most instances, but the way in which the information is searched and displayed varies considerably. From a user's perspective, they would like a single result set that would satisfy the search criteria, and not have to visit (at least) three different sites to gather appropriate and useful information. It would be helpful if the Z39.50 protocol could be of assistance in this situation, but unfortunately, the protocol is not easily extensible in its current form to deal with the extended records that make up databases such as ENC and the Math Forum. ENC, for example, includes the entire table of contents for materials, as well as information on audience, standards, and grade level, none of which are included in the Z39.50 protocol. The Math Forum, AskERIC, ENC and dozens of other databases devoted to curriculum materials or other educational resources go well beyond traditional bibliographic formats in order to provide more immediate and useful information for teachers and others.

Often, a deterrent to the use of structured data accessible via the web is the presentation of a separate search interface, particularly one which attempts to take advantage of the ability to make complex searches from a rich, large database. For most web users, a search engine is a one-line interface used to type in a few keywords. It is not one that involves pull-down menus, browse lists of subjects or keywords, or the ability to construct Boolean searches. Compare for example, the main search page at Yahoo, www.yahoo.com along with the associated browse list structure, with the advanced search page for the ENC Resource Finder, watt.enc.org/main2.html. The former is a familiar front-end to a search page, either for web-wide searches for searches of individual sites--see for example, ENC's site search page: enc.org/rf/nf_index.htm#site. This simple format invites a brief listing of terms of interest, but leads, as discussed earlier, to a large number of returned hits, many of which may be irrelevant or inappropriate. The latter front-end to the ENC database of curriculum resources provides sophisticated features and increased likelihood for retrieving relevant resources, but it is often daunting to many web users. One alternative interface for those who use the web is to create a browse structure for retrieving records from a structured database--see, for example, watt.enc.org/cgi-bin/tree0.pl but the tradeoff is reduced functionality for constructing precise searches.

New developments to improve search capabilities

We know enough firsthand about the shortcomings of current approaches to searching the web--albeit with acknowledgment for the tremendous increase in information discovery capability over the last five years. What does the future hold for addressing some of the problems identified above in searching web pages and structured databases to address the increasingly sophisticated, yet time-sensitive needs of education users? One of the first developments to address these problems has been in the works for several years, and can be described under the general heading of metadata. Metadata is analogous to data definitions for fielded data sets. Thus, author, title, document type, media are all carefully defined, and those who adopt the metadata agree to follow the data definitions. For the domain of instructional and other educational resources, the Dublin Core metadata standards are particularly useful and appropriate. The Dublin Core grew out of decades of experience by librarians developing and using the MARC format for cataloging library resources. The Dublin Core was developed under the leadership of the Online Computer Library Center in Dublin, Ohio. The Dublin Core essentially creates a framework for developing a catalog of electronic resources. Information concerning the Dublin Core can be found at purl.org/DC. Using extensions to the Dublin Core, metadata tags can be created in web documents and databases so that standard descriptors such as subject, grade level, instructional methods, and standards can be employed in a consistent fashion.

The second technical development is the next generation of web document markup language, called XML. XML is designed to replace HTML with a considerable number of new features and enhancements. Like the Dublin Core, XML is based upon years of previous research and application in the development and use of SGML, originally developed by IBM. Detailed information on the XML standard can be found at www.w3.org/XML. XML uses Document Type Definitions (DTD) derived from SGML to allow for web documents to be consistently encoded with metadata. Thus, a teacher who has created a lesson plan for a science class would use XML to encode metadata describing subject, grade level, equipment required, method of assessment, duration of the lesson etc. Once encoded, a search engine could be programmed to read the encoded data fields and assign higher weights or specific categories when conducting searches. So, a metatag such as grade level would include the numeric entries for the appropriate grade or grades, and the search engine would then be able to return meaningful results even if the text of the lesson plan itself did not refer to grade level.

The third technical development to improve search capabilities is RDF, or Resource Description Framework. RDF is basically an agreed-upon schema for describing electronic resources that can be used by search engines and other programs to parse the metadata included in XML electronic documents as described and adopted by particular communities of users. RDF makes is possible for a search engine to know that the metatag "grade" may have specific meanings for different audiences that make use metadata. For example, "grade" in an educators' schema will be different from "grade" used by civil engineers or diamond merchants. RDF allows for communities to develop agreed-upon meaning and syntax for metadata that is appropriate for the intended users. Metadata, XML and RDF will work together to provide the document preparation and processing environment to return more meaningful results from search engines.

Although XML and RDF are not yet implemented in commercial browsers or search engines, efforts are underway to build metadata structures that will take full advantage of these capabilities as they become available. One project which incorporates many of the desired characteristics is GEM, the Gateway to Educational Materials, funded by the U. S. Department of Education and led by Syracuse University. GEM takes elements developed in the Dublin Core and provides extensions to more fully describe educational resources. Vocabulary for the various metadata fields is derived from ERIC descriptors, the Eisenhower National Clearinghouse (ENC), and through the work of GEM taskforces to develop consistent document descriptions. Organizations who contribute resources to the GEM virtual collection agree to adopt GEM metadata protocols. In the case of ENC, for example, its entire collection of over 11,000 detailed descriptions of math and science curriculum resources was exported from its current database with GEM metadata. Others will create new GEM descriptions using GEM cataloging software or by direct inclusion into tag fields in HTML files. Currently the GEM Consortium is composed of 40 organizations that have contributed approximately 3,000 resource descriptions to the GEM collection. Growth of such a consortium requires additional institutional commitment of educational resources, and the time and training necessary to employ the GEM metadata schema, but momentum is certainly in favor of continued growth, given the long-term advantages for educational users. A similar effort is underway with the sponsorship of EDUCAUSE for the development of metadata for use with college and university resources. Information about this metadata schema, called the Instructional Management System (IMS) is available at www.imsproject.org.

In order to take advantage of the benefits of metadata, it is not essential that all metadata elements in a particular schema are used. For example, a particular developer of educational materials may choose to only include a subset of metadata tags; but as long as this subset is encoded following established schema, then the search will be enhanced by their inclusion. Similarly, a developer may choose to use two or more schema in a particular document--one for educational materials, and perhaps one for commercial distribution and income flows. This is particularly likely to occur if commercial developers choose to use the IMF schema, since many of its features are tied to for-fee transactions. As various RDF schema are developed, it is essential that they be developed from a common "core" of appropriate metadata for the discipline or field, just as the Dublin Core has emerged for educational and research resources in electronic format. It is obvious that the various schema must be developed in concert, and that communities of interest must engage seriously and openly in developing metadata that will be useful and accurate for the resources created by and for the community.

One of the major impediments to the use of metadata is arriving at agreements concerning the vocabulary to be used consistently in the metadata fields. Some are at the nuisance level: is it "computer-based" instruction, or "computer-assisted" instruction? Others are far more critical, particularly in the development of subject matter hierarchies that describe subject domains. Some terms may be tied to passing educational trends, others may the basis of fundamental debate in a discipline. All require consistent cataloging and periodic analysis to assure currency and accuracy. Just as authors prefer articles for journals using prescribed formats, it is likely that over time, the vocabulary and procedures for imbedding metadata in electronic resources will become a byproduct of document creation. But until that time arrives, a fair investment in time and training will be required for documents already on the web as well as those to be added in the future. This cataloging can be done by third parties with the necessary subject matter knowledge and expertise to describe the electronic documents to meet the metadata standards. In addition, organizations like GEM and IMS are already far along in development of cataloging tools to make this process more consistent and less costly. Organizations with large document collections may also choose to employ metadata so that documents for internal as well as external use are more effectively located. As more and more student projects and teaching materials are produced in electronic formats, metadata can be a useful way of archiving these resources as well for use on school intranets.

In effect, metadata is an effort to transform the web from being a very large collection of unstructured "flat" files and isolated database records that can only be searched with great difficulty, into a structured database environment with superior search and retrieval capabilities. It also is an effort to increase the likelihood that trusted and useful electronic resources will be made available by content providers and developers so that less time is spent wading through perhaps interesting but unrelated resources to find the few that are of interest. We are, for better or worse, still in the Paleolithic stage of the web, struggling to be hunters and gatherers of information as best we can, following paths defined by others, breaking twigs along the way, or at least creating bookmarks so that we won't be lost when we return. Metadata is a logical and necessary next step to increase our search and retrieval capabilities as the scale and scope of electronic information resources continue to grow quickly. The use of metadata and associated schema will make it possible for search engines to make more intelligent use of keywords entered into search screens, so that through analysis of these terms in the context of specific schema, the likelihood of retrieving relevant resources will be increased.

Qwhiz: An Interactive Tool For Math And Science Learning

Stephanie Smith
NASA Information Technology Office, NASA/JSC GT, Houston, TX 77058
Tel: 281-483-9626, Fax 281-483-9988, E-mail: slsmith@gothamcity.jsc.nasa.gov

The Qwhiz is a real-time, multi-player Web game for math or science teachers and students. Teachers can use this Internet technology to evaluate student learning and fulfill instructional technology teaching requirements by making Qwhiz a part of student activities. Students can take a Qwhiz against the computer or other students to study class materials, learn technology skills, and they can make Qwhizzes for others in this student centered learning environment. The Qwhiz is one of many tools available from the Learning Technologies Project which develops Internet technology tools, disseminates NASA mission and research data, and promotes academic excellence in math and science education.

Introduction

The Qwhiz is a real-time, interactive, multi-player Web game that incorporates resources from electronic and print resources. In practical use, it is a vehicle for teachers to learn and use new computer technologies, integrate the Internet into their classroom experience, evaluate student learning, and fulfill their instructional technology teaching requirement.

There are three parts to the Qwhiz technology; the Qwhiz, the QwhizMaker, and the QwhizMiner. The Qwhiz game consists of a matrix of question categories that are assigned point values. The object of the game is to answer as many questions correctly as possible. The QwhizMaker is a set of Web forms that create the gameboard matrix, the question categories and the question/answer sets for each question on the gameboard. The QwhizMiner searches, retrieves and formats Internet information to facilitate the creation of Qwhiz games. Taken together, these three components provide a teacher or student the tools to harvest Internet data, formulate test material, and present it in a novel and challenging manner. It is an integrated approach to inserting electronic resources into classroom curriculum for learning validation.

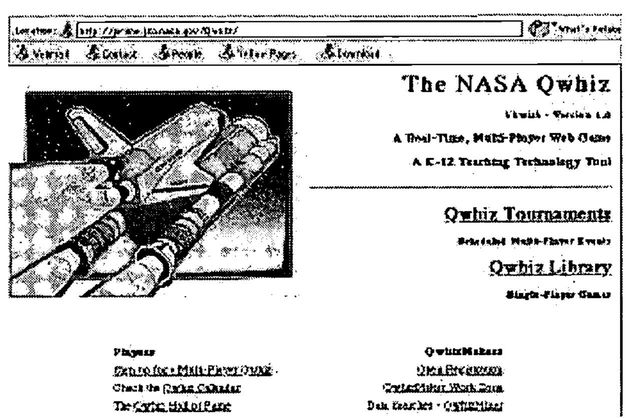


Figure 1: The Qwhiz Homepage

The Qwhiz Game

The object of the Qwhiz game is to answer as many questions correctly as possible. There are two ways you can play the Qwhiz; in single player mode or real-time, multi-player mode. In single player mode, you play

against the computer. In multi-player mode you play against an opponent at another computer with a timer to decide who answered the question first.

An individual playing against the computer selects a question within a category and has a fixed amount of time to provide a multiple choice, true/false, or short answer. If the player answers correctly in the allotted time, she retains control of the gameboard. If the question is answered incorrectly or the player runs out of time the computer gains control of the gameboard. Users can select from four categories in the Qwhiz Library: Fun, Kids, NASA, and Standards-Based. The "Fun" category is the place to go for trivia and Qwhizzes not aligned with standards, "Kid" Qwhizzes are made by kids, and "NASA" Qwhizzes are, naturally, about NASA. The "Standards-Based" collection contains Qwhizzes made by teachers that align to various educational standards.

When played in real-time mode, the Qwhiz is a contest between contestants at different computers and/or different locations. One player can play against another or two teams can play against each other. Players can sign on to their scheduled Qwhiz 30 minutes early and chat with their opponents and anyone can observe a multi-player game by logging into a tournament as "Audience". Qwhiz tournaments are generally scheduled on school days between 10:00am and 2:00pm CST to accommodate players in time zones across the United States. Once a Qwhiz tournament begins, players have between 10 and 60 seconds to answer a question. The length of time available to answer a question is set by whoever made the Qwhiz although in a multi-player game, the fastest players get the points. To equalize bandwidth differences, timers reside in the applet on each of the player's machines so each side has an equal opportunity to answer a question. Once answers are submitted, the central Qwhiz server logs response times, determines the fastest response and awards points.

The Qwhiz was designed with and works best with Netscape Navigator 3.01+. Your computer should have at least 16MB of RAM and a Java enabled browser. Qwhiz requires an Internet connection and the game will run over a 28K modem. If you're using a Mac, optimize the virtual memory setting at 40MB. If you're using a PC, Windows 95 will take care of it.

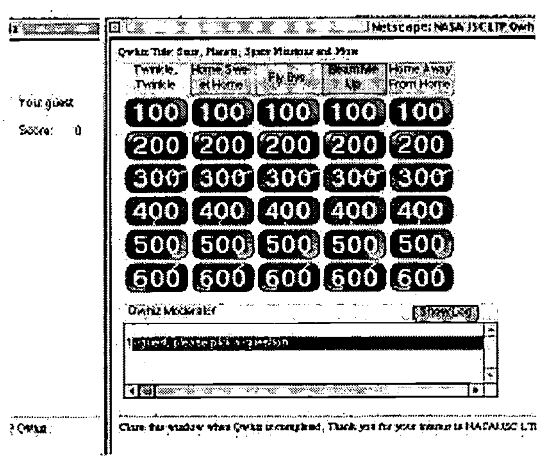


Figure 2: An example of a Qwhiz Gameboard

The QwhizMaker

Any user can make a Qwhiz by registering on the Qwhiz Homepage and creating a workspace on the Qwhiz server. Upon registration, a user may enter the Work Zone to create new Qwhizzes or edit, test, or submit Qwhizzes to the library and/or tournament areas. Creating or editing a Qwhiz is a series of gathering information and filling out a few Web forms.

QwhizMaker has two main activities; "Setup Qwhiz Board", and "Create Q&A". The "Setup Qwhiz Board" establishes the infrastructure of the gameboard itself. By filling in the "Setup Qwhiz Board" form, a Qwhiz receives it's structural attributes such as a title, objectives, standards, references and applicable

study materials. Authors specify the grade level of the Qwhiz, the categories for the gameboard, how many questions per category (1-6), and how many seconds a player gets to answer a question (10-60). Any and all of these fields can be modified at a later time to reflect new information. To save this structural information the user may select "Save Qwhiz Board" at any time. It is recommended that data be saved frequently.

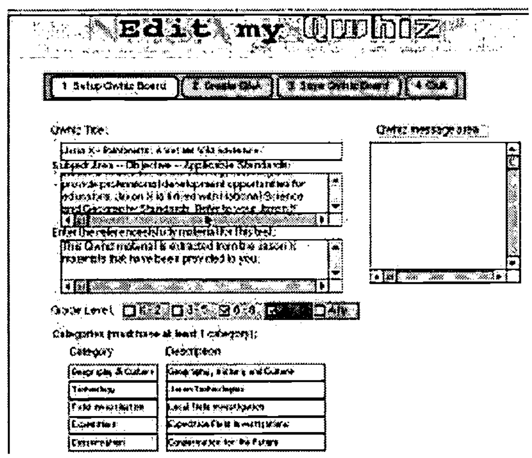


Figure 3: Setup Qwhiz Board

To continue development of the individual gameboard cells, select "Create Q&A" from the top of the Edit page menu bar.

Once "Create Q&A" is selected, the gameboard specified in the "Setup Qwhiz Board" will appear with the designated categories and point values for the number of questions requested. To complete the Qwhiz, each cell in the matrix must be filled in with a question/answer pair. To create a question/answer cell, click on a point value within the matrix and fill in the question form that appears below the gameboard. The actual content of Qwhiz questions and answers is drawn from printed resources from the classroom or electronic resources on the Internet. The Qwhiz site provides a specialized data miner to search for Internet information and position it within the QwhizMaker which will be discussed in the QwhizMiner section of this paper. Entries on the question form include the question itself which can be multiple choice, true/false, or short answer, plus image or audio clips that supplement the question at hand. After completing the question/answer information, the user must select "Done" to save the individual question and also select "Save Qwhiz Board" from the top menu bar to save the entire Qwhiz. Again, it is recommended that users save data frequently by selecting "Save Qwhiz Board".

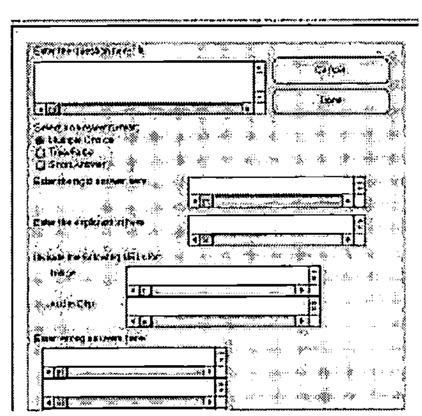


Figure 4: Creating Qwhiz Question/Answer Pairs

The QwhizMiner

The QwhizMiner was designed to provide a onboard tool to collect and integrate electronic data into Qwhizzes. To collect information, users can perform a search on a local collection of NASA documents, browse the Web via a subject listing of links, browse saved personal data, visit a specific URL or review K-12 educational standards that are available on the Web. To integrate the data from these electronic sources into a Qwhiz, choose the "Start" option under "Make a Qwhiz". This activates various options such as "Make a Question", "Capture Image", "Capture Audio" and "Make Qwhiz".

Searching the local collection of NASA documents is a quick way to find the resources NASA has on a particular topic. This NASA "K-12 Resources" collection is automatically presented in the top frame when the QwhizMiner page is loaded or can be accessed by clicking "Miner Search". "K-12 Resources" is a collection of nasa.gov Web documents that is spidered on a regular basis. This and any document collection is indexed with a frequency algorithm and then a statistical matching algorithm to ensure that relevant documents surface when a search is conducted. Search results are presented as a summary list in the top window with the option to link to the document and view it in the lower window.

A good way to use the QwhizMiner is this series of actions; run a Miner Search, review documents in the summary list, and view individual documents as appropriate. To pull data from individual documents into the Qwhiz; select "Start" under Make a Qwhiz, then select "Make Question" and cut and paste information from the document into the question form. Remember, to perform an action within the "Make a Qwhiz" section you must be a registered Qwhiz user. This sequence works with the other information gathering links; "Browse WWW", "Browse My Stuff" and "Go To URL".

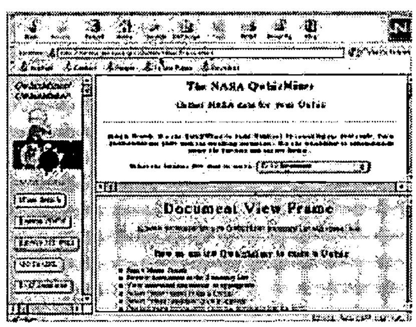


Figure 5: The QwhizMiner

Conclusion

We have yet to meet a player who does not instinctively know how to play the Qwhiz, however, the art of making a good, standards-based Qwhiz appears to be a learned skill. Our work with teachers who make Qwhizzes has provided some lessons learned in functionality and interface design. Additional Qwhiz features may include user customized data collections within the QwhizMiner and locally saved Qwhizzes.

The Qwhiz is an Internet tool that can be used to learn and reinforce information in an engaging and fun way. Teachers can prepare Qwhizzes for students to provide learning validation exercises and technology instruction or students can make Qwhizzes for each other for the same reasons. While the Qwhiz was created to support math and science instruction and the dissemination of NASA resources in these areas, Qwhizzes can be created about any topic of interest.

The Qwhiz is one Internet technology offered by NASA's Learning Technologies Project (LTP). The LTP is dedicated to promoting educational excellence in science and math education, disseminating NASA

mission and research data, and advancing the use of Internet technology in the classroom. The program has over 50 products available to the public and almost all of them are free to the public. The LTP welcomes educator contributions and feedback and strives to provide relevant technologies to the education community.

To follow up on the information presented here or to learn more about other Learning Technologies Project activities please visit http://prime.jsc.nasa.gov or http://learn.ivv.nasa.gov

A Systematic Tool for Developing Math, Science and Computer Science Course Web sites

Lon Smith, Ph.D.
Department of Computer Science
Northeast Louisiana University, U.S.A.
smith@cs.nlu.edu

Troy Kammerdiener, Ph.D.
Department of Computer Science
Northeast Louisiana University, U.S.A.
tkammerd@cs.nlu.edu

Abstract: Traditional classroom materials have always been presented in a consistent format. Yet, this is not always true on the net. AutoHTML is a tool that, unlike commercial web authoring tools, allows the instructor to work from a framework to develop web pages that present information in a consistent manner. This system requires little HTML knowledge with changes to the web page being done in a simple check box and fill-in-the-blanks format. AutoHTML is a academic web authoring tool developed to promote web based presentation of classroom material to the level of traditional information paths.

Introduction

As the Internet becomes a greater part of the typical math, science and computer science classroom environment, the desire increases for all instructors, regardless of web authoring ability, to provide distance access to classroom materials. These materials may include assignments, lecture notes, demos and many other such materials that historically have only been disseminated by hand. Typically, the only instructors who have been able to provide their students with these materials over the Internet have been those with strong HTML backgrounds. The creation of a tool that aides in the posting of this information, in itself, is useful (which is evident with the popularity of such software as FrontPage and PageMill). However, a tool that, regardless of user ability, promotes a consistent look and feel across an entire course web site is both academically important and useful.

The AutoHTML system, a work-in-progress, is a web-based tool for authoring course web pages for math, science and computer science classes from standard templates. AutoHTML provides a mechanism for generating a consistent and intuitive framework for accessing classic classroom materials via the Internet. This tool provides a simple way for instructors to place the classroom materials and assignments on a course web site and present an intuitive framework from which students can access the information. This project focuses on the enforcement of consistency with regard to organization and presentation of an instructor's course materials and assignments. AutoHTML is designed not only for the placing of individual pieces of data on the course web site but instead, provides a means of packaging materials for an entire academic course in a dynamic way. Thus, as the class progresses, more materials are placed on the web site. This organization has two benefits: the students are not overwhelmed by a large collection of data at a single point and the instructor is allowed the ease and flexibility to add materials on an "as needed" basis. As with any tool, there is the desire to minimize its distractive effects, so that the class is not dominated by the utilization of the new tool, but rather attention is directed to the material it is designed to present. There are two major reasons for the promotion of a organized and consistent web site design. First, students are aware of where the material will be and how it is organized; this minimizes the students' effort in finding these new materials on the course web site. Second, with the utilization of AutoHTML, the instructor does not have to posses a high level of competency to place the materials in the appropriate location of the web site.

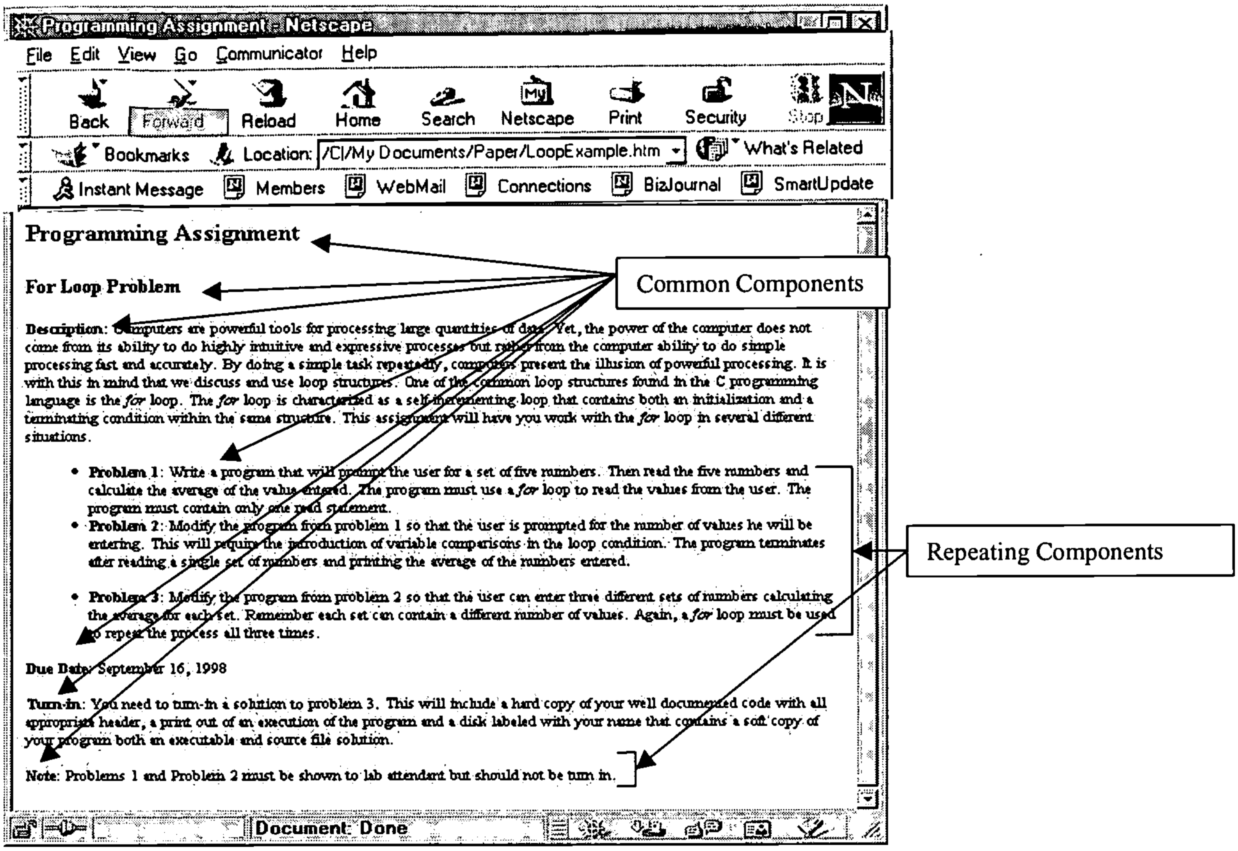


Figure 1: Simple Assignment

This paper will explain how, with the AutoHTML system, templates can be created. These templates will serve as a consistent baseline for the entire collection of web pages for a particular math, science or computer science course which might appear in a common web site. These templates are designed to allow an expert author the freedom to modify their HTML directly, while providing a complete novice with the ability to maintain web pages, which utilize polished HTML techniques. The focus of this project is to allow all types of authors the ability to work, at their own level, with a single tool that allows the individual to design course web sites. Methods of achieving this goal, through the use of AutoHTML, will be addressed. An example of a functioning system, currently in practice in a post secondary computer science course, will also be examined. With an understanding of the project and its applicability to the computer science classroom, a discussion will be made of the methodology and feasibility of incorporating the AutoHTML system into a math or science course web-site structure. Current implementations have been at the post-secondary level. However, the design of AutoHTML provides for utilization at all academic levels.

Course Web Pages Creation

AutoHTML was developed out of the observation that for generations teachers have used the same form for all classroom work. This was done for many reasons, both for student and instructor benefit. One student benefit is having a consistent framework to work from so that the likelihood of error due to test format is reduced. One benefit for the instructor is that a pattern, which works well, can be repeated. Yet on the web, a pattern may be laid down but only the most talented HTML authors are able to develop consistent web pages for student access. This unprofessional appearance leads to a diminished utilization of the Internet. AutoHTML begins by identifying common structures that will be present in all documents of a particular type, for example assignments, homework, quizzes etc. Then after common structures are identified, structures that are repeated are identified. These are structures that may be repeated an unknown number of times. A homework may have 15 question while another may have 6; yet, all fall into the same structure. In Figure 1, a simple example of a computer science assignment is given. These structures are identified as common and repeating items.

Several items are identified as common structures since these will be part of all assignments. A common structure is identified in the text of an HTML document by a section delimiter. AutoHTML can then use the sections for inclusion or duplication in any new assignment. The text for each section is marked as a merge field. AutoHTML generates a form with a simple, fill-in-the-blank format for changing the merge fields. The blank HTML page is used as a framework for all pages of a particular type of page. The blank template page is shown in Figure 2. There are three steps to using AutoHTML: 1) the creation of a template document, 2) the development of the sections and 3) the elaboration of merge fields.

The development of sections involves the selection of the number of sections you wish to have on your final page. For each section you have several choices: No Change, Delete, Ignore, Restore, Make Copies. The "No Change" command leaves a section unchanged. Later it will be shown how leaving a section does not mean two web pages look a like but that they will contain the same structure. "Delete" is used to permanently remove a section. This command will completely eliminate a section. "Ignore" masks a section from the browser and leaves the section on the page. If for some reason the user decides that the section would be useful, the user can restore that section to the page by using the "Restore" command. The "Make Copies" is the most powerful of the AutoHTML commands. The user can simply select the section and the number of copies of that section they wish to make. The example given in Figure 1 shows how the web page has several problem statements which are all alike in structure, though each is different in content. This is a key point to AutoHTML; sections define structure while merge fields define content. Of course, each assignment or homework is different. AutoHTML captures the structures that are similar between the documents are similar. An example of the section development step in AutoHTML is

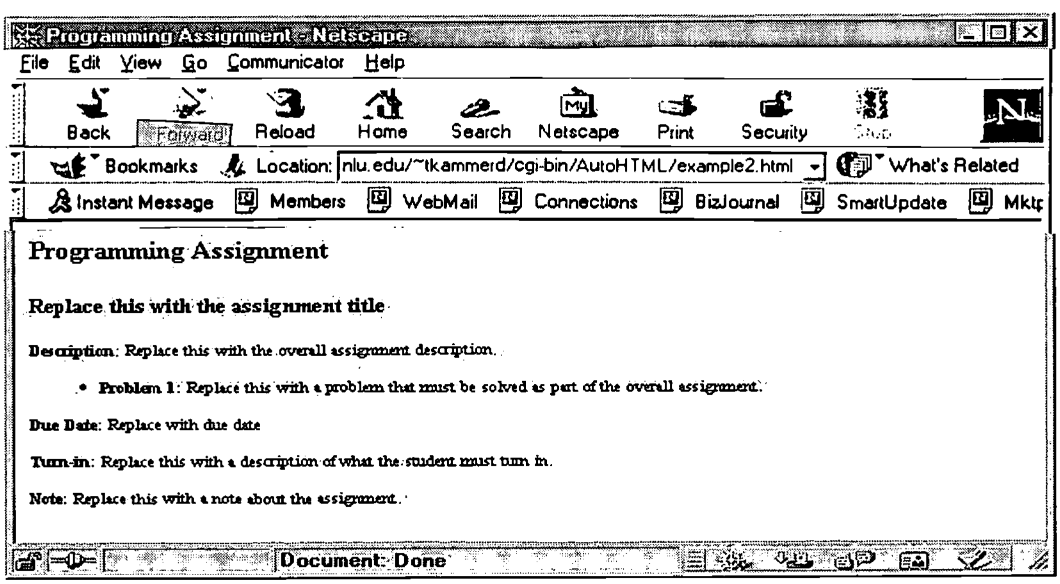
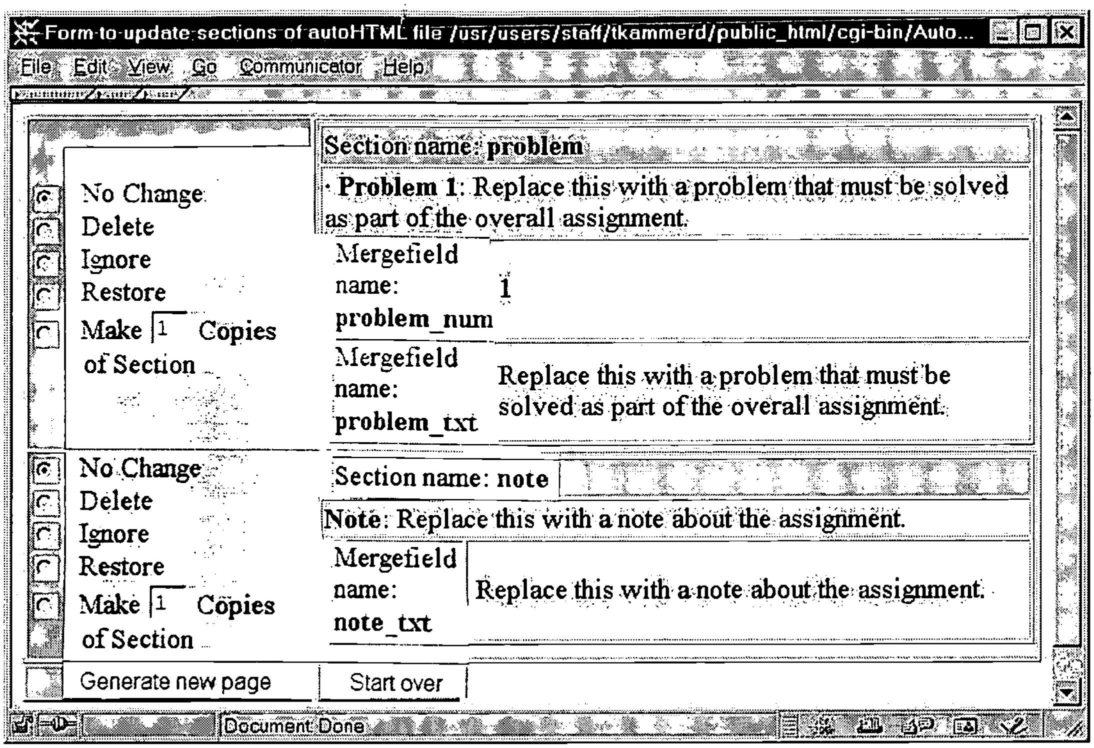


Figure 2: Blank Assignment Template



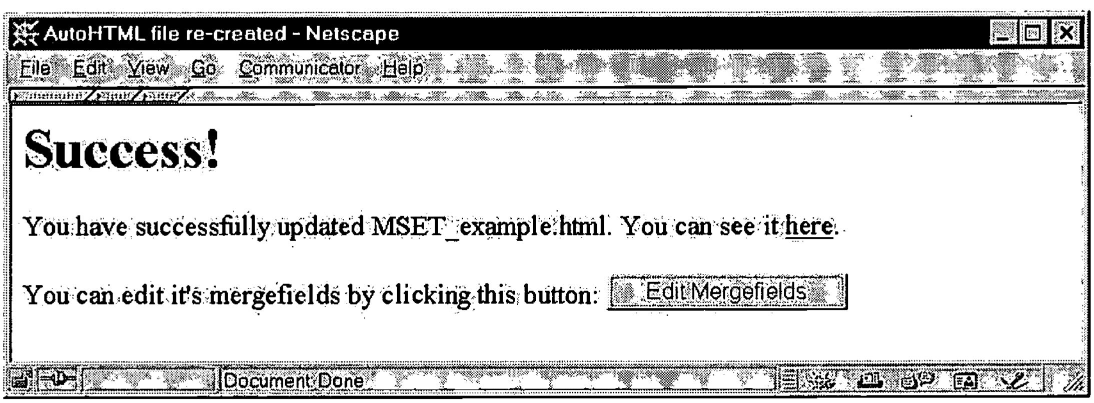


Figure 3: Section Development and Confirmation

presented in Figure 3.

The merge field step allows the user to place the content of a page. The user has already developed a framework in the section development. The elaboration of merge fields consists of entering the text that will be within each merge field. A merge field may be part of a section or a merge field may stand alone for text areas that can never be removed or duplicated. An example of a field that would never be removed would be a title. In Figure 4, there is an example of the merge field insertion. After the creation of the template, the section development step and merge field step can be done in any order and as many times as needed. It is best to view the document in a browser during the development process.

Consistent Course Web Pages

The development of AutoHTML evolved from observations of web pages presented to students in several disciplines. One observation was that it is necessary to develop consistent web presence for a course

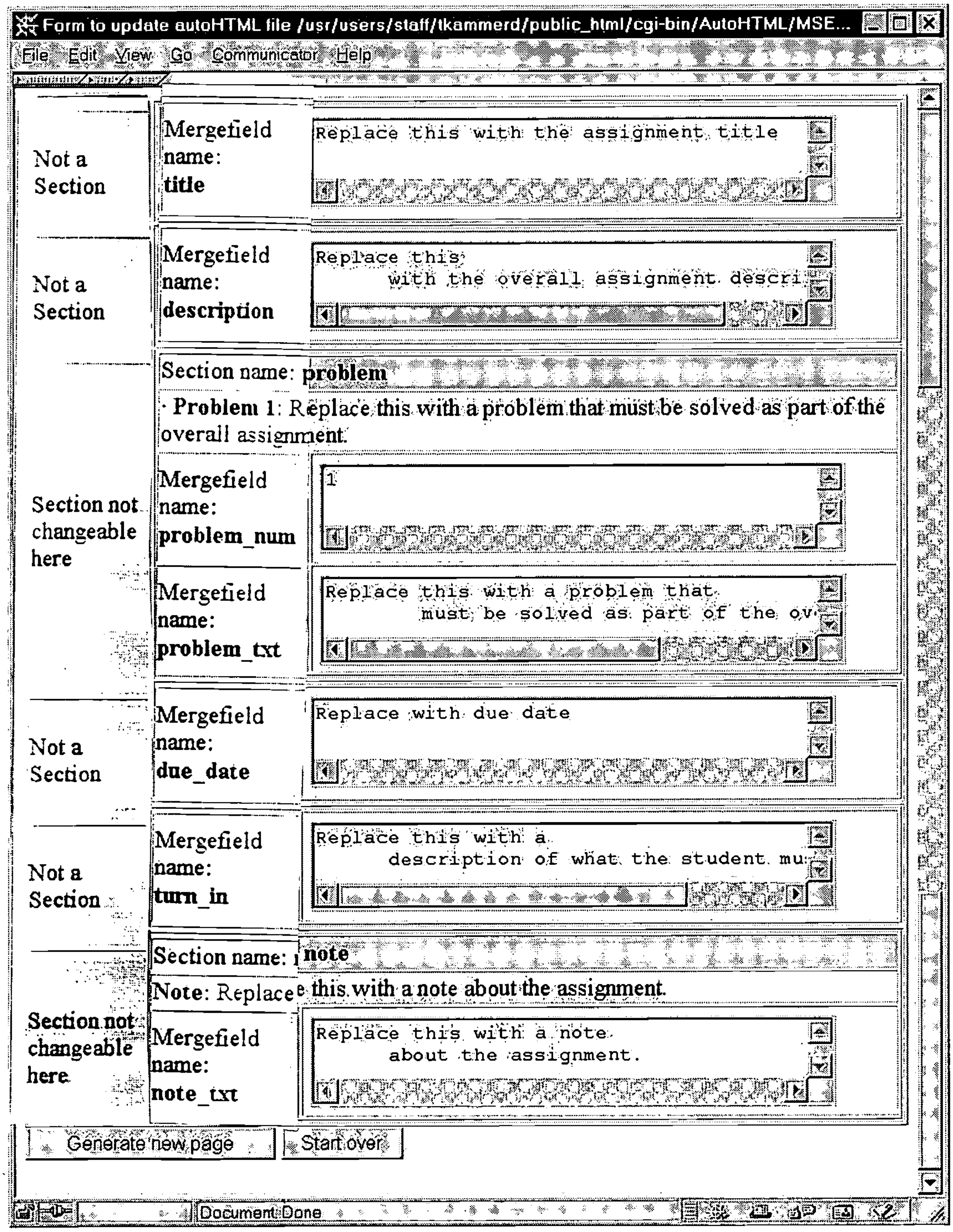


Figure 4: Elaboration of Merge Fields

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in order to present a professional look to the course on the web. Another observation is that student will not use the web if it involves excess effort to discover needed information. Students will prefer traditional information paths like classroom handouts if excess effort is involved in retrieving information from the net. Consistent web pages promote a reduction in student effort for information discovery. This is due to the fact that student have expectation of a format for all classroom materials. The instructors are less likely to use the web to present information if they feel that they are going to have to prepare the information twice. Yet, the advantage of using the web allow the instructor immediate placement of information. This will allow the instructor to present information faster than traditional paths of information dissemination. This is especially important in classroom environments where there is infrequent contact (like classes that meet once a week.) Another observation is that poor classroom pages tend to have one of two flaws. The page either contains all or most of all information for the class or the page contains little information on each page but contain excessive linkage. In either case the student has a hard time finding information and difficulty determining when the new information has been added to the page. This is generally due to a weakness in web authoring capabilities. This is not to say that all instructors have or should the time to develop strong web authoring capabilities, but that it is usually only the people with strong web authoring expertise who could develop and maintain classroom web sites that truly added to the classroom experience. A tool like AutoHTML makes it easy to develop consistent pages, and placing links to these new pages in a centralized location provides the student with a simple interface and a consistent presentation of any type of classroom web page.

Conclusion

This project is currently focused at providing a means of developing consistent web-based course materials for math, science and computer science. Future directions to be explored are that of applicability to other course topics and the development of AutoHTML to assist in the creation of distance learning course sites. With the utilization of AutoHTML, typical instructors can bring themselves and their classes to the Internet environment. It is hoped that with future development of AutoHTML, that these same instructors will be motivated to venture into the realm of developing distance education courses that are offered through the Internet.

Java Tutorial for Basic Computer Concepts

Joaquin Vila, Ph.D.
Department of Applied Computer Science
Illinois State University
United States
javila@ilstu.edu

Barbara Beccue, Ph.D.
Department of Applied Computer Science
Illinois State University
United States
bbeccue@ilstu.edu

Hetal Badeka
Department of Applied Computer Science
Illinois State University
United States

Abstract: This paper describes a web-based tutorial using Java to teach computer fundamentals to freshman and sophomore students in computer science programs. The tutorial covers the following topics: logic gates, parity detectors/generators, and conversion of numbers between various number systems. Students are encouraged to experiment with the simulation models included in the tutorial to test their understanding of the topics being presented. Students and teachers having an interest in learning or teaching these concepts will find this application useful.

Introduction

Learning the nature and interrelationships of computer architectures, hardware, operating systems, data types, programming languages, networks and communication are essential for the formation of information technologists (IT) and computer science (CS) professionals. For years, faculty members have relied on textbooks and assignments to cover and drill such concepts. However, some of the difficulties faced by the students in grasping these concepts is the limited scope of the assignments and the lack of opportune feedback. In order to strengthen students' understanding of these concepts, they need to have more immediate feedback when solving assignments than traditional textbooks and teaching methods can provide.

In order to provide students with a different type of learning environment, it was decided to develop a supplemental tool for teaching the required hardware and software concepts. Providing students easy and convenient access to the information both at school and at their place of residence was also an objective of the project. To meet these objectives, a web-based tutorial was designed and implemented in Java.

Contents of the Tutorial

The tutorial covers the following topics: logic gates, parity detectors/generators, and conversion of numbers between various number systems. When the user first enters the web-based tutorial, he/she sees an introductory section which describes the scope of the tutorial. In addition, information is supplied about each of the three major sections in a table of contents so that the user knows what information is included in the tutorial. The tutorial uses frames. The one on the left side of the web page provides navigation

options. Initially, the navigation options are the three major topics of the tutorial. Once the user selects one of the topics, it expands to show the subtopics that are available within that selection. The user can either choose to go to one of those or to select a different major topic. Each time a major topic is selected the previously selected major topic collapses and the current selection expands. Thus, the user has the option to navigate non-linearly throughout the tutorial at any time. When the user clicks on any of the subtopic links, the applet associated with the link is executed. Each applet displays on the right frame of the web page. The tutorial is very simple to use and needs no explanation. The user simply follows the directions on the tutorial for navigation.

Each major topic of the tutorial will be discussed in the following subsections. The subsections will give an overview of the functionality and scope of the topics covered.

Logic Gates

Logic gates are the fundamental building blocks of any computer. A logic gate executes a simple Boolean equation. The output of a logic gate is completely specified by its Boolean equation. A Boolean equation relates a binary output to 1 or more binary inputs according to the laws of Boolean algebra. Multiple logic gates are used in combination to construct more complex circuits such as an adder or a multiplexer. The section of the tutorial on logic gates shows the truth table for selected gates (such as AND, OR, NOT, EX-OR, EX-NOR), their symbol, Boolean equation, derivation and circuit diagram. Figure 1 shows a three input EX-NOR gate with its corresponding symbol, truth table, and circuit diagram.

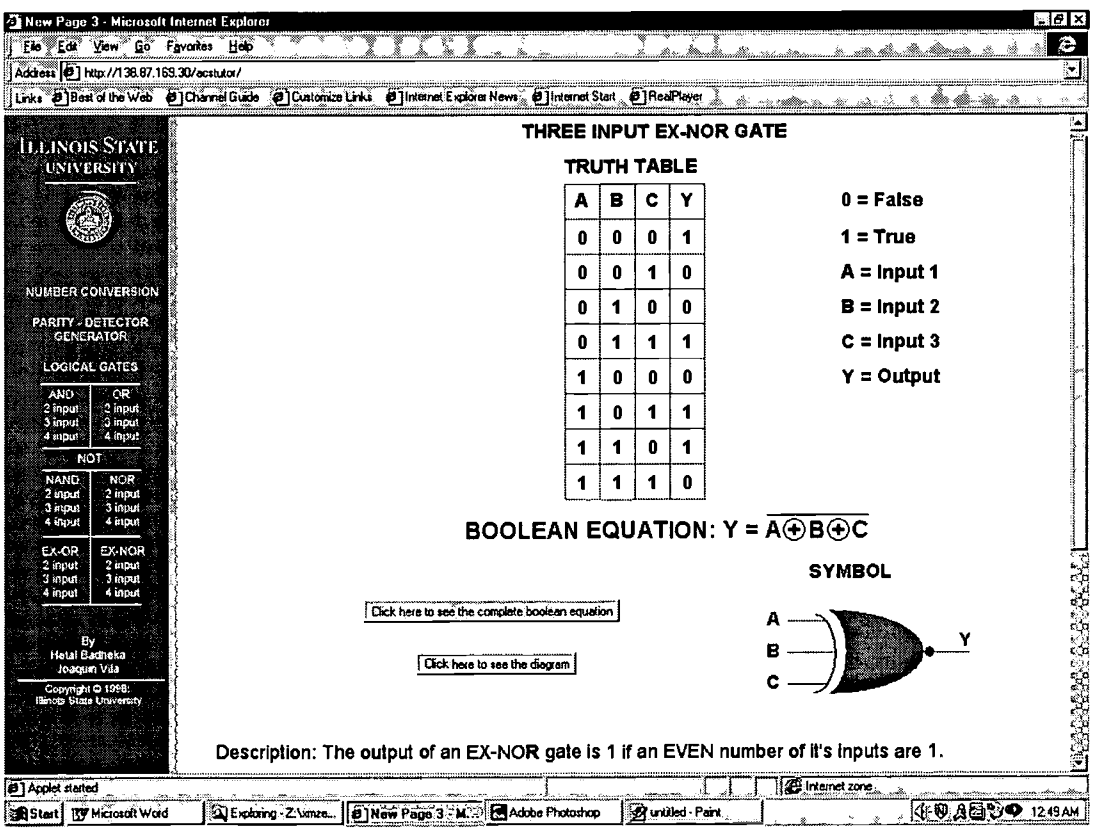

Figure 1: Three input EX-NOR gate.

Parity Generators/Detectors

Parity of a binary number is defined as the number of 1's in the number. It is used in detecting 1-bit errors that occur during data transmission. Parity of a binary number is even if it has an even number of 1's in it, and it is odd if it has an odd number of 1's in it. The receiver and the transmitter decide on the parity with which their data should be transmitted. If the parity of the received data is different from the transmitted parity, then an error has occurred during transmission.

A parity generator is a device that is used to generate a parity bit for a binary number. A parity bit is an extra bit that is appended to the end of the binary number to make the total number of 1's in the number either odd or even. If the input to an even parity generator has an odd number of 1's in it, it appends an extra 1 at the end of the number to make the total number of 1's even. Likewise, if the input to an odd parity generator has an even number of 1's in it, it appends an extra 1 to the end of the number to make the total number of 1's odd.

This tutorial shows the circuit diagram of commonly used odd and even parity generators. It allows the students to supply binary inputs at each of the 4 input gates of the odd or even generator and click a button to view the parity output. This gives the user an opportunity to learn the functions of every logic gate in the circuit without actually having to build the circuit in a lab.

A parity detector does the reverse function of a parity generator. Whereas, a parity generator is used at the transmitting end to append a parity bit to the data, a parity detector is used at the receiving end to check the incoming data and strip off the parity bit. A parity detector checks every byte of data arriving for parity. If the parity of the incoming number is supposed to be even, but it turns out to be odd, the parity detector raises an error signal. Likewise, if the parity of the incoming number is supposed to be odd, but it turns out to be even, the parity detector raises an error signal.

This tutorial also shows the circuit diagram of traditional odd and even parity detectors. It allows the students to apply binary inputs at each of the 4 data input gates and at the parity input gate of the circuit and click a button to see the error output of the circuit. The system tells the user whether the parity input supplied is right or wrong. The user can follow the path from the input to the output and see how the various inputs are combined to generate the output.

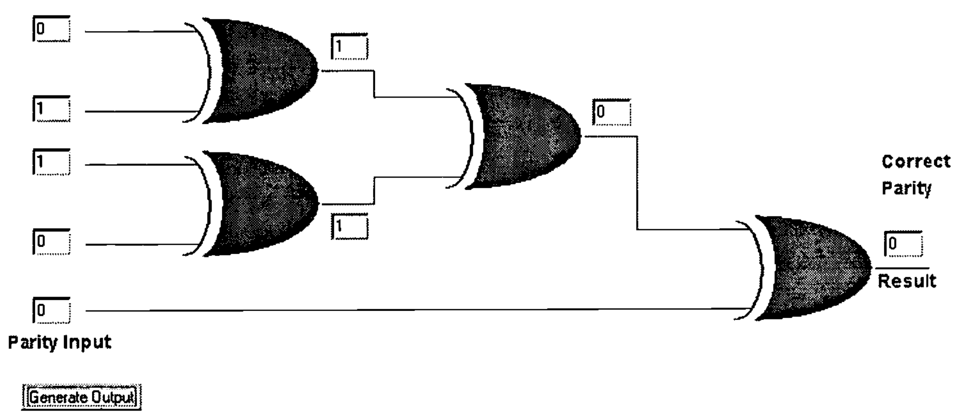

Figure 2: Parity Detector.

Number Conversion

In working with computers, different number systems are used. Students should have a good grasp on conversion between these various number systems. The tutorial includes a complete set of conversion applets. These include all possible conversion combinations among the four most commonly used number systems: binary, octal, decimal and hexadecimal.

Once the type of number conversion has been selected, the user will be asked to type in any arbitrary number, fractional or whole, that he/she wants to convert from the original number system to the target number system. The application will convert the number into the target number system and also display in detail each step involved in the conversion. Thus, unlike a calculator which just displays the result, this tutorial teaches the user each step involved in the number conversion process.

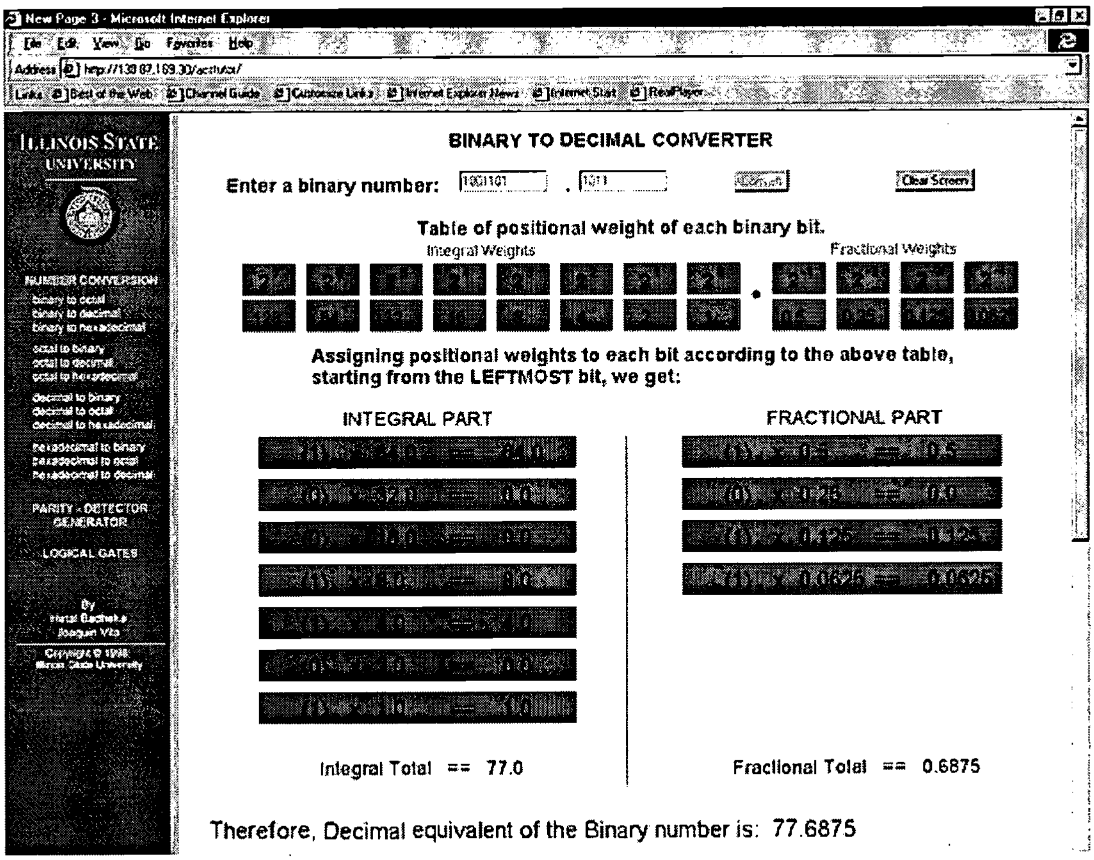

Figure 3: Number Conversion.

Technical Description

This tutorial exemplifies the capabilities of Java as a platform independent, internet enabled, object oriented programming language. It makes the tutorial accessible to anyone having an internet connection. It is implemented as thirty five independent Java applets. Each applet can be started by clicking on one of the hyperlinks present on the opening page of the tutorial. When the user clicks on one

of the hyperlinks, the Java byte codes for the applet associated with the hyperlink are downloaded on the user's machine and executed by the Java Virtual Machine within the browser.

The tutorial can only be viewed properly with a screen resolution of 1024 X 768. This is because X and Y positions of the various widgets, graphics (pictures) and static text have been hard coded. The need to hard code the coordinates arose out of the decision to implement the entire tutorial in Java, including drawing the pictures.

The tutorial on number conversion supports the twelve different types of conversion involving binary, octal, decimal and hexadecimal number systems. Since there is a lot of similarity in the conversion techniques of different number conversions, reusable Converter classes were created which dynamically change their behavior depending upon the instance of the State class used to parameterize them at the time of instantiation. For example, the technique to convert a binary number to a decimal number is the same as the technique to convert a hexadecimal number to a decimal number or an octal number to a decimal number except for the positional weights which use the base of 2 in case of a binary number, 8 in case of an octal number and 16 in case of a hexadecimal number. Therefore, a single converter class called BHO2Dconverter was created to convert either a binary, hexadecimal or an octal number to a decimal number. The behavior of BHO2Dconverter depends upon how the BHO2Dstate class is initialized upon instantiation since this class is used to parameterize the BHO2Dconverter. Similarly, a single converter is used to do the other conversions.

Since this is a tutorial and not just a scientific calculator, there was a need to store the result of each step of conversion for display at a later time. This was accomplished using special Result classes. For example, D2HBOResult was used for storing the conversion steps involved in converting a decimal number into hexadecimal, binary or octal number.

In order to restrict the user input to valid input, a special widget called MaskedTextField was created using the TextField class provided by Java as a superclass. In order to make it as reusable as possible, the mask that it uses to filter out the characters typed by the user has been separated from it and made into a different class called Mask. An instance of Mask is used to parameterize an instance of MaskedTextField. The behavior of MaskedTextField depends upon how the Mask class is initialized upon instantiation. The way the Mask class is initialized is by passing a string that contains the characters that the user will be allowed to enter on the screen. Then, each time the user presses a key, the MaskedTextField asks the Mask to verify whether the character typed is valid or not. If it is, then the character is displayed on the screen, else the key press is ignored. The way the Mask class verifies the validity of the character typed is by looking in the mask string for the presence of the character typed. If the character is present then the validation has succeeded and the character typed is displayed on the screen, otherwise the key press is ignored.

A parity generator has a lot in common with a parity detector. They both share the same circuit with the Parity input grounded in the case of a parity generator whereas in case of a parity detector, the user supplies the Parity input. Both, parity detectors and parity generators use combinations of multiple EX-OR gates to generate or detect the parity of an incoming number. This tutorial has made an attempt to create a software model of the real world circuits. Since both a logic gate as well as entire circuits consisting of multiple logic gates can be viewed as electronic components, an abstract super class, Ecomponent, was created to represent the behavior exhibited by any electronic component.

A class called EXORGate models an EX-OR gate, a class called EXNORGate models an EX-NOR gate, a class called EvenParityGeneratorCircuit models an even parity generator, a class called OddParityGeneratorCircuit models a parity generator circuit, a class called EvenParityDetectorCircuit models an even parity detector circuit, and a class called OddParityDetectorCircuit models an odd parity detector circuit. All these classes are sub-classed from EComponent since all of them are electronic components.

In order to make the EComponent class truly generic so that it can have any number of inputs and outputs, a special ExternalInterface class was created to model the input and output of an electronic

component. The class "Input" which is a sub-class of EComponent models the input of an electronic component, and a class called "Output" which is also a sub-class of EComponent models the output of an electronic component. An instance of a sub-class of EComponent such as an EX-ORGate can have any number of instances of Input and Output within itself, thus permitting us to model a multiple input or a multiple output EX-ORGate.

The final design of the tutorial on parity generators and detectors follows the classic MVC (Model, View, Controller) pattern promoted by SmallTalk. In this, the screens are separated from the software models of the parity generator and detector circuits by controller classes called facades. This is done to de-couple the screens from the model layer classes so that each of them can change independently of the other. Thus, if any major changes are made to the public interface of either the model layer classes or the screen class, only localized changes will need to be made to the intermediate facade class; therefore, it is not necessary to make any changes to the code in either the screen classes (or the View layer classes in MVC jargon) or the parity generator or detector classes (or the Model layer classes). The concept of a facade class provides an important abstraction to simplify the public interfaces of complex classes, and so they serve a very useful purpose in this tutorial.

Conclusions

There are numerous books available that cover these topics thoroughly. However, books have their limitations in a learning environment. For example, they are static by nature. Though they may be able to explain concepts in great detail, they still do not present students with an opportunity to apply concepts in solving problems in an interactive fashion. Actually using or applying the concepts helps students improve their understanding of the subject matter. This limitation of textbooks can be effectively rectified by using interactive instructional multimedia technology like the web-based tutorial presented in this paper. In this tutorial, the user works with simulation models that enable him/her to drill on concepts in an interactive fashion. The user supplies the input and gets a solution in real time. In addition, the solution is customized with detailed explanations of the steps involved in arriving at the solution. Thus, this tutorial makes the learning experience more dynamic and interactive. The immediate feedback helps students grasp the concepts and techniques more readily.

Implementing Technology into the Teacher Education Program

Joseph J. Walsh, Ph.D.
Teacher Education Center
Southeastern Louisiana University
United States
SLUDRJOE@aol.com

Abstract: This paper reports how the Teacher Education Department at Southeastern Louisiana University is infusing technology into its education courses, in order that its students will be better prepared to use technology in the schools. Specific activities, that take the ISTE Standards into consideration, are also detailed. The paper also tells the direction in which the graduate school is headed in making technology courses available for teachers who seek certification or want to be more technologically literate. Overall, the paper is an overview of what is being done and what is planned for the direction of the Teacher Education Department at Southeastern Louisiana University.

Until 1995, Louisiana had registered little progress in the area of school technology. At that point the state garnered a $4.8 million challenge grant from the U.S. Department of Education and the National Science Foundation. Since that initial acquisition of funds, the state legislature has allocated additional money to enhance technology around the state. However, according to Carol Whelan, the director of educational technology for the state education department (Technology Counts, 1997), "There's never enough professional development and trying to get it statewide is difficult." This is where Southeastern Louisiana University's Department of Teacher Education is playing an important role.

Southeastern Louisiana University has become a leader in training teachers in the state of Louisiana. SLU has a reputation for having an excellent teacher education program, but realizes that it must make changes in its curriculum if it is to keep up with the changes in our society in the area of technology. With an impending visit from NCATE, the Teacher Education Department has devised a plan to even surpass the expectations set by the accrediting association.

Since the state of Louisiana has been making great strides in providing funds to get more and more technology into the schools, the Teacher Education Department must train its pre-service teachers in the use of technology in order that they can utilize it when they reach the classrooms. The faculty also realizes that the teachers already in the schools need training and are making this training available through the graduate school. SLU's Teacher Education Technology Task Force, as well as the Undergraduate Task Force, started meeting to come up with ways in which technology could be taught in all education classes, so that there is a logical progression as to when different technology is implemented into the curriculum. The committees' common goal is to have each class in the education core include the implementation of technology in order that the pre-service teachers will fully be able to use the technology in their teaching when they enter the classroom, not only upon graduation from the program, but also in the practicum part of the curriculum in teacher education in which the students go out into the schools and teach.

At SLU, every education student must take *Education 305, Computer Applications in the School Setting*, which emphasizes how computers are utilized in the school setting. Instructors in this course currently teach a variety of applications that the students can use in the classrooms. In the course, students are introduced to the areas of word processing, data bases, spreadsheets, PowerPoint, software evaluation, Internet, and their uses in the classroom. However, there is a strong feeling among the faculty that so many other things should be included in this course as new technology is being introduced, and therefore they believe the introduction of the aforementioned areas should be done in the methods courses. It is also believed that being exposed to these applications in the methods classes will be more meaningful to the students since it would be in context of the classroom. Also, *EDUC 305* can be taken at any time during the student's program, so not all students have had the course when they begin their methods classes. This made certain students totally unable to implement technology in their classes.

There is a progression of courses a student must take in order to complete the teacher education curriculum. *Introduction to Education* is the first course a student takes in the curriculum. Special emphasis is placed on the guidance and screening of applicants into the professional program and pre-

student teaching professional laboratory experiences begin in this course. This is a one credit course and one of the major assignments is to write an autobiography, so word processing is introduced at this level. In the different assignments given during this course, the instructors point out the role word processing plays in the educational setting.

Upon completion of the introductory course, the students go on to take *Teaching of Reading in the Elementary School*. In this course, the students study the reading process and do field work in the classrooms in different capacities. The uses of data base is emphasized in this course since a great deal of record keeping in the form of observations is an integral part of this course.

After satisfactorily completing the introductory reading course, the students take their first methods course which is entitled, *EDUC 321, Elementary Curriculum and Instruction*. The content of this block includes the development of reading and mathematics competencies. During this course, students get first hand experience in teaching students in the public school classrooms. In this class, the students are exposed to the use of scanners, digital cameras, video cameras, and appropriate software to be used in their teaching during their practicum experiences. The students each teach whole class twice during the semester for one full week in reading and another in mathematics. The students use digital cameras in their classrooms to record activities which take place in their classrooms. In one section of the course, all students have their own floppy disks that are used to take pictures of certain points of emphasis in the lesson. Video cameras are also used in this course to monitor student progress. Students use the Internet in planning their lessons and use scanners to copy information to their electronic files. In the mathematics section of the course, students devise ways in which the spreadsheet can be used in their classrooms.

An important part of *EDUC 321* is *Project CREATE* which is an enhancement to the program. Two instructors offer labs, as well as their assistance, to make the practicum experience more profitable for the students. In the labs that they offer, the instructors emphasize the use of technology in the classroom. Students not only correspond with the two instructors face to face but also consistently do so through the use of the computer. The students are also required to complete several technologically-based activities for this portion of the course.

At the same time as the students take *EDUC 321, Elementary Curriculum and Instruction*, they take a course entitled *Diagnostic and Prescriptive Reading*. In this course, the use of the spreadsheet and data base is utilized as the students take records and analyze the results in the classrooms where children are involved in the reading process.

The final methods course the students are required to take prior to student teaching is the second block of *Elementary Curriculum and Instruction, EDUC 410*. This is a ten hour credit course which includes, reading, language arts, science, social studies, and music, as related to the needs of the child. In this class, the students also go into the public school classrooms where they are responsible for teaching for two weeks at two different times during the semester. In this course, the students design, deliver, and assess student learning activities that integrate computers/technology for a variety of student grouping configurations and for diverse student populations.

At the same time as the students take this course they also have to take a course in *Physical Education for the Elementary School Teacher*. For this course, the students use different applications to analyze data collected in their classes. After their completion of the second *Elementary Curriculum and Instruction* course, the students do their student teaching which is a full semester of teaching in the Louisiana public schools.

There are many specific things that are being implemented to infuse technology into the classroom. At Hammond Westside Elementary, the SLU students use hand-held computers with their students. Each student is given the freedom to choose the activities using the computer that they deem appropriate for the lessons that they teach. Some students use them for students to write their own class books. Some opt to have the students use them collectively in word processing activities. In other instances, the students take advantage of the Internet capabilities of the hand-held computers and work with the children on some exciting projects.

In another section of the same course, students are paired in their teaching experience and while one student teaches for a week the other student acts as an observant in carrying our specific partner tasks. One of the assignments is concerned with on-task behavior and the digital camera is used to record data. Another task concentrates on questioning and again the camera is used to record the gender of students being called upon, whether they had their hand raised or not, as well as the location in the room where the child is seated. Another task in which the camera is used is to track teacher movement. The camera serves a valuable purpose in collecting data for this task.

Also, in the aforementioned course, the digital cameras plays a role in the mathematics part of the course. Various pictures are taken in which students write their own mathematics problems that relate mathematics to the real-world. The students also expose the children to the use of the spreadsheet to solve problems that they encounter in mathematics class as well as in their daily lives.

In the second *Elementary Curriculum and Instruction* course, *EDUC 410*, the students implement the use of the data base and the Internet in teaching the children how to conduct research. When doing research the students can also take advantage of laptop computers to record data outside of the classroom environment.

In all education courses, students are exposed to educational software that they can use with the students in their classroom. In the *Computer Applications* course, the students do an in-depth study of educational software in general, but in the other classes the study of the software becomes more area specific.

Using Power Point, students make portfolios detailing their teaching experiences. In turn, the students can use these portfolios upon graduation when applying for teaching positions. Included in the PowerPoint presentation is the student's vita, photos of the student working with children, outside activities, list of favorite books, and related information which gives the prospective employer a better picture of the applicant.

It is the department's objective that all ISTE Standards be met during the course of the student's curriculum. In the area of Basic Computer/Technology Operations and Concepts, the courses will enable the students to use computer systems to run software; to access, generate and manipulate data and publish results. In all courses, the students will operate multimedia computer systems and be able to install and use software packages. All instructors will use appropriate terminology and the students will be encouraged to do this in their classrooms as well. The instructors will inform the students how to deal with problems that arise when out in the field which invariably will happen on occasion. The students will use scanners, digital cameras, and video cameras especially in their methods classes. All students will be able to connect what is being studied to the real world because this gives the most meaning to the subject at hand.

In the area of Personal and Professional Use of Technology, the students will apply tools for enhancing their own professional growth and productivity. They will do this by keeping records of their own using spreadsheets and data base programs. They will learn how to use a spreadsheet to record information and data bases to keep anecdotal records. They will also teach the children how to use these applications for projects of their own. The use of the Internet will also be a very viable part of the curriculum in the university and public school setting. The students will use presentation tools to enhance their teaching. The instructors will cover how best to teach a child and address their special needs. The students will also be able to become life-long learners by assessing different sites which will help them to improve upon their teaching performance. The students in doing so will become aware of the ethical issues involved with the use of computers.

At the university, a distance learning committee has been established. There are some faculty members who currently teach through various mediums of distance learning and this number is ever increasing. The students in their education experiences will be able to observe how the needs of diverse populations can be met through distance learning.

The main focus of teacher education is the application of knowledge. As for the Application of Technology in Instruction, the students will apply computers and related technologies to support instruction at their grade level and subject areas. The students are guided by the instructors in planning lessons that integrate technology and develop assessment strategies for a diverse population.

At Southeastern, the graduate program in technology is also being updated to meet the needs of teachers in the schools. Some of the graduate students are classroom teachers who wish to integrate technology in their classrooms, while others are those who work in computer labs or are in charge of technology at their schools. Also, the state has released its new requirements for certification in the area of technology, and SLU is changing their program so that the graduate students can meet those requirements through their courses.

EDUC 643, Integrating Computers Into the Elementary and Secondary Classroom is an introductory graduate class which infuses many of the ISTE Standards for Basic Endorsement In Educational Computing and Technology Literacy. All of the 1.1 Basic Computer/Technology Operations and Concepts are introduced in this course. This course covers many of the 1.2 Personal; and Professional Use of Technology as well. Courses such as *Utilization of Audio-Visual Equipment* and *Media Production* cover many of the other standards not met by EDUC 643. EDUC 643 also covers much of 2.0 Specialty

Content Preparation in Educational Computing and Technology Literacy. New courses are being currently being developed, including a specific course in Hardware Design, which maintain as well as master the other areas stated in the ISTE Standards.

Southeastern Louisiana University is making strides to provide the best education possible for its students. In training its preservice teachers and graduate students in the implementation of technology, the university will have a great impact upon all the children who attend schools where SLU alumni teach.

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Moving into the 21st Century with High Tech/High Touch Teaching: Integrating the Curriculum On-line

John R. Watret
Department of Computing and Mathematics
Embry-Riddle Aeronautical University
Email watretj@cts.db.erau.edu

Abstract: This paper describes the new approach to the calculus sequence that Embry-Riddle Aeronautical University (ERAU) is piloting for the freshmen Aerospace Engineering (AE) students. In addition to having the traditional engineering curriculum, ERAU is in the second year of its Integrated Curriculum in Engineering (ICE) in which the Mathematics Department has played a leading role. We have implemented two important changes. We have realigned our calculus sequence with Physics courses, and we have integrated technology fully throughout the curriculum. These changes have facilitated a new way of teaching: we have refocused our teaching methods to a more learner-centered approach in which teaming, problem-solving and collaborative learning play a key role.

Introduction

One of the goals of the Integrated Curriculum in Engineering (ICE) that Embry-Riddle Aeronautical University has successfully piloted with 65 freshmen Aerospace Engineering students was to restructure and integrate the calculus and physics sequences in the engineering program. In doing so, the Mathematics faculty not only realigned the content of the calculus sequence, but also introduced the use of technology into the courses to maximize the students' learning experience in calculus. This includes providing all students in the ICE program with a laptop computer and incorporating Maple into the calculus courses. In addition, we created a website for each course on which we post all class materials, including a syllabus, daily worksheets, homework assignments, and review materials.

Background

Over the past few years there has been growing concern in the way in which the freshman engineering students are educated. Specific interest has been in the Calculus and Physics courses taken by the engineering students. These courses traditionally have a high unsuccessful rate. Out of this concern grew several Engineering Coalitions - groups of colleges and universities working together to investigate ways to improve the engineering curriculum.

We formed a committee to research the attempts of these coalitions to remedy this situation, and we became especially interested in the Foundation Coalition (Winkel & Froyd 1992), led by Texas A&M University (Glover & Erdman 1992). Further research into the Foundation Coalition, which included visits by us to their sites (Rogers & Winkel 1993) and by representatives from Rose-Hulman Institute of Technology (RHIT) (Froyd et al. 1993) and Texas A&M University (Barrow et al. 1996) to our campus, we implemented an Integrated Curriculum in Engineering (ICE) (Martin & Watret). Using ideas gained from our colleague institutions, we have successfully completed three semesters of ICE, which included calculus, physics, humanities and engineering courses.

One of the key goals of the ICE program was to rearrange the topics in the calculus sequence so that the topics have an inherent relevance to the physics and engineering courses. This included teaching vectors and parametric functions as the first topics in calculus I. These topics were normally taught in the later semesters. Physics moved optics to the beginning of the first course to allow time for the calculus course to cover the vectors and parametric equation. However it should be noted that by the end of the third semester of calculus and physics the bothe the students in the ICE program and the traditional program had covered the same material, just in a different order.

Laptops

In addition to realigning the content of the calculus sequence to support the physics topics an important goal of the ICE program was to maximize the use of technology. Several options were considered, such as having the classes meet in a computer classroom once or twice a week. Finally the IT department came forward with an offer from IBM to provide the pilot group with IBM ThinkPad's. Also, using funds provided by a donor, IT was able to renovate and wire two classrooms with internet connections for the laptops.

As a group we decided on standardized software for the ICE program: Microsoft Office with Word97, Excel and PowerPoint, which was chosen by all disciplines for word-processing and presentations. The computer algebra system Maple was used in the calculus sequence and in some of the physics and engineering classes. For graphics Bentley Microstation was used.

Webpage

With the specifics of the laptops and the software decided upon, it was now time to plan the layout of the webpages. IT provided a great deal of technical training and support in this area. The mathematics faculty really took a lead in content of the webpages.

A webpage (Fig. 1) was established for the entire ICE Program that would act as a homepage from which students were able to navigate to the course pages of each discipline participating in the program. The homepage also had a scrolling announcements section, where we were able to announce up coming events, such as exams. Also, the communication center provides a direct link to the ICE communications webpage. From the center, the students are able to send email to each other and to faculty, participate in online discussions and access the ICE profile system.

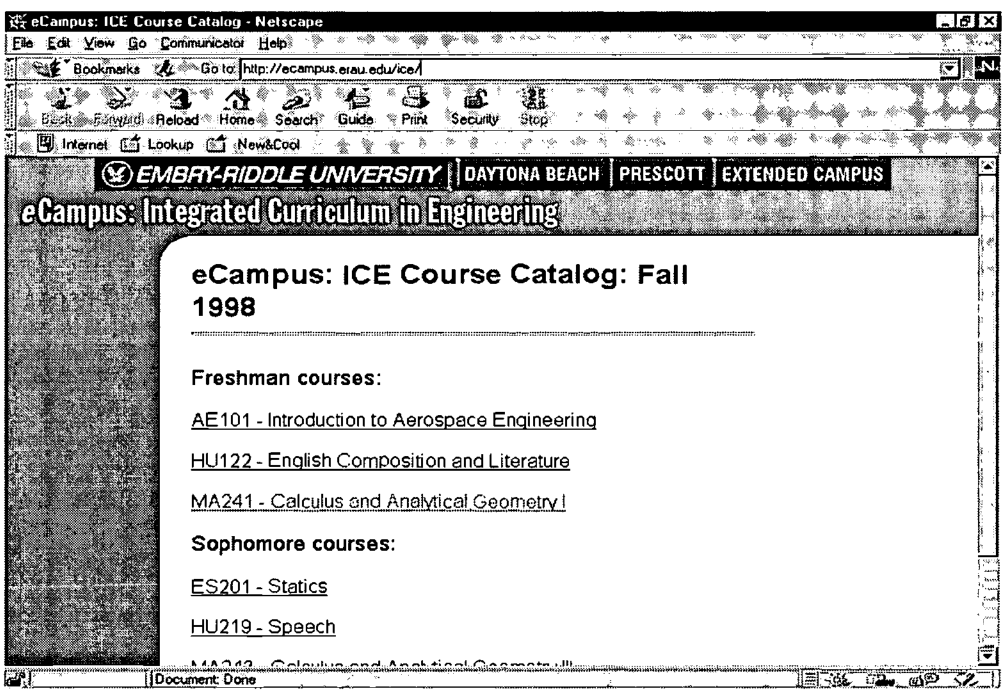
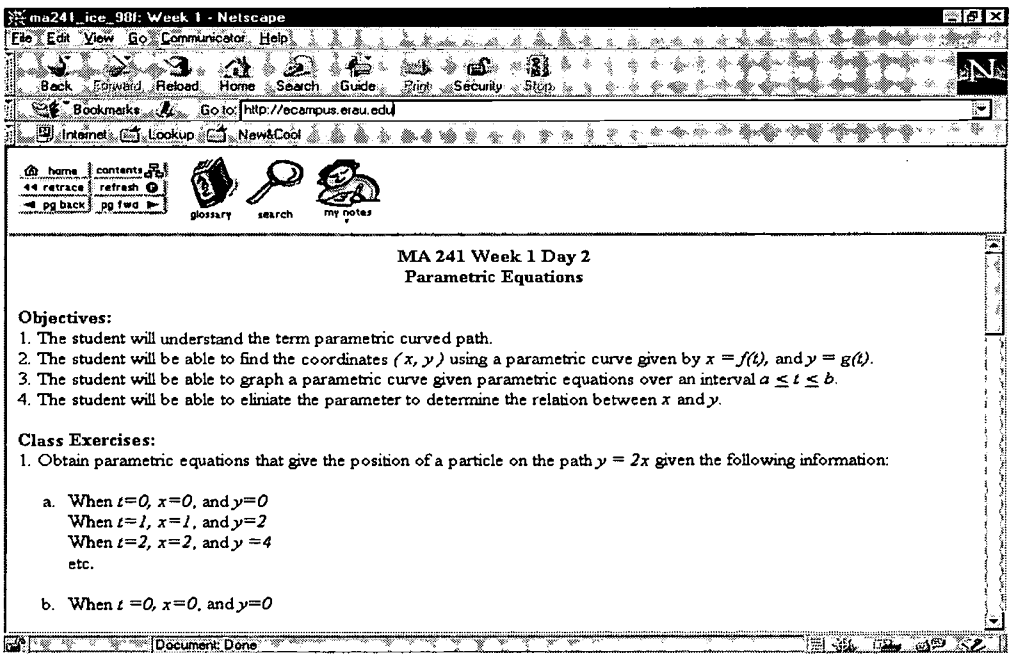


Figure 1: ICE homepage

From the ICE homepage the students could access the individual subject pages, for example MA241-Calculus and Analytical Geometry I, which had links to different areas. The first was the syllabus describing the course policies

and grading procedures. The next area was the classroom section on which the daily worksheets were posted. Each week was listed, then within each week were the daily worksheets.

The same template for the daily worksheets has been used in all sections of calculus. The worksheet (Fig. 2) includes the objectives to be covered and class exercises - 3 or 4 exercises which the student do in class in their teams to help them investigate and understand the concepts. The next section is the text reference. Since the ICE course moved topics around to support physics, the sequencing of the topics did not always match the sequence presented in many of the standard Calculus textbooks. Thus it was important to reference the material being covered to the textbook being used for the course. The ICE program used the same texts as being used in the traditional courses. Finally, probably the most important part of the work sheet is the homework section. Here homework problems from the text are listed as well as supplemental problems.



MA 241 Week 1 Day 2
Parametric Equations

Objectives:
1. The student will understand the term parametric curved path.
2. The student will be able to find the coordinates (x, y) using a parametric curve given by $x = f(t)$, and $y = g(t)$.
3. The student will be able to graph a parametric curve given parametric equations over an interval $a \le t \le b$.
4. The student will be able to eliniate the parameter to determine the relation between x and y.

Class Exercises:
1. Obtain parametric equations that give the position of a particle on the path $y = 2x$ given the following information:

a. When $t=0$, $x=0$, and $y=0$
When $t=1$, $x=1$, and $y=2$
When $t=2$, $x=2$, and $y=4$
etc.

b. When $t=0$, $x=0$, and $y=0$

Figure 2: Example of a daily worksheet

The next area is the reference section. Here is posted the tutorials, exam reviews, exam solutions and team problems. On a day-to-day basis the classroom section is the one that is used most. With the worksheets posted on the web the students are able to download them and be prepared for the upcoming class.

In the Classroom

One goal of the ICE program is to foster in students an attitude of shared responsibility for their learning. With this in mind the daily worksheets are the script for the class. The objectives for the day's class are clearly stated at the top of the worksheet. In a typical class the instructor would give an introduction to the topic, and then the students would work on the class exercises in their teams. This allows the student to explore and understand the topic, thus acquiring a deeper understanding of the concept.

Normally, the students will be given a set time to work on the class exercises. During this time the instructor will walk around encouraging and providing helpful hints to the teams that request it. At the end of the allotted time, one team is selected to present the solution to the problem on the document camera. The solution a team gives may not be completely correct, which prompts a general discussion to the problem. This additional class discussion proved to be useful in identifying the problem area for the student, which could then be clarified by the instructor

Computer Algebra System

At all times the students are able to use Maple to help solve the problems. Maple allows the student to solve more challenging problems while still applying the basic concepts. Maple has proved to be very helpful in allowing the students to solve problems. One of the most useful features of Maple is the plotting package. This allowed the student to visualize graphically many of the concepts of calculus.

Students soon became very proficient in solving problems using Maple. They used it to check solutions to their homework. To make sure that the basic concepts were still being learned, quizzes were given both with and without the use of Maple. When Maple was used the quiz was saved on a disk and handed in or the Maple worksheet could be emailed to the instructor to be graded.

Exams were given in two parts. The first part was designed to test the basic concepts. These problems would not require complicated mathematical manipulation. However, part II included some problems that could only be solved using Maple. These problems test the problem solving skills of the students. This part of the exam is either saved to a disk and handed in or the Maple worksheet is emailed to the instructor. It takes a little longer to grade the Maple questions, but the benefits to the students are many.

Working in Teams

Although the exams and quizzes are given and graded on an individual basis, as in the traditional college programs, the ICE program has the students working in teams, so we also wanted to assess how the students perform in a team.

As part of the course, we assigned four to six team problems throughout the semester. These problems were posted in the reference section of the website. Normally, the teams would be given one week to solve the problem. Most of these problems required the used of Maple in the solution. The solution was presented in a report format. To ensure that all students in a team participated in the solution, the cover sheet of the report had to be signed by each team member that contributed to the solution. You may think that the brightest student solved the problem and the rest just signed. Well, this may happen the first time but this soon changed. If a student did not contribute the other team members would not allow him/her to sign and turn in the solution with only their signatures. The non-contributing student would receive no grade for the problem.

Another method used to challenge the problem solving skills of the teams was the integrated team exams. Two or three of these interdisciplinary exams were given each semester. These problems were more "real world" type problems. A prelude to each team problem was posted in the reference section of the engineering webpage and for some problems in the reference section of the calculus webpage. The solution required the teams to make some wise assumptions. The time allowed on these exams ranged from 2 to 5 hrs. The problems in these integrated exams also were a way to illustrate the connection between the mathematics, physics and basic engineering courses. These were integrated interdisciplinary exams, so were graded by faculty from each discipline.

Assessment

Since the final exam in the calculus sequence at ERAU is a common final for all section, this provided an opportunity to compare the performance of the students in the ICE program with the students in the traditional classes. At the beginning of the Fall semester, a peer group of students were selected from the engineering students in the traditional program. In selecting the peer group care was taken to choose students who had similar SAT scores, similar High School rankings and who were taking the same freshman courses. Comparative data was gathered for each discipline.

(Tab. 1) shows the grade distribution of the ICE students and the traditional students who took MA241 - Calculus I. Although more students in the traditional group got A's, overall there were more successful students in the ICE group with "Successful" defined as students having attained a grade of "C" and above. In addition, there were more students completing the course in the ICE group.

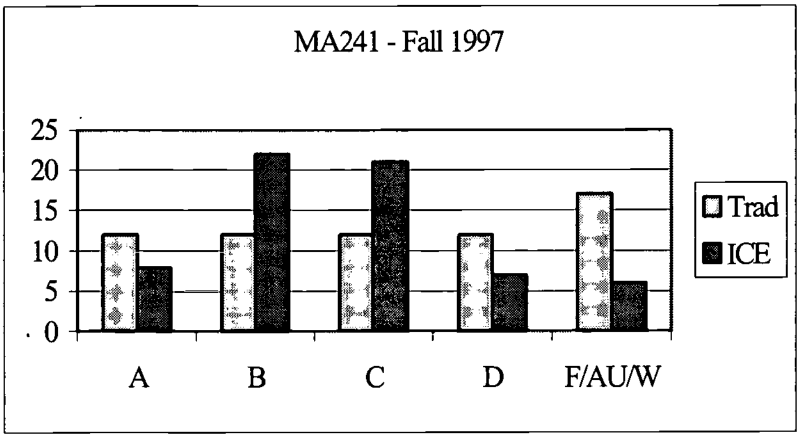


Table 1: Grade distribution for Calculus I

(Tab. 2) shows the grade distribution of the MA242 - Calculus II course. The same comparison group was used as in calculus I. A similar trend is observed. There are more A's in the traditional group, but overall there are more successful student in the ICE group.

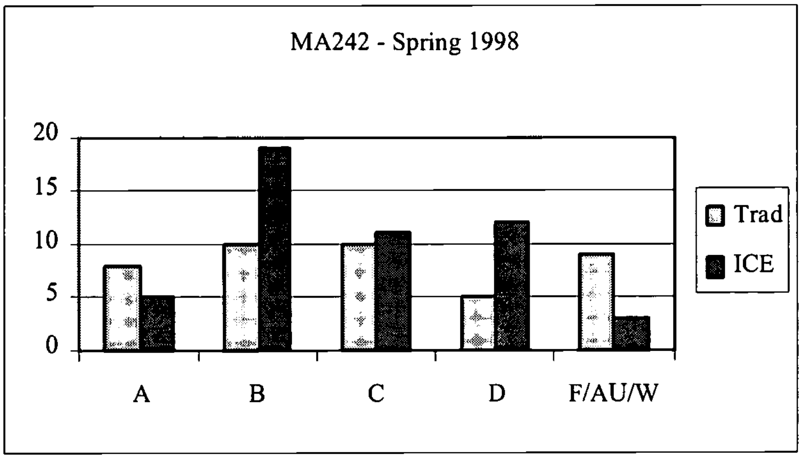


Table 2: Grade distribution for Calculus II

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Self Monitoring: A Study of Student Interactive Assessment

Dean Eichorn, Science and Math Department Head, Mountain Secondary School, Langley, B. C., Canada, deichorn@sd35.bc.ca

Janice Woodrow, Professor Ermerita, Department of Curriculum Studies, Faculty of Education, University of British Columbia, Vancouver, B. C., Canada
Janice.Woodrow@ubc.ca

Abstract This paper describes the results of a study which examined the impact of interactive assessment practices on science teaching and learning at the secondary level. Interactive assessment, in the context of this paper, consists of students taking quizzes/tests at a computer, and receiving immediate feedback and mastery information. Situated in a longitudinal (7 year), collaborative action research project, the Technology Enhanced Secondary Science Instruction (TESSI) project, the study examined the use of interactive assessment procedures and documented the impact of these procedures from both the students' point of view and the teachers'. The study's results indicate that the use of interactive assessment promotes student self-monitoring, goal setting, time management, responsibility and mastery learning. Teachers report that the use of interactive assessment facilitates and supports student-centered, instructional practices.

Introduction

The context for this study is the Technology Enhanced Secondary Science Instruction (TESSI) project (see Woodrow, Mayer-Smith & Pedretti 1996), a multifaceted, collaborative research endeavor between teachers and educational researchers. Initiated in 1992 in two Physics classrooms, and now expanded to ten science classrooms spanning grades 9-12, and the disciplines of Physics, Biology, Chemistry, and General Science, TESSI combines the educational opportunities provided by classroom-based, commercially-available, multimedia technologies with student-centered teaching strategies. Student learning is variably paced, individualized, collaborative, and mastery-based. TESSI's longitudinal design has provided a platform for the critical study of the consistent use of technology by both students and teachers. This paper documents the use of interactive assessment in the TESSI classrooms. Within the context of this paper, interactive assessment consists of students taking quizzes/tests at a computer, and receiving immediate feedback and mastery information. The underlying research questions are: What happens when interactive assessment is used in a technology enhanced science classroom? What impact is there on student learning and teacher instruction?

In their essay, "Does Technology Work in Schools?", Baker, Herman and Gearhart (1996) state that "*Technology use must be grounded firmly in curriculum goals, incorporated in sound instructional process, and deeply integrated with subject-matter content*" if changes in teaching and learning are to be achieved. Interactive assessment effectively addresses each of these three domains. In addition, interactive assessment promises to reduce the teachers' workload thereby freeing time for more individualized instructional practices and enable a level of tracking and monitoring individual student progress virtually impossible using traditional techniques. In the TESSI project, the focus of interactive assessment is on the use of objectives-based assessment to monitor student understanding and progress (what they know and can do), challenge and enhance student learning by providing self-regulatory and self-monitoring opportunities, and guide teacher planning and analysis of learning/instructional effectiveness. The goal is to make assessment an integral part of the instruction process, thereby enriching both teaching and learning.

Interactive Assessment in TESSI Classrooms

TESSI uses the testing program, LXR•TEST™ for its assessment procedures. This software can create interactive tests (with or without feedback) as well as standard, paper-based tests based upon user selected key-words or objectives from stored item banks, and provide feedback on mastery to both teacher and student. Each TESSI unit includes several interactive quizzes which students complete when they judge that they have mastered the requisite material. Some TESSI teachers provide both practice and scored quizzes for their students, while others provide the option of doing some corrective work designed to help with learning the specific concepts that were not mastered at the time of the first quiz, and an opportunity, upon completion of this corrective work, of- taking another quiz. All interactive quizzes are configured to provide immediate scoring and item feedback. While some students are at the computers taking quizzes, the other students remain engaged in other classroom activities. Students are also given the opportunity of completing their interactive quizzes outside of classroom time. The interactive features of LXR•TEST™ enable the setting of questions based upon QuickTime® movies of simulations, animations, or video clips, as well as digitized images of equipment and examples encountered in the learning activities. This capability of LXR•TEST™ promotes the visualization of concepts and enables the assessment of higher order objectives than is generally possible with objective tests. ——The end-of-unit tests are prepared and scored using LXR•TEST™ but the students write these tests traditionally—i.e. using pencil and paper—in part, to prepare them to write the Provincial exam at the end of grade 12. To facilitate the marking of the unit tests, responses to the objective questions are entered on optical mark reader (OMR) bubble sheets and scanned into the computer. Marks for free-format questions are entered into the computer manually by the teacher. As with the interactive quizzes, the LXR•Test™ Scoring Edition is used to generate test statistics and update test item statistics.

Mastery reports are given to students after each quiz in order for students to examine how well they did on each objective. These mastery reports provide both the teacher and the student with information about what has been learned and help the students to study effectively for the summative, unit tests. LXR•TEST™ can generate a variety of mastery reports based on the objectives which have been used to organized the item bank or question file. For this process to generate useful information, (and to enable tests to be created quickly) the item banks must be carefully constructed to coincide with curricular objectives. TESSI teachers use item banks being collaboratively developed by the Assessment Resource Consortium (ARC). ARC is a consortium of teachers from across the Province who are developing, testing and categorizing test items geared to the Provincial learning outcomes. Each item in the ARC bank is stored via an assigned objective and a set of seven "key words": Topic, Sub Topic 1, etc. The key words provide a rapid method of selecting subsets of questions from the item bank. These item banks are upgraded and published yearly in CD-ROM format.

Method and Data Sources

A qualitative case study methodology (Yin 1994; Stake 1994; Merriam 1988) was used to examine the implementation of interactive assessment within the context of the TESSI classrooms. Techniques borrowed from the ethnographic tradition (Hammersly & Atkinson 1990) were used to document the multiple perspectives and views about interactive assessment of the TESSI teachers and students spanning a period of three years. Two major sources of data informed this study: journal entries by the ten TESSI teachers and audiotaped interviews with TESSI students during 1995-96. Supplementary data sources include informal, teacher-administered student questionnaires, focused interviews with the TESSI teachers, video tapes of meetings between TESSI teachers and the project director, field notes compiled during researcher visits to TESSI classrooms, and results of required, grade 12 Provincial exams. The study's findings are based on the analysis of these multiple data sources.

Findings

> *Student-centered, variable paced programs became manageable in this project because the technology takes over much of the traditional assessment role of teachers allowing them to interact in new and more effective ways with their students." (Feedback,*

TESSI Teacher, 1998)

"I couldn't do what I do without interactive assessment!" (Journal entry, TESSI teacher, March, 1998)

The above quotes, by two of the founding TESSI teachers, are persuasive statements about the value of interactive assessment. All teachers in the TESSI project regard interactive assessment as an indispensable element of their instructional practice—one which has generated many significant outcomes. Some of these outcomes are described below. Quotes from teachers and students are included to provide context, support and emphasis.

a) Self-Monitoring

It is well established that young people are very anxious to achieve, generally, and, more importantly, to achieve stated goals. Yet, many young people, including those of high school age, do not see the relationship between concept attainment (i.e. understanding) and summative achievement (test marks). Students too often take a pragmatic approach to school and engage in what Fenstemacher (1994) refers to as "studenting,"—participating in the actions of completing assignments and writing tests with little regard for learning. Students' essential focus, and often, primary goal, is just completing the job by leaping all the hurdles. In this study, it was found that most TESSI students came to regard assessment as a means of monitoring and enhancing understanding rather than as an "obstacle to be overcome." For example, two students commented:

"It gives you a greater view of how tests are like. This also can test your ability/knowledge/understanding after you learn the topic. If you seem to have wrong answers on that certain type of questions, you would know you need to go over notes/seek help." (TESSI Chemistry 11 student, 1997)

"It definitely makes the test easier if you do the practice quiz on the computer before you write the test. You know what's on the test as well as your weak points immediately. It gives me a chance to prepare for a tests from a different point of view. It also shows me how I made my mistakes and what I can do to correct them." (TESSI Physics 12 student)

Most TESSI teachers create electronic files for students to enter their own assignment and quiz marks. This process contributes to student self-monitoring:

"We keep all our assignments in a file folder and then we take them up to the computer and we put them in under the name of the assignment. It tallies up your marks so you know where you are in the class. It's hard work but I like to know what I'm getting." (TESSI Science 10 student, 1995)

b) Changing Student Behaviors

TESSI students showed evidence of conceptual change in how they viewed their role and that of their teacher in the science classroom. They regarded themselves as directing and monitoring their own learning, and saw their teacher as a "helper" in that process. While this conceptual change is partly attributable to the nature of the TESSI instructional model and the technology enhanced learning activities in which students engage, it is also clearly related to the use of interactive assessment. For example, a teacher who was using the TESSI model for the first time this year commented that

"There is not as much focus on marks—they have switched to a focus on learning. ... They are more concerned with meeting the learning outcomes (largely as a result of the mastery reports)." (Journal Entry, TESSI teacher, 1998)

Since the students cannot all take quizzes at the same time with just 8-10 computers available, they are given a measure of choice as to when they complete the quizzes. The students view this opportunity to determine for themselves when they were ready to take a quiz as an important feature of their class.

"I like [interactive quizzes] *better `cause you just go and do the quiz whenever your want and if you're not ready one day to do it, `cause you didn't study enough, then you can wait till the next day." (TESSI Science 10 student, 1995)*

Students have also demonstrated an increased level of responsibility and effective time management by writing quizzes on their own time.

"Some students write quizzes outside of class time (which is no burden since they are on the computers and they can only write once). This helps [them] to devote more class time to learning." (Journal Entry, TESSI Teacher, 1997)

The teachers who provide practice tests for their students have found that students often work on these practice tests collaboratively. Some even begin to design their own tests. For example, two teachers write:

"two or more students often work together on the practice tests which often puts an edge of competition into the learning and also makes it a co-operative learning situation." (Feedback, TESSI Teacher, 1998)

"sometimes the practice test can be 2 or 3 times as long as the real test, so the kids can actually "make up" their own different practice tests from within that like a test bank." (Feedback, TESSI Teacher, 1998)

c) Interactive Assessment as a Learning Opportunity

Many students fear exam situations; they see tests as mysterious and unknown situations over which they have little or no control. Tests for these students are viewed as "end points" to the educational process, not as tools for learning. Interactive assessment, however, can become a learning opportunity for students and is one means of reversing the ingrained student perception of tests. The ability to mark questions and access solutions as the quiz is in progress was valued as a learning opportunity by nearly all TESSI students. For example, student feedback on a questionnaire querying TESSI students' opinions about interactive assessment included the comments:

"The computer marks it for you and it's a better way of learning because when you take the quiz if you get a question wrong, it will explain it to you right there what you did wrong." (TESSI Physics 11 student, 1996)

"I like how you can mark the question right afterwards because then you learn while you are doing the test, instead of when you get it back and you have forgotten all about what you have done." (TESSI Physics 11 student, 1996)

d) Mastery-based Learning

Mastery-based learning in TESSI is managed and promoted through the teacher's ability to diagnose specific learning problems, provide additional learning materials, and retest individual students with a minimal expenditure of time. For example, one teacher commented:

"The mastery reports provide both teacher and students with detailed statistics as to strengths and weaknesses of the individual student (so that they may organize tutorials and activities with me) and of the class as a whole (weaknesses in classroom understanding means re-teach the concept)." (Interview, TESSI Teacher, March 1998)

Feedback from the interactive quizzes includes information on mastery by course objectives. Teachers make this mastery information available to the students who soon learned to use it to direct their learning strategies.

"I found that they love the LXR mastery reports because it gave them something positive to focus on (i.e. even though test score wasn't high, they knew 3 of the 5 objectives cold)" (Journal entry, TESSI Teacher, 1997)

"The mastery reports are extremely useful. When I go to study for a final exam or unit test I simply have to focus on those areas that I did not master." (TESSI Physics 12 student, 1997)

e) Changing Teacher Practices

The TESSI teachers have found that the integration of student interactive assessment has impacted their classroom practice in many positive ways. Being able to use technology to produce frequent, formative assessment opportunities for their students is an efficient and reliable process that permits them to focus on other organizational and management aspects of instruction. Managing a learner-centered, technology enhanced classroom places enormous pressures on teacher time. Interactive assessment was viewed as a means of providing more "quality teaching time":

> *"... the interactive tests helps to free up teacher time on useless administrative tasks that the computer can easily accomplish such as marking, arranging a time for the quiz, checking the solutions, organizing a requiz - all of which can be taken care of in a one shot deal." (Journal Entry, TESSI Teacher, 1998)*
>
> *"This type of testing has freed me up from time consuming photocopying, although the time spent with students going over quizzes has increased. Bottom line is contact time with students is increased." (Journal Entry, TESSI Teacher, 1998)*

The TESSI teachers have also increased the frequency with which they assess their students and their assessment has become more focused on specific curricular objectives. Formative assessment, in particular, has increased partly because it has become feasible to do so.

> *"[Interactive assessment] is probably the best aspect of TESSI for me. I'm able to quickly generate quizzes and tests that are meaningful and within curricular specifications. Students can get instant feedback and corrective solutions to their answers and I can expose them to a far greater variety of questions because I don't have the same paper concerns as with hard copies." (Feedback, TESSI Teacher, 1998)*
>
> *"Using the technology also makes offering requizzes or practice tests possible and not cumbersome. Students really like having the opportunity for a requiz if they fall short of their goal." (Journal entry, TESSI Teacher, 1997)*

f) Increased Opportunities for Student Success

The changes in teaching practice that interactive assessment has facilitated has provided many opportunities for increased student success. All teachers want to help their students succeed. TESSI teachers have been able to realize this goal. For example, two teachers write:

> *"I find that the students are more prepared [after interactive assessment] for any tutoring... They are much more focused and have particularly thoughtful and relevant questions." (Feedback, TESSI Teacher, 1998)*
>
> *"my good students use the interactive tests to check their understanding as they sequentially progress through the study guides and they complete the corrective assignments and try the retests when they are not successful the first time." (Feedback, TESSI Teacher, 1998)*

These increased opportunities for success are not lost on the students.

> *"You're freer to work at your pace [on individual activities]... if you take a test and do really bad on it there's a lot of extra things, work you can get to fix that. There's help if you need it.... [in] a lot of other classes you just work up to your test and then you have your test and that's it." (TESSI Physics 11 student, 1996)*

The increased enrollment in, and successful completion of, the senior science courses in TESSI is a testament to the effect of these increased learning opportunities. After his first year implementing TESSI, one teacher wrote:

> *"... last year's [Physics] 12 class was very small (16 guys) and my over-all class average was slightly below the Provincial [average]. ... This year the class size has doubled (more kids who, normally, would never take Physics) ... I was quite worried about [the results on the Provincial Exam] since 40% of my class were C students in Ph 11 and very*

weak in math. They came out of the test feeling pretty good (some even said it was easy). The overall average was the same as the Provincial average. Furthermore, the top students did extremely well (better than last year). I had a 97%, a 96%, three with 92%, an 87%, and an 84%. Last year (with the "cream of the crop kids") I had a 98% and an 89% (no other A's recorded). (Journal entry, TESSI Teacher, 1998)

Another wrote:

"I feel that the marks in my classes have gone up by up to 10% across the board, just because of the greater opportunity I have offered to my students when it comes to exam preparation." (Journal entry, TESSI Teacher, 1997)

g) Classroom Management

The use of student interactive assessment has a major impact upon classroom management. Some of these impacts are positive. For example:

"Marks are quickly imported (within 10 minutes of a quiz) to a Marks program. This insures that students have a quick idea as to their current grade and frees up my time." (Feedback, TESSI Teacher, 1997)

Some, however, require creative solutions:

"it is hard to monitor what students say outside of room regarding a quiz." (Feedback, TESSI Teacher, 1997)

"Since everyone is not writing at the same time, the noise in the room can get a little high for a test situation." (Journal entry, TESSI Teacher, 1997)

"With very large classes, 28 students, trying to fit everybody in one class is a problem, especially if quizzes take more than 20 minutes. Students not taking the quiz didn't use the non-quiz time as effectively as I'd hoped. Also the class layout isn't the best for this. Cheating is a whole other potential problem!" (Journal entry, TESSI Teacher, 1998)

In the school in which two TESSI classrooms are operating, students are given the privilege of using a computer in either classroom for their quizzes. Very few students abuse this privilege. Another innovative classroom management strategy is for the teacher to access the classroom fileserver from home to create quizzes or analyze results. This strategy is not without it problems:

"Just downloaded a file containing student passwords from school to create an interactive test, and guess what!!? Another hard drive crash. So here I am, sick at home with my computers saying "Just try to get me working!!!" (Journal entry, TESSI Teacher, 1998)

Conclusion

Teachers from the ten classrooms currently participating in the TESSI project viewed the implementation of interactive assessment as an essential and enabling element of their student-centered, variable paced, instructional practices. Students viewed interactive testing procedures as a means for assessing their own learning, frequently commenting on the usefulness of the formative feedback they received. This study supports the notion that changes in student assessment should accompany, and be congruent with, changes in educational practice, and demonstrates how this congruency can be achieved. Furthermore it shows that technology based interactive assessment can promote student goal setting, self-monitoring, time management skills, student responsibility and mastery learning—skills that will aid our graduates in being successful life-long-learners.

"Interactive assessment not only allows for more understanding but also increases student confidence and provides more opportunities for remediation." (Feedback, TESSI Teacher, 1998)

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Acknowledgments

The authors would like acknowledge the support of the many agencies and firms that have provided financial and in-kind support to TESSI including the Vancouver Foundation, the Chawker's Foundation, the Langely, Richmond, Abbotsford, Kelowna and Powell River School Districts, the University of British Columbia, Prentice Hall, Canada, Apple Computers, Canada, Logic eXtension Resources, Knowledge Revolution, Merlan Scientific, Pasco Scientific, Texas Instruments, Center for Image Processing in Education, the B. C. Ministry of Education, and the TeleLearning Research Network.

INVITED SPEAKERS

Combining Art and Science through Information Technology

Johan Groth, Ph.D.
The Interactive Institute
Sweden
<johan.groth@interactiveinstitute.se>

Abstract: For the last 200 or so years a "division of knowledge" has characterized the collection, creation, structuring and presentation of information. This division may have had advantages but today the need for a closer coupling between natural sciences, social sciences, humanities and "pure" art becomes more and more apparent. A closer coupling will make methods, tools and ways of expression that today are used only within one field of knowledge available within other fields to mutual benefit. Information technology (IT) can help lessen the "division of knowledge. The reason for this is that IT fundamentally changes how we communicate and exchange knowledge. In Sweden the Interactive Institute will try to explore these new possibilities to see how they affect society in general and, not least, the educational sector.

Introduction

It is not much of an exaggeration to say that during the last 200 or so years there have been three distinct realms into which all human thoughts, ideas and pieces of knowledge could be divided or sorted. The boundaries between these realms have in many cases and at many times been hard to transcend. The different realms have been characterised by different ways of collecting, structuring and presenting knowledge, and by different methods for validating and evaluating ideas, propositions and facts. Within the educational sector this structure has been reproduced resulting in separated subjects and different ways of teaching, assessing the students' results and, in the end, giving value to the students' achievements. The realms are, first, art, second, social sciences and humanities, and, third, natural sciences and technology.

This division of knowledge has not always been as "natural" or obvious as we may experience it today. Leonardo da Vinci was both an artist and a man knowledgeable in medicine, fluid mechanics and engineering. Pythagoras worked within both mathematics and music. There are many similar examples from ancient Greece and onwards of persons who have combined and used knowledge from what we today perceive as different fields.

At the end of the eighteenth century something appears to happen. Human knowledge is divided into subjects, disciplines or fields. A spectrum evolves from "pure" art via the humanities, social sciences and technology to "pure" science. In this model art and the natural sciences are seen as opposite entities, each one placed on the end of the spectrum.

The "experts", i.e. persons with a main interest in a certain part of the spectrum, become less interested in, or at least produce less important results within, other parts of the spectrum. Berzelius was a chemist, but did he paint? What about Faraday, Maxwell, Bohr, Röntgen and Edison? What did Gaugain know about geology? What about Kafka, Matisse, Moore and Caruso[1]? Perhaps they did know but we do not know of it, which is a point in itself. Sometimes a passage of boundaries has been tried on a more public scale but with varying results. One example of this is Albert Einstein, but even such a great mind did not produce any noteworthy results when he engaged himself in politics and social sciences. August Strindberg's dabbling with mathematics and chemistry is an opportunity for many good laughs, but not for any new insights[2].

[1] It should be noted that while Kafka, Matisse and Moore created art Caruso was an interpreter of art. This should not lead to any confusion, the discussion about the "division of knowledge" is equally valid whether you are a creator or an interpreter within art, social or natural sciences.

[2] On other hand Strindberg was not only a writer but was also interested in painting and music. It is not unreasonable to believe that had he had the tools he would have worked with multimedia. In that sense Strindberg is a precursor to the artists of today who work with and combine different media.

Perhaps this "division of knowledge" was a natural consequence of the ever growing amount of knowledge being collected, invented, analysed and structured from the Enlightenment and thereafter. Perhaps there were also deeper reasons, a wish from the "logical" and "objective" natural sciences to make a clear separation from other fields of knowledge so as to rid themselves from "illogical" and "subjective" feelings and their consequences dogmatism, superstitions etc. One can even get the feeling that sometimes artificial differences and barriers were introduced and promulgated between the different areas on the spectrum.

Today the "division of knowledge" has reached a level where it is rather uncommon for a person to have a deeper knowledge of more areas than one. Another interesting phenomenon is that many people make it a point that they do not know anything about a certain subject: "I've never understand anything about math. I've tried, but I just can't learn anything." Such remarks are common, normal and do not lead to any comments.

The "division of knowledge" is also reflected within the educational system, which thus supports and enhances the division. Perhaps most obvious is that most school systems are based on the concept of subjects. A subject can be seen as the teaching about a certain part of the spectrum mentioned above. Due to the separation, in school, at higher levels of education and in society as a whole, the different subjects have taken on different characters. The teaching within natural sciences has often been, in a general sense, theoretic. The teaching within art has been based more on practical or hands-on experience. The assessment of knowledge has been based upon written exams or a "repetition of facts" within natural science whereas within the field of art assessment in many cases is based on the presentation of the pupils' own work and creations. In most cases, at least in Sweden, there has also been an implicit value placed on the different subjects from the "important" science subjects to more "fun" subjects, such as music and art. It is also common that the older we get the more subjects we drop and the smaller becomes our part of the knowledge spectrum. Of course, these are all generalisations, which are as true as generalisations usually are.

It is our opinion that the "division of knowledge", even if it in some sense has been both useful and practical, has, in many cases, introduced unnecessary limitations on the development of knowledge within the different areas of knowledge.

Information technology (IT) has the potential to change this and "bend" the spectrum back into a circle where all areas of knowledge are equally close to each other. The reason for this is that IT provides us with a new tool to use when collecting, structuring, transforming and presenting information.

IT's six changes

What is IT and how can IT lessen the division of knowledge? Here IT is to be understood as computers connected to each other through different networks. The networks provide an infrastructure that makes it possible for the computers to exchange information. The Internet is perhaps the most important computer network today. A main reason for this is that even though the Internet is a "network of networks" the users experience the Internet as a transparent and open platform.

There are at least six changes that are a direct consequence of IT and its underlying technologies. All are related to how we communicate and exchange information and knowledge between humans.

The first change is the transition from analogue to digital information. Digital information is easier to store and distribute than analogue (compare a vinyl record to a digital sound track). Digital information is possible to copy and multiply without any loss of quality. If information is stored in digital form it becomes easy to change the format of the information (e.g. from a table to a graph). The reason for this is that digital information can be seen as a sequence of numbers that can be manipulated by various algorithms. This is opposed to, e.g., a printed book or an oil painting that can not be operated on in such a way. All sorts of digital information can also be handled with the use of one machine: the computer. When using analogue techniques different machines were often required to present different media formats. The use of computers thus makes it easier and less expensive for everyone to work with information of different kinds. It becomes easier to transform and reinterpret data, to look for new structures or patterns. The use of sound, motion pictures, elaborate graphics etc. are no longer reserved for those who have access to sound studios or special printing machines. This makes it possible e.g. for engineers to present new findings in the formats currently used by artists.

The second change is related to two other characteristics of the computer: the computer's ability to rapidly execute simple instructions such as sorting, transforming or copying information and the computer's, in practice, unlimited (both in volume and time) memory. Humans, on the other hand, are, in most cases, not interested in performing simple, stereotype tasks. We also (luckily) forget pieces of information. Now we can leave the simple tasks and the remembering of all sorts of information to the computers and focus on what humans do better

than any machine, viz. imagine, invent and create. In the case of the natural sciences this could mean that we could rid ourselves of some of the "number crunching" and use more time to discuss the how and why of our problems. This could bring philosophy and science closer again.

The third change concerns computers going from standalone machines to being connected to networks. This change makes it possible for us to share resources and information between people. It also makes it possible to work together globally. One could say that the back of the computer has opened up and become a door to the world. It also becomes less and less important what computer you have on your desk and more and more important to what the computer is connected. Indeed, many would agree to that it is the network that is the computer. As the physical distance between persons becomes less important in regards to communication, exchange of information and collaboration shared interests become more important. We will see new communities develop, communities based on shared views and experiences. The members of these communities may develop a strong feeling of relation even though they may never have met each other. In regards to the discussion here this change means that it will become easier to meet persons, persons that you very well might not have had a chance to meet otherwise. Since the meetings will be global we will to a greater extent be subjected to opinions and traditions that differ from our own. This will help break the barriers between different areas of knowledge.

The fourth change concerns our roles as consumers and producers of information. Traditionally a majority were information consumers only. The production of information for a broader audience was the privilege of those who had the knowledge and resources to put up a printing press, a tv-studio etc and had access to proper means for distributing the information. In many countries the production and, perhaps even more, the distribution of information has also been severely regulated. Today anyone with a computer can become an information producer. This means that we will all go in and out of the different roles, being producers within our fields of work or interest and being consumers otherwise. The computer has made it possible for everyone to access all types of information with one tool and to create information in any format. The networks in turn have made it possible to reach a worldwide audience. This also means that our information or knowledge to a greater extent than before must compete for the attention of the intended audience.

The fifth change concerns the formats of information. We see today how the primacy of text is removed and how all formats become equally easy to handle. The dominant role of text is a legacy of the printing press. This technology made it possible to create and multiply texts at a low cost per copy. Images, sound etc. were not possible to handle in the same way. Computers treat all formats equally which makes it possible to use the format of information that suits the needs best. In a sense we are witnessing a return to pre-printing press times when text and pictures were equally easy (or hard) to make and copy. The beautiful, hand written books from medieval times illustrate a way of presenting information that has been lost and now is being reinvented.

The sixth change is about issues and what we may call concurrent publication. We are used to the fact that a piece of information is permanent in the sense that once it is published, as a book, a film, a picture, then it is impossible to change the information except if you publish a new version. What happens now is that we see "living" or dynamic pieces of information. Information, while available for the consumers, can change with time. It is also possible to change the information according to who accesses it or even with the specific user's needs.

Taken together these six, in many ways fundamental, changes will create a new landscape of communication and information exchange. New and larger groups of society will be given tools to work with more and different formats. This will have a direct impact on all sectors of society where information and communication play a central role. The educational sector is one such sector.

IT in the educational system

The changes described above have all had impact on the educational systems of the world. Actually it appears safe to say that no other technology has had such an effect on education in such a short time as IT.

An explanation for this could be that to achieve its goals (which in most cases can be summarised as "to increase the knowledge of the students and improve their skills in various fields") an educational institution typically carries out activities that can be grouped into five categories: communication, presentation, information retrieval, use of tools and developing skills.

Information technology provides a new and powerful infrastructure for working within the first three categories. If school also should prepare pupils for working life, then IT is also of use in the last two categories. Few things have such a broad.

More directly, how do the described changes affect the educational sector?

For one thing new "doors" are opened between educational institutions and the rest of the world. There are many examples of how IT has been used to create new ways of communicating between students and persons from universities, government bodies, companies, organisations etc. The simplicity of sending an e-mail makes it possible for students to interact directly with students in other countries or with experts in different fields. The World Wide Web has made information readily available for everyone, information that earlier was hard or impossible to access.

It is also possible to see a change in what is taught in school and how. The new ways of handling and presenting information reveal connections between subjects, which tend to lead to that subjects change and merge. An example is that in many schools art and music classes merge into a media class.

The availability of information and the ease with which information can be collected from experts imply that the role of teaching materials changes. The most obvious change is that a common teaching material, used by all students in a class or perhaps even in a country, is replaced by individual sources of information collected by each student.

There are also changes taking place within the educational sector whose coupling to IT is less clear. However, experience show that these changes often occur in parallel with the introduction of IT and the direct changes that follow from this. One such change is a shift within education from results ("What is the capital of Brazil?") to processes ("How do we find the name of the capital of Brazil and why do we want to know that?"). Other changes include teachers working in pedagogical teams instead of alone with individual study plans for each student and 40-minute lessons being replaced by longer "working blocks". Interesting is also that whole schools are being rebuilt, from "knowledge factories" to something that looks more like an ordinary workplace.

One should also remember that the pupils and students that leave school today encounter a new work environment. 100 years ago about 80 percent of all Swedes worked as farmers, today the number is 3 percent. The numbers for those working in traditional industry has changed in a similar way, from 50 percent 40 years ago to less than 25 percent today. So where does the jobs go? It is generally believed that by the year 2010 more than half of the workforce will be engaged in work where information and cognitive processes play a central role. These changes will impose new demands on the educational systems of the world. This is indeed a challenge since those that start their careers as teachers today will educate children whose work life will end around 2100!

The Interactive Institute – doing research where art and science meet

In many cases IT has already had an impact on the educational systems. Still we are only in the beginning. There is much more to be done if IT is to bridge the division of knowledge.

One initiative in this field is the Interactive Institute[3], a new Swedish research institute. The overall aim of the Interactive Institute is to combine technical and artistic research and production with reflection on the results and their relations to the users as well as society at large. The vision of the institute is to improve interaction and communication between individuals, groups, and organisations through innovative use of art and technology. The vision is to be realised by creating a setting where researchers and students can meet and through cross-disciplinary research develop new services and products.

The Interactive Institute consists of a network of studios spread over Sweden. The institute and its studios are closely connected to academic institutions, industry and the public sector[4]. Collaboration with international institutes[5] is also a natural part of the institute's activities.

One important activity within the institute is to initiate meetings for persons with different backgrounds and competencies. The idea behind this is that a creative process is based on an exchange of information. To assume that the information needed in this process is well structured, takes on a well-known form or follows a known sequence is not possible. What is certain, however, is that creative processes need direct interaction between humans in ever changing combinations.

The main "deliverable" of the institute will be creative, interdisciplinary persons with an understanding not only of technology and art, but also of what it takes to bring new ideas to a larger audience. Studio and project

[3] http://www.interactiveinstitute.se

[4] E.g. the University College of Arts, Crafts and Design, The Royal University College of Music, The Centre for User Oriented IT Design at The Royal Institute of Technology, Ericsson, Volvo, IKEA and Telia.

[5] E.g. MIT Media Lab, GMD in Germany, Domus Academy in Milan, Goldsmith College in London and InterMedia in Denmark, Yamaha, SEGA, LEGO and Warner.

results will be presented as reports, demonstrators, exhibitions, and other formats depending on what is suitable for each studio. The institute will not deliver market-ready products, but ideas and prototypes that together with an entrepreneurial atmosphere will contribute to new business enterprises.

Admittance to the institute will not only be based on traditional academic merits. This allows young, creative persons who would never go through the normal academic career to work at the studios.

The institute will work within a number of fields among which are smart environments, expressive media, user-oriented design for everyday use, environments for day long and life long learning, and studies in learning and co-operation.

In smart environments embedded computing devices enable rich experience of the environment that can be used for enhancing daily life as well as for art, education and media expressions. Sensor techniques can be used for, e.g., controlling information presentation through detecting presence and movement of people and objects. The work will need a combination of applied aesthetics in text, images, sound and spatial expressions together with advanced sensor and tracking technology. Smart environments can also be used to support the construction of interaction devices and reactive environments that are usable by artists, performers and audiences. Through a combination of expertise in the fine arts and performance arts, hardware and software development, computer science and social science, principles for constructing interactive artistic environments can be developed.

Another interesting field of work is tacit knowledge. While explicit knowledge is possible to formalise and share through the use of "languages", written, spoken or expressed in pictures or sounds, tacit knowledge can not be treated in this way. Thus, to share tacit knowledge in an educational situation demands other methods than to share explicit knowledge. Tacit knowledge is sometimes called "knowledge through experience", which illustrates how this type of knowledge is best transferred. In a classic classroom situation the focus has been on explicit knowledge. With the use of IT it becomes possible to create environments where experiences and tacit knowledge can be shared. This could e.g. make it possible to help students in developing their personal judgement and attitudes to different subjects. A person's ability to make judgements and his/her attitude towards different aspects of life are important for their functioning in society and working life.

The use of digital worlds and mixtures of real and virtual meeting places are also interesting for the educational purposes. One example is information assistants represented as animated characters, which are increasingly being explored as a complement to traditional, direct manipulation, visualisation interfaces. Virtual "doors" connecting different geographical places is another example of how IT can create new ways of meeting and interacting. This has already been tried in one case where a secondary school in Rågsved, a suburb of Stockholm was linked to Arlanda international airport. The pupils, who represent many different cultures, could meet and talk, in their own languages, with those passing through the airport.

The institute will also try to explore how the commonly used method for providing the public with experimental learning opportunities in science and technology can be extended to art, social sciences and the humanities. Major "science experimentarium parks" exist in many cities throughout the world. The institute is involved in one "cultural experimentarium" project and one that will exhibit not the technologies used today but those of tomorrow. The later exhibition will be located in an old industrial area outside Stockholm. On the premises there will also be two high schools, which will make it possible to directly involve high school students in the institute's work.

Even if IT offers many new possibilities it is also of importance to investigate possible problems of using IT on a broad scale. What happens when virtual reality is perceived nearly as intensely as material reality? What happens to us and our conditions for living and working when fact and fiction blend? One example of what may happen is in industry, when the physical processes at a distant location are monitored virtually in central control rooms. This is one of the main reasons for alienation and loss of skills.

The Interactive Institute will strive to become an internationally well known meeting place were work will be carried out in the areas described above as well as others. The work carried out will, hopefully, also show how the benefits of combing knowledge, bridging the division of knowledge.

Concluding remarks

We believe that the teaching of mathematics, science and technology has much to gain from the use of the means of expression and thinking used in the creative arts. We also believe that the methods and tools developed within the natural sciences can be used to develop new forms of art. As pointed out in one of the proposals for a studio within the Interactive Institute:

> "Artistic experiments in themselves are not research. Close co-operation between artists and researchers is necessary for beneficial results. Researchers get in contact with artistic ways of approaching problems that may result in new solutions, and artists are inspired by new technologies to developing new forms of expression."

In another proposal it is concluded that

> "many recent international research projects in areas such as Human-Computer Interaction (HCI) and Computer Supported Co-operative Work (CSCW) already blur the line between IT research and artistic expression – our aim is to remove that line completely. Since we are working with the use and implementation of new technologies with the potential of creating a high impact on modern culture, we find it only natural that our work is informed by trends in popular music, literature, movies, visual and conceptual art, comic books and computer games."

In yet another one it is stated that

> "modern information technology radically changes the conditions for research and development in the humanities, cultural sciences and natural sciences, letting them adopt a more interactive approach to their research objects, doing virtual 'laboratory work', which will also move them closer to, and strengthen their role in creative cultural work, like art, literature, drama and industrial design."

The "division of knowledge" may have contributed to a clarification of different knowledge areas specific problems and possibilities but it has also limited the toolboxes available within the different fields.

In our opinion much can be gained by combining art and science. This can be done in various ways but we see IT as an important tool for this.

Ethics and the Internet - Soft Issues and Hard Wares

how to Handle the Ethical Problems and Possibilities of Internet

Stig Roland Rask, Fredriksdal School, Lidkoping Sweden,
supported by the Swedish Foundation of Knowledge and Competence Development

My name is Stig Roland Rask, I was born in 1953 and have been working as a teacher in Music, Social Society and Religious Education at Fredriksdalskolan (Fredriksdal School) in Lidköping since 1980. Lidköping is a little town of approximately 40,000 located between Sweden's two largest cities, Stockholm and Gothenburg, just south of its biggest lake, Vänern. Fredriksdalskolan has 325 students between the age of 13 to 16, which is the upper level of the Swedish primary school.

I am also the manager of a project named "Ethics and the Internet – soft issues and hard wares" which receives support from the Swedish Foundation of Knowledge and Competence Development. This foundation was established in 1994 by the Swedish government, and was endowed with over $450 million to promote the use of IT, to stimulate research in new areas at universities and to create knowledge transfer. Over $100 million of these funds are being invested in primary and secondary schools. The goal is to obtain concrete results and spread these results to the entire educational system to create a long-term ripple effect. Ethics and the Internet has developed into a special project area among the Foundation school project, and the students at Fredriksdal's School have become pioneers in this field. I am proud to say that our project "Ethics and the Internet" is one of the projects in this program that have attracted the most attention. Our idea of combining traditional and eternal ethical issues with modern technology has been viewed as surprising, exiting and interesting.

Internet – the ethical marketplace

New technology always challenges our ethical views and the Internet is certainly no exception. Does not necessarily mean that we need to create new ethical opinions – our old system of ethics is still valid - but perhaps we need to re-express and reformulate our common foundational values, and apply our conclusions to this new area that the Internet has created.

The over all aim of the project "Ethics & Internet – soft issues & hard wares" is to develop pedagogical methods that will make it possible for questions of democracy, humanism and ethical values to find their place in a modern school. The appearance of the Internet just gives us one more reason to take these issues seriously. As a teacher I have a responsibility not only to transmit facts, but also to help the students in their emotional development and their growth into social maturity. I think that the way to understand oneself, society and the world we live in arises from a combination of theoretical knowledge, emotional ability, social maturity and ethical awareness. That's why we must involve both the brain and the heart in our considerations and try to pay attention to all of these aspects in our pedagogical plans.

I think that the best way to stimulate these ambitions is to bring the students face to face with ethical standpoints and let them take part of the debate. During this process we have found that the best way of getting in contact with all kinds of opinions is to use – the Internet! In a few years Internet has grown to become the main meeting place for ethical discussion. The Internet is the ethical marketplace where every kind of opinion, attitude and view can be found. This means that in the same time as the Internet challenges our ethical viewpoints – it offers us a superior tool for developing methods that will stimulate our ethical education.

Soft Issues & Hard Wares

In the most concrete part of the project we let the pupils chose an ethical question that they are interested and engaged in. It could be everything from abortion to euthanasia, from child labor to animals rights, from weapon export to genetic engineering, etc.

The student's task is to produce a report based on seven given subheadings...

- presentation of the issue
- facts
- arguments for...
- arguments against...
- the actors in the discussion
- something about their own thoughts, ideas and reflections
- sources

If, for example, the students are interested in the issue of child labor they may want to visit the homepage of UNICEF, if they have chosen to study death penalty a visit to Amnesty Internationals homepage could be interesting, and if they engaged in environmental issues perhaps Greenpeace could offer one point of view. To help the students we have established a collection of links that will connect them to the ethical debate in a number of areas. This link collection is dynamic and new useful sites found by the students are immediately added to the list.

Their report becomes one chapter in an ethical book that every class produces, and this book will be the basis for a debate that takes place in the classroom. Our experience is that whatever ethical issue the students choose to study, the Internet offers them facts and opinions in seemingly endless ways.

The eight targets

We have formulated eight targets that we hope that our project will help the students achieve:

1. Ethical awareness – the students will be aware of that life contains a vast number of ethical issues that sometimes demand personal decisions and selections.
2. Computer competence – more a side effect than a goal, it is interesting to see how the Internet has changed the role of the computer from being a closed room to become the door to the outside world.
3. Pedagogical progression –optimal learning ability is reached when the students are searching for answers to questions that have been formulated by themselves. Establishing this pedagogical situation in the classroom is critical.
4. Increased international perspective – Internet has no geographical borders.
5. Awareness of the necessity of languages – The need to study English goes beyond the next English exam.
6. Social maturity – developing maturity requires tasks that demand maturity.
7. Emotional intelligence – information is not equivalent to knowledge - and knowledge is definitely not equivalent to wisdom.
8. Increased equality – we must offer reasons for both the girls and the boys to sit down the computer. Ethical issues on the Internet are an example of such a good reason.

The answer to its own question

Our experience tells us that if the ethical issues will show the way to Internet, the attitude and knowledge the students receive will follow them throughout their future use of Internet. This is an important and very positive effect. It is crucial for Internet users to develop their ability to be critical of the opinions and attitudes behind the information they have researched. It has been our experience that the students learn to be more critical of their sources if they are allowed to work this way. If the students use the Internet when they are reflecting on ethical issues, they will achieve a new awareness through the information provided. The pupils will learn that the Internet is a medium providing subjective information, which need to be carefully reviewed. That is why we have come to this simple but perhaps slightly paradoxical and surprising conclusion that the solution to the ethical problems of the Internet is the positive use. The Internet is the answer to its own ethical question.

Protection & Preparation

So far I have only described Internet as an ethical possibility. But you can not avoid the fact that the Internet also contains information that is definitely dubious from an ethical point of view. Just a mouse-click away from a good and useful site, you can find another site that shares disinformation or even destructive material.

As far as I can see there are only two ways to protect from the Internet's dark sides: Isolation or vaccination. The same methods that we have at our disposal in the face of approaching disease. Both methods offer protection, but the problem with isolation is that its effects are not lasting. Vaccination, however, allows the disease to be faced without getting infected. There is just one problem left to solve – developing the vaccine!!! I consider the development methods to vaccinate our teenagers against the different destructive components in the information society, to be one of the most important questions that a modern school has to handle. We hope that our project in some way will contribute with useful ideas.

I think that it is a good idea to compare a good attitude toward the Internet with a good attitude toward deep water. When our children are small, we bring them carefully to the quay or the riverside. We hold their hand firmly, show them the deep water and tell them about its danger. After some years they begin to develop their own awareness. We can let them go on their own, but we still follow them with watchful eyes. Likewise, we put our children into swimming lessons. The best way of protecting our children from the danger of deep water is to teach them to swim. The water will be used as a pedagogical tool to solve its own problem. You can look upon our project analogously. We use the Internet in our ethical education in the same way a good swimming teacher uses the water in his swimming education. It seems like a good idea – doesn't it! Sitting on the beach and learning how to swim will be boring after a while.

The most important point is that there is no long-term solution in isolation. We could never get rid of our responsibility by leaving it to cyberwatches or netnannys. If we equip the children with too many life preservers, safety belts, crash helmets, air bags, safety nets and bodyguards we will perhaps forget to tell them that life is dangerous. They will face real life without the awareness and preparedness that will be necessary. In a world that is the way it is they will run the risk of being very vulnerable. As teachers we must prepare our pupils for a life outside of the family and the school, where they are beyond the reach of our shelter and our warnings. If, for example they haven't developed their ability to chose and select in this enormous media flow that the Internet is just one part of they will certainly drown.

New technology necessitate ethical guidance

As a teacher I have a responsibility not only to put ethical discussions on the agenda, but also to give ethical guidance. There are components in a democracy that are so fundamental that they should not only be discussed - they should be transmitted. Experience has shown that many young people view the adult world as unclear and lacking when it comes to providing the guidance they need. Has the school failed to live up to its responsibility of providing guidance concerning the ideals that make up our democratic society? I believe that the development of the Internet necessitate that ethical issues must be given greater consideration. Developing methods that will make this mission possible and successful is one of the most important tasks for a school today. Our experience tells us that the use of new technology can be one of the pieces in this very important puzzle. The Internet could be the solution to its own problem, the answer to its own question.

Stig Roland Rask

Fredriksdalskolan
Floragatan 4
531 36 LIDKOPING
SWEDEN

Tel +46 (0)510-770630
Tel +46 (0)510-14343
Fax +46 (0)510-770623

http://www.fredriksdalskolan.lidkoping.se

rask@swipnet.se

MATHEMATICS PAPERS

Computer Based Instruction and General Logic Actions Development in Teaching Mathematics

Mikhail M. Bouniaev
Math/Cs Department
Southern Utah University
United States
bouniaev @suu.edu

Abstract: In this paper based on the theoretical foundation of Stage-by-Stage Development of Mental Action Theory (further on DMA theory) we analyze the structure of different actions of undergraduate mathematical courses that must be developed in students minds. We also try to answer the question how information technologies can be used in developing general logic actions, that are mental by their nature. We use as factual material the experimental data obtained in teaching calculus, linear algebra, abstract algebra and mathematical analysis.

Introduction

The foundations of the DMA theory were developed in the 50s-60s by Russian psychologists: A.Leontiev (Leontiev,1972) P. Galperin (Galperin&Talizyna, 1979), T.Talizyna (Talizyna,1975). The theory was further developed by M.Bouniaev (Bouniaev,1991) in application to advanced mathematics and computer based instruction. In this paper we do not focus on the basic concepts of the DMA theory, therefore we'll try to use only notions that can be understandable at intuitive level.

Basic notions of the DMA theory are: activity, action, operations. For any concept there exist generically inherent for this concept actions aimed at the objects that can be attributed to this concept. An object exists in the students mind only if they can perform generically inherent actions aimed at this object. The more actions generically inherent for the given concept are developed in a student's mind the more advanced level of the concept is constructed in the student's mind.

Thus, if we take developing the function concept as an example, then the main actions to be developed at the initial level of understanding are that of function evaluation and the action of representation of the simplest functions as graphs. At the next level arithmetic operations, composition, attributing the function to different classes of functions (linear function, quadratic function, polynomials, rational functions etc.) are to be developed. The next actions to be developed are: the actions of finding limits, differentiation, integration, action of prove that involved function concept etc.

According to the DMA theory the process of instruction is considered to be a process of developing mental actions with objects of the studied field. Teaching is understood to be managing and controlling of the mental actions development process. All actions can be referred to two categories: specific actions and general logic actions. Specific actions are basically inherent in a given subject field.

Examples of specific actions in calculus: function composition and arithmetic operations with functions, differentiation, integration, finding limit, etc. In linear algebra: performing elementary row operations, reducing matrices to the reduced row echelon form, finding solution set of a system of linear equations, arithmetic operations with matrices, finding eigenvalues and eigenvectors, finding basis for the given linear space, representing linear transformation as a matrix, etc.

Examples of general logic actions.

1. Classification: classify all given functions for monotone functions and functions that are not monotone; classify all given matrices for symmetric matrices and matrices that are not symmetric.

2. Attributing to the concept: attribute matrix to the concept of matrix in the reduced row echelon form; attribute function to the concept of continuous functions
3. Implication: if a function is differentiable then the function is continuous; if the determinant is equal to zero then the matrix is nonsingular

Note, that modern software such as MATLAB or MATHEMATICA can execute almost all listed above specific actions. Performing specific actions manually very often is a time consuming process and does not add much to the understanding of the concept. A good example of this type of specific action is a reduction of matrix to a reduced row echelon form. General logic actions must be executed mentally and information technologies can be used only at the preliminary study that lead to some conclusion.

Action Structure and the Role of Technologies

Usually the goals of teaching math courses are defined either in terms of major specific actions that are planned to be developed in this course or in the terms of basic concepts of the course. Thus the goal of teaching calculus may be defined in the following way: to teach students how to differentiate and integrate and how to apply calculus to problems in economics, physics, mechanics; how to interpret and process data in terms of calculus concepts and notions. For linear algebra and abstract algebra it is more usual to formulate goals in terms of concepts to be developed. For example, to develop a concepts of linear space, linear transformation , etc.

When the question arises about the goal of today's class, usually the answer is given in the same form of specific actions to be developed. For example, to teach students how to find a limit, or how to differentiate rational functions; how to find the solution of a system of linear equations; to develop a concept of linear independence; how to find rank of matrix or bases of row space etc. It is natural that the goals of learning a particular subject are formulated in the terms of specific actions and notions of the subject.

But does it mean that the objectives also include developing only specific actions? In teaching practice usually this is the way it is. The sets of examples or model problems that we want students to know how to solve, usually play the role of objectives for a particular lesson. So, in classrooms we spend most of our time developing actions that can be executed by computers or calculators. But at the same time students are pretty comfortable with modern calculators and quickly learn by themselves how to obtain an answer without performing huge computations. The problem they are facing is what sequence of actions must be executed, in what order, and why.

The DMA theory also offers a method of structuring an action. For the purposes of this paper it is sufficient to consider the structure of the operational composition of an action. As a rule, performed actions consist of other, more primitive actions, which in their turn can be part of other actions. Actions that are part of a given whole are called operations. To simplify the concept we may assume that operations are also actions. Hence the term "operation" implies the hierarchical subordination among actions.

Let us consider an example from calculus i.e. the action of finding a limit of a rational function. Let f(x) = P(x)/Q(x), where P(x) and Q(x) are polynomials, and the action of finding limit of f(x) when x converges to **a** is performed. The method of solution depends on the value of functions P(x) and Q(x) at the point **a.**

There are three different cases, each one implies different method of solution.

The first case: Q(a) is not equal to 0.

The second case : Q(a) is equal to 0 and P(a) is equal to 0.

The third case: P(a) is not equal to 0 , but Q(a) is equal to 0.

The forth case: a is either plus infinity or minus infinity

Before starting the computation students have to understand what class this problem belongs to. Therefore, the first operation of the action performance is attributing the problem to a class of objects. This is a general logic action. It has to be performed mentally, calculators can be used only for the purpose of function evaluation at a given point.

Assume that the problem is attributed to the second class. For example $f(x)=(x^3-1)/(x-1)$. Then, students have to decide what method of solution must be chosen. Hence, the next operation is also a general logic action of implication that has a pattern :"f(x) belongs to the second class" implies "apply the method of solution of the problems of the second class". The method of solution consists of factoring out (x-a) from P(x) and Q(x), rewriting f(x) in the form of f(x)= (x-a)P'(x)/(x-a)Q'(x) and canceling the multiple (x-a). The last three operations are specific actions that were developed in the intermediate algebra course.

If we want our students to perform this action manually probably it will take some time to remind them how it can be done and it will take them some time to perform division. But this is not a major problem. The major

problem is that this particular task diverts them from the concept that they are trying to learn. So the best we can do to avoid this effect is to use technologies to perform the action of polynomial division.

As a result of performing the described above operations, new function $f'(x)=P'(x)/Q'(x)$ was constructed. The entire procedure with respect to function $f'(x)$ is repeated. If $Q'(a)$ is not equal to zero, then the limit is equal to the value of function $f'(x)$ at point a. If $f(a) = 0$, then attribute problem to class I or class II and apply an appropriate method of solution.

As we could observe the action of finding a limit consists of general logic and specific components. As experiments show the students ability to perform the action of finding a limit mostly depends on their ability to perform general logic actions. Specific actions of factoring, canceling, determining the sign of a function (in case when the function belongs to the third class) can be executed by technologies.

The same conclusion can be made in general. If we analyze specific actions to be developed in the calculus course we'll find out that a lot of these specific actions have a general logic component. Mostly it is this general logic component that causes difficulties for students in performing the entire action. In the course of training attention should be focused on developing general logic actions. Specific actions, that have already been developed at the previous stages of instruction, can be performed with the help of technologies.

In our experiments while teaching the topic "limit of functions" to one group of students general logic actions were developed separately from specific actions. While developing the entire action we discriminated all operations and showed students what operations compose the action. For example, studying limits computational technique with the experimental group we spent approximately 80% of time developing the general logic component and just 20% developing the action as a whole.

In the control group we did not discriminate operations from each other. In our short presentation and in student practicing the action performance looked like a smooth process. We spent all time just developing the action as a whole.

The test that we gave in both groups at the beginning of the calculus class showed that the level of performance of algebraic actions was approximately the same in both groups. The test on limits and our discussions with students showed that the level of performance as well as the level of understanding of different types of situations that may occur in the computation of limits was much higher in the experimental group.

The action of attributing to the concept and action of conclusion are parts of the action of finding a limit of rational function. In almost any mathematical problem we can find these two actions as operations. And in most cases the ability to perform these operations is vital for performing the entire action. Almost all other operations in the action development but general logic actions can be performed with the help of technologies.

Let us consider an example from linear algebra prove oriented course : prove that if **M** is nxn matrix and **a** is a vector in a n-dimensional Euclidean vector space, then multiplication by M is a linear operator .This action itself is an action of attributing to the concept. But while performing it students have to execute some specific actions – matrices multiplication , matrices addition, multiplication of a matrix by a scalar. Performing these operations manually adds nothing to developing the concept of linear operator, so in this case it also makes sense to let technologies to do it.

Let us show that the logical structure of an action of attributing to the concept has the following pattern that can be described in general (not depending on domain terms).

The logical structure of the action of attributing to the concept.

I. Description of an object of an action.

Verification that the procedure of the attributing to the concept is applicable to this object.

In the example with the linear operator concept students have to understand what function is determined by matrix multiplication. In the example of attributing rational function to one of three groups students have to understand what rational function is and what polynomials P(x) and Q(x) are used to define this function.

II. Listing properties Pi (I=1...n) to be verified.

III. For i=1...n verification of Pi.

IV If Pi is true, verification of Pi+1. If Pi is not true the object does not belong to the concept.

V. If for any i Pi is true the object belongs to the concept.

VI. Verify whether all properties Pi (i=1..n) are checked.

All operations but the operations of verification of the properties must be performed mentally. Operation of properties verification can be performed with help of technologies.

In the process of teaching any mathematical course we can gradually and consistently develop the action of attributing to the concept with the described above logical structure, but different objects and different properties to be verified. As our experience shows if we do it systematically and encourage students to discriminate all operations

including logical component of the actions to be developed, in a month or two the students feel comfortable when new objects along with specific actions appear in the course.

It is not hard to see that first of all general logic actions of attributing to the concept and implication occur in the undergraduate mathematics. These actions are kind of "prime" general logic operations, that can not be represented as sequence of some other logical operations. But in advanced mathematics a lot of other general logic actions are involved. For example classification, comparison, choice, establishing hierarchical relations etc.

As we have already demonstrated the action of attributing to the concept and the action of implication are the most important actions of undergraduate mathematics. But this does not mean that we have to limit ourselves to developing just these two actions. There are at least three reasons for it. First of all a major goal of any mathematical course is developing specific actions of the field. Development of other general logic actions can contribute to this task. Then, when a general logic action is developed, and attributing to the concept performs the role of an operation we at the same time develop attributing at the new level. And finally, if mathematics does not take care of general intellectual development of students what subject does?

The DMA theory prescribes five stages of action development. General ideas how technologies can be used at different stages of action development were described in M.Bouniaev (Bouniaev, 1996). Here we focus on the second stage, when general logic action must be developed in the material form. The material form of action is connected with manual activities (manipulation, hands-on activities, hands-wave activities etc.). Objects of action are presented in the material form. When students work with manipulative they perform actions in the material form. But there may be other manual activities as well. For example, we can use the following computer-oriented problems for developing the action of classification in the material form.

Assume we have a table.

$F_1(x)=P_1(x)/Q_1(x)$ xa	The first case	The second case	The third case	The fourth case
$F_2(x)=P_2(x)/Q_2(x)$ xb				
$F_3(x)=P_3(x)/Q_3(x)$ xc				
$F_4(x)=P_4(x)/Q_4(x)$ xd				
$F_5(x)=P_5(x)/Q_5(x)$ xe				

The task is to paste a function in the first column and drag it to the appropriate column. So even the primitive features of computers let us develop general logic actions in the material form

If we analyze such courses as linear algebra or calculus or any other mathematical course of the undergraduate level we will come to the conclusion that majority of actions to be developed are general logic actions. Some examples of action of attributing to the concept to be developed in linear algebra course are the following: attributing a system of equations to the concept of system of linear equations; attributing a matrix to the concept of matrix in reduced row echelon form; attributing matrix to the concept of symmetric matrix; attributing a set with addition and scalar multiplication to the concept of vector subspace of the vector space etc. To perform most of these actions it is necessary to perform only three operations: design certain matrix, reduce this matrix to reduced row echelon form, make conclusion, based on the form of the matrix in reduced row echelon form. The most time consuming operation can be performed with technologies.

Conclusions

General logic actions are an integral part of particularly any action to be studied in a math course. The success of performing an action as a whole is determined to a great extent by the ability to perform its general logic component. Thus particular attention in the teaching process should be paid to develop the general logic component of the action. Specific actions should be developed with the help of technologies. This approach significantly increases the effectiveness of developing an action as a whole.

The level and diversity of development of general logic actions determine to a great extent the level of intellectual development of an individual, his/her ability to adequately and critically judge the reality. Diversity of general logic actions that were developed with objects of abstract nature make it easy for an individual to process data with objects from any domain. The study of undergraduate mathematics (calculus, abstract algebra, linear

algebra etc.) provides an ample opportunity for development of general logic actions to the benefits of both intellectual development of students and the learning process of mathematics. Performing specific actions with the help of technologies contributes a lot to the process of development of general logic actions.

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Visualizing Mathematics: On Motion's Mettle

VM Camerlengo
University of Alaska Anchorage, USA
Secondary Mathematics Education
afvmc@uaa.alaska.edu

Abstract. The dynamic presentation of mathematical concepts should be directly engaged, via computer technology, in the teaching and learning of mathematics. The National Council of Teachers of Mathematics has defined the number one mathematics curriculum standard as problem solving. In order to concentrate on implementing strategies and heuristics of problem solving, students have to possess knowledge of mathematical facts and concepts as a necessary pre-requisite. Three examples from different areas of mathematics - geometry, algebra, and number theory - illustrate the possible contributions of technology in helping students retrieve and apply the needed conceptual information. Pedagogical techniques for integrating computer strategies in the teaching of Calculus are suggested.

Introduction

As we look towards mathematics education in the third millennium, we see a continuing focus on developing proficiency in mathematical problem solving. At the end of the last century the questions that were considered were concerned with what comprised problem solving and whether problem solving should be the emphasis in instruction. Now we are faced with deciding when and how it can be implemented in our classrooms. The developments in computer science technology over the past twenty-five years provide a base for the answers to when and how. The current availability of programs and interactive video that consider the visual-spatial component of mathematics point us toward a curriculum that will use the increasingly present technology to its fullest. The relationship between the visual use of factual knowledge and problem solving is analagous to the Christmas hysteria depicted in the following lines:

It's Christmas Eve and there you sit
With screwdriver, hammer, and the kit
Filled with nuts and bolts and "stuff"
Blueprints, designs, and if that's not enough
You hear the chimes and fill with despair
    It's 3 A.M. --- St. Nick will be there
    But the bolts are too many, the nuts too few
The screws don't fit -- what will you do?

Much like the harried father trying to successfully produce a completed doll house from the many pieces, problem solving requires artful application of many mathematical facts and concepts. The purpose of this paper is to delineate some ways that mathematical concepts, one of the necessary components of problem solving, may be presented in a visually enriched computer domain. Additionally, it suggests that through increased visual and spatial activity a method for selection and implementation of creative problem solving strategies can be found, particularly in the domain of proof generation.

While today's mathematics instruction includes - in some cases focuses on - insuring that students' learn mathematical facts, teachers are all too familiar with students who respond accurately to items of factual knowledge on a unit test but later are unable to recall them for use in a problem solution. The fact that memory can serve to produce what is needed at the time of immediate evaluation with little or no permanency of conceptual meaning is not surprising to the experienced professional, although it may seem inconsistent with the teaching strategies and activities that have been implemented in the classroom. Teachers ponder this fact and often decide that what is needed is more review of the basics. The following discussion presents another alternative to the more-of-the-same strategy: a way of linking conceptual knowledge through the use of dynamic motion and generalizations. In

addition, it suggests that through increased visual and spatial activity a method for selection and implementation of creative problem solving strategies can be found. The frustration experienced by the tired parent in the rhyme above would be resolved if a way to effect the organization and construction of the desired product could be discovered. Both the components and strategies in the form of visual schematics are necessary to achieve the problem-solving goal.

Teaching Today's Geometry

The mathematics education community today is taking a second look at the teaching and learning of high school geometry. Mathematics educators have reviewed the role of rigor and proof, as seen in the van Hiele levels; they have recommended the incorporation of technology through the use of computer packages such as the Geometric Supposer and have suggested that we teach geometry on the secondary level from both a synthetic and algebraic perspective (NCTM, 1989). This last suggestion includes objectives that address the student's ability to: represent problem situations with geometric models; interpret and draw spatial phenomena; deduce properties of figures from given assumptions; and apply and analyze Euclidean transformations. Secondary mathematics teachers would agree with the appropriateness, albeit incompleteness, of this set of objectives. They are aware of how difficult it is to teach the concepts necessary for achievement of these objectives. Students who have completed a high school geometry course often remember it, if at all, with confused concepts and fragmented pieces of the notion of proof (Senk, 1985). An expanded application of the notion of dynamic motion attempts to address the issue.

Visualizing a Proof

Consider an application of dynamic motion that results in an overview of a proof that can readily be "seen" and provides a plan for generating a logico-deductive corroboration in prose or T-proof format. The following sequence of dynamic visuals may serve to alter the student's perception that mathematics consists in *rules to be memorized* when he considers the following theorem,

> If a tangent and a secant are drawn to a circle from an exterior point,
> the square of the length of the tangent segment is equal to the product
> of the lengths of the secant segment and its external secant segment.

The most direct and literal diagram is shown below (Fig. 1). However, if we use the content-specific heuristic of defining appropriate auxiliary lines and construct GA and GR, we note that both triangle GRN and triangle GAN contain angle N. We now have one set of congruent angles, angle N, in both triangles (Fig. 2).

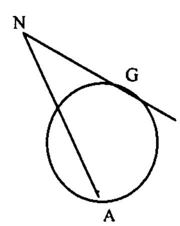

Figure 1

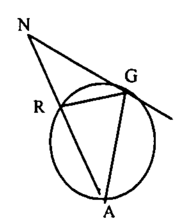

Figure 2

If we can locate one more pair of congruent angles, we will have similar triangles and can utilize its consequence, the proportionality of corresponding parts.

Applying another content-specific heuristic, that of looking for angles that intercept the same arc, we see that both angles NGR and NAG intercept arc GR and have the same measure. Since we now have the measure of two angles from triangle NRG congruent in measure to two angles of triangle NAG, similarity is established. We now disembed these triangles for clarity and precision (Fig. 3). We note that the separating of triangle NRG from triangle NAG is initially a rigid translation. One more movement that can be dynamically generated by the

computer is needed. We want to reflect triangle NRG about R and rotate it 120 degrees counterclockwise. Also, we need to move triangle NAG appropriately so that the orientation of

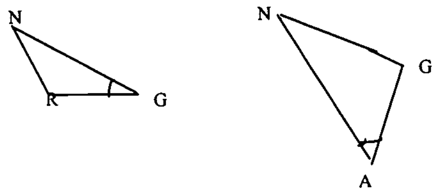

Figure 3

the two triangles more clearly reflects the similarity relationship.

One more movement that can be dynamically generated by the computer is needed. We need to reflect and rotate the two triangles RGN and GAN so that they are seen with the appropriate orientation (Fig. 4).

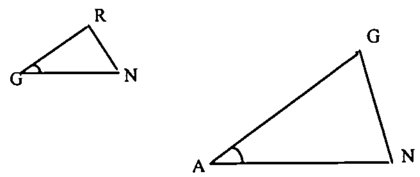

Figure 4

Since a consequence of similarity is that corresponding parts of similar triangles are proportional, it is clear that NG / NA = NR / NG. One more algebraic manipulation produces the result that is stated in the theorem. Since other equally accurate statements could be made throughout the development of this series of visualizations, students may compose their own interpretations and discuss them in class. Each student could be actively involved in constructing his own statement or definition of the concept.

Looking at Algebra

We have taken Piaget's suggestions seriously in the teaching of mathematics and have revised our pedagogy; we begin on the concrete level, move through the iconic stage, and finalize our findings with the abstract symbolic statement that we used to use to begin instruction. The current United States Secretary of Education, Richard Riley (Riley, 1997) along with many other federal voices dictate that we educate our middle school children so that *every* student who graduates from the eighth grade will be sufficiently proficient in both algebra and geometry to allow him full access to options open to him in high school mathematics courses.

Another example where we can replace the *rules to be memorized* in teaching algebra is the way we can now teach the completing the square technique in a unit on quadratic functions and their zeroes. We used to say to students that if you have a quadratic equation,

$$ax^2 + bx + c = 0$$

and you want to solve for possible solutions, you have three choices: factoring, if possible; completing the square; and the quadratic formula - which comes from completing the square of the general. The instructions used to be "Put the constant on the other side, take half the co-efficient of the first degree term. square it and add it to both sides of the equation." Let's take a look at how technology can pictorially make sense of these words. Suppose our equation is,

$$x^2 + 6x = 0$$

Of course, the simplest way is to rename the left side as $x(x + 6)$ and solve directly. However, if we wanted to model the completing the square technique, we could use - and often do use - the manipulative device known as Algebra Tiles. Alternately, the computer could generate the visual shown in Figure 5 to represent the square term and the six first-degree terms.

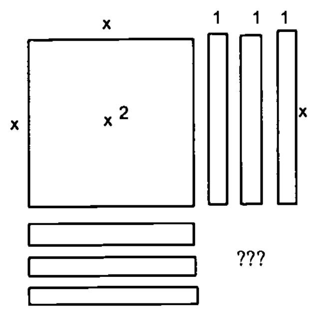

Figure 5

Simply by observing what needs to be inserted for the question marks to make the configuration a "perfect square," students can conjecture the visual schematic needed; clearly we need nine 1 x 1 tiles (Fig. 6). Since students have already been exposed to the balance notion of equations, they quickly realize that nine tiles have to be added to both sides. They see visually the meaning of the abstract statement,

$$(x+3)^2 = 9$$

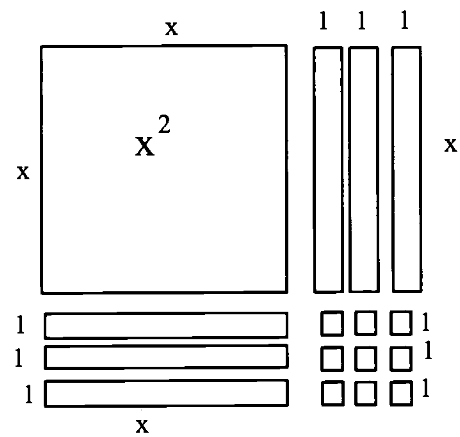

Figure 6

Seeing Number Theory Connections

In a senior high school college-preparatory mathematics class or in a beginning university mathematics course students encounter the formal expression for the sum of the first n positive integers. Most of us dutifully memorize that it is equal to $n (n + 1) / 2$. Let's consider a visual representation that clearly exposes the meaning.

```
                                  o o o o o
               o o o o            o o o o o
o o o          o o o o            o o o o o
o o o          o o o o            o o o o o

2 x 3          3 x 4              4 x 5
```

We can see that this configuration represents n (n + 1). If we divide the representations in half along a diagonal, we get the following diagram depicting n (n + 1) / 2.

```
                                  o o o o o
               o o o o            o o o o o
o o o          o o o o            o o o o o
o o o          o o o o            o o o o o
               2 x 3           3 x 4         4 x 5
                 2         2                   2
```

The only thing that needs further clarification is the picture in the half diagram. Certainly we can see that the number of pebbles in that region represent 1 + 2 + 3 + ... + n, what we originally wanted to show.

An interesting finding that manifests itself in this investigation involves movement again - movement of the half diagram region to appear as the triangular numbers, another ubiquitous concept in mathematics. Non-routine problem solving often involves the triangular numbers, as in the well-known handshake problem.

```
                                         o
                        o               o o
          o            o o             o o o
         o o          o o o   o o o o
o       o o o        o o o o          o o o o o

1         3          6              10
```

Clearly, these depict the triangular numbers; they also are represented by n (n + 1) / 2.

Wide Open for Calculus

The application of motion techniques to the teaching of Calculus topics is consistent with its history, structure and intent. Every Calculus course starts with an investigation of the movement of a point travelling along a curve to arrive at a limiting position of secant lines to produce the definition of a derivative as the limit of the secants, i.e., the slope of the tangent line to a curve at a point. The obvious visual representation, which should be presented in subsequent stages of generation, is simple and powerful. It allows the student to formulate the meaning of the definition that we usually find in Calculus textbooks.

Since one of the most important applications of the derivative concept is to optimization problems, we find in every Calculus text a collection of steps to follow to determine the existence and behavior of relative extrema. With the dynamic capabilities of the computer, the behavior of the first and second derivatives may be simulated in a generation of changing and moving-in-place visuals that would allow the meaning of the procedural process to be assessed and refined by the student. The important point here is that instead of beginning with another series of rules-to-obey to complete the homework assignment, the student constructs a procedure to follow as a consequence of his own visual-spatial activity. In both cases the assigned task is completed but with different internalization procedures. In one case the situation is viewed as a series of static, fragmented, somewhat independent steps where movement through the procedure itself is performed in a logico-sequential stepwise fashion. In the other case the

student's interaction with actively generated computer graphics results in an increase of visual spatial activity which serves to clarify and deepen the meaning of the process.

Closing Comments

Throughout this paper we have suggested some ways to capitalize on the notions of motion that are intrinsic to mathematics. This is very different from the static fait accompli approach that is frequently employed by many professors at some of our best universities; undoubtedly replicating the pedagogy by which they learned mathematics. The dynamic approach does carry with it the necessity of a different organization of the learning environment; indeed, of the philosophy of mathematics education itself. Students will have to move from the position of passive recipients of what many of them consider a completed and lifeless body of knowledge to constructivists who experience the joy of doubt, conjecture, and hesitancy to accept the principle without having looked at it from different points of view. Mathematics educators will have to provide the pedagogy and curricula models necessary to support the movement.

It's 3 A.M. in mathematics education! Are we still waiting for St. Nick?

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Using Interactive Diagrams as a Means to Promote Deeper Content Knowledge by Students and Teachers

José Castro-Filho
jacf@mail.utexas.edu

Jere Confrey
jere@mail.utexas.edu

Jennifer Wilhelm
Jwilhelm@astro.as.utexas.edu

Maria Meletiou
Meletiou@math.utexas.edu

Systemic Research and Design Center
For Mathematics, Science, and Engineering Education
The University of Texas at Austin
United States of America

Abstract: This paper discusses the use of an innovative technology, called Interactive Diagrams (ID's), to introduce the ideas of accumulation and rate of change in the context of banking transactions and balances. The study follows one teacher while using an ID called Bank Account (your ATM). We describe how the teacher used the activity as a catalyst to deepen her own understanding of rates of change and how those should be introduced in the Algebra I curriculum. The episode illustrates issues of appropriate and transitional technological design and effective professional development.

Introduction

This paper will discuss the use of an innovative technology, called Interactive Diagrams (ID's), as a transitional strategy to encourage mathematics teachers to begin a more extensive content-oriented use of technology. ID's are Java applets designed to address key ideas in mathematics and science (Confrey, Castro-Filho, & Maloney 1998). Though they are restricted compared to full-purpose software tools, previous studies have shown they have a great potential for exploring mathematical ideas both by students (Confrey, Maloney, & Castro-Filho 1997), and by teachers (Castro-Filho & Confrey 1998). In this paper, we will argue that ID's can be used with teachers as a catalyst for initiating more technology use around content topics. In a related paper, Wilhelm, Confrey, Castro-Filho, & Maloney (1999) discuss student use of the same ID using clinical interviews.

The ID, which will be discussed here, is called Bank Account. It was designed to investigate the ideas of rate of change and accumulation in the familiar context of banking transactions. Within that context, rate of change and accumulation are represented as the daily transactions (deposits or withdrawals) and total balance respectively. The Bank Account ID is used in the curriculum as one of the activities that bridge qualitative aspects of graphing and numerical analysis leading to slope.

There is extensive literature about rates of change (see Stroup 1998 for a review of the literature about rates of change and qualitative calculus). The majority of those studies have focused on students' understanding of rates of change. Typically, situations involving velocity (or speed), position (or distance), and time (e.g. Nemirovsky, Tierney, & Wright 1998; Thompson 1994) have been the focus. Very few studies have addressed teachers' understandings of rates of change. Thompson and Thompson (1994 & 1996) conducted a study in which one teacher and one of the authors tried to teach concepts of speed, distance, and time to a student. The authors pointed out that even though the teacher had a strong conception about speed, his focus was on the use of numbers and operations, instead of on the underlying concepts. In the conclusion, Thompson and Thompson emphasize the need to prepare teachers to teach conceptually. We argue here that by introducing technology and innovative curricular

approaches, we can create opportunities to discuss content knowledge and pedagogy with teachers that will support reform in mathematics teaching.

The Study

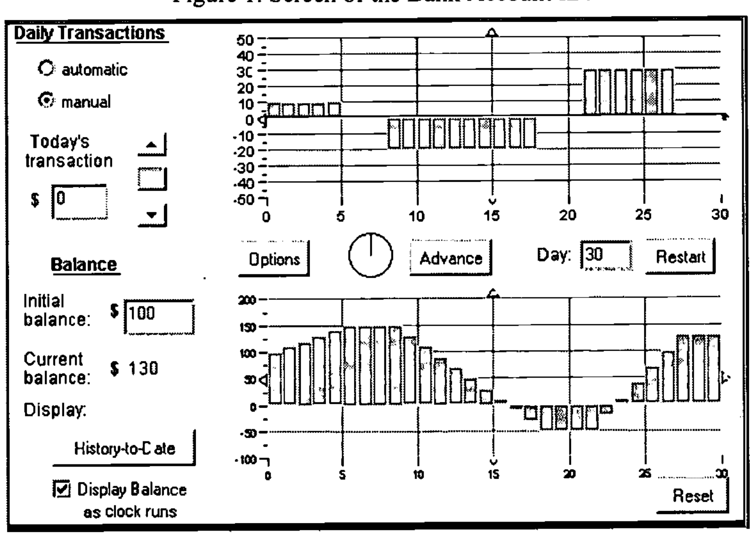
The study was conducted at Tree High School, an urban high school in Austin with a majority minority population of Hispanic students. Eight math teachers were implementing a replacement unit in the Algebra I curriculum (Castro-Filho in progress). The unit involved a transition from qualitative graphing through to simultaneous equations with an extensive use of technology. Although only the Algebra I teachers were implementing the unit, the whole math department was participating in discussions about the implementation of the unit and the effective integration of technology. Other issues were also investigated such as what teachers learn from implementing the unit in relation to content knowledge, pedagogical content knowledge, students' thinking, and technology[1]. The unit started with some activities on ratio, followed by materials on qualitative graphing with motion detectors and graphing calculators. The Bank Account ID was used as a transition from a qualitative sense of slope to more numerical aspects.

This paper will discuss how one of the Algebra I teachers planned and implemented a lesson using the Bank Account ID. Three data sources were used: interviews before and after the lessons, videotaping, and observations[2] of the classrooms. The paper explores the professional development demands and opportunities provided by the use of an Interactive Diagram designed to emphasize new materials.

The Tool and Activities

The Bank Account ID displays a daily transactions and a balance graph. The daily transactions graph is produced by pressing the button "advance." The value displayed in the "Today's transaction" box is recorded in the daily transaction graph and accumulated (added or subtracted) in the balance graph. A balance graph cannot be produced directly. A daily transactions graph has to be produced in order to create a balance graph. The graphs can be displayed as points or bars graphs. The purpose of the ID is to help students develop intuitive ideas about how to accumulate quantities to produce balance graphs and how to analyze balance graphs for rates of change to produce transaction graphs. The figure below shows the Bank Account ID, after two graphs had been produced.

Figure 1. Screen of the Bank Account ID.



[1] A more extensive analysis will be presented in Castro-Filho (in progress).
[2] The classroom observations were conducted by the first author.

A handout was provided to be used with the ID. The first part contained two word problems, one involving constant deposits, and another constant withdrawals. The problems asked to use the ID to model the situations and then asked to describe the shapes of the daily transactions and balance graphs. The second part asked to create a balance graph from a daily transactions graph and a daily transactions graph from a balance graph. In those graphs, both had constant deposits and withdrawals, as well as increasing and decreasing balances.

Results

The Teacher - Teresa

Teresa has been teaching mathematics for four years. In her previous years, she had taught an integrated mathematics and science curriculum for Algebra I. This is her first year teaching at Tree High School. She had used some technology for teaching before, mostly graphing calculators and spreadsheets. She was teaching two Algebra I sessions, and was observed in both periods. Before implementing the Bank Account ID, she had opportunity to use it in two different occasions, one at a professional development workshop and the other in a replacement unit planning meeting with all teachers.

When she taught the lesson on qualitative graphing using motion detectors, she noticed that students had difficulty understanding the relations between position vs. time and velocity vs. time graphs. She reported that, in a graph of position vs. time, students were able to identify when a person was walking away from the motion detector, towards the motion, or when a person had stopped. She also said that students were able to tell if the person was walking faster or slower and relate that to steepness of the graph. Their difficulties were encountered when they were asked to draw a velocity vs. time graph from a position vs. time graph.

In the pre-interview, Teresa predicted that the Bank Account ID would be easy for students. She predicted that as long as students understand what a balance and a transaction means, they would be able to explain that a balance graph will show changes for each of the increases [or decreases] day by day. She predicted that if they did not understand the terms, transaction and balance, they would only be able to independently describe the curve shapes. She also said that students should be able to perceive the difference between an increasing and a decreasing balance in terms of the deposits or withdrawals. She said she was not going to modify the activity, and was going to use the handout that was given.

Teresa used the Bank Account ID and the activities in two occasions. In the first day of the activity, she went to the computer lab with her students. She had assistance of two graduate students to answer students' questions during both periods. In her first period, she started by explaining how to operate the ID and assigned a handout. The handout contained two problems, both of which had constant transaction graphs and therefore linear balance graphs. One involved positive transactions and the other negative. She walked around the room helping pairs of students. Students completed the packet with relative ease and even undertook extension problems. Teresa commented on how engaged students were in using the computer and answering the questions. In her fourth period, students showed more difficulties with some questions, particularly with the ones that required them to predict or describe the shape of transaction and balance graphs. Halfway through the class, she reviewed with the class previous discussions about different types of slopes. She emphasized that when your graph is increasing it has a positive slope. When it is decreasing, it has a negative slope and when it is a straight line horizontally it has no slope or zero slope. She told students they should write in the handout what type of slope each graph had. For her, the purpose of the lesson was to relate the graphs through a concept of slope.

On the following day, she did not have access to the computer lab and continued to work on Bank Account problems. On these problems, students were asked to draw balance graphs from non-constant transactions and to derive transaction graphs that would produce the given balance graphs. The balance graphs were also non-linear although some could be analyzed as piece-wise linear. In these tasks, the teacher experienced her own conceptual difficulties. She was easily able to treat the activity as a numerical one, asking how much was deposited or withdrawn each day without relating to ideas of change or slope. After the class, she commented that she thought she had lost track of the goal of the lesson. When asked why, she said because the graphs given on the problems were not linear. She discussed with the interviewer that the balance graph could be split piecewise into parts and analyzed relative to constant positive, zero, and negative transactions. One possibility would be to discuss the issues of slope as slope changed over the course of the function. In her fourth period class, she started by reviewing the first two problems, with constant deposits and withdrawals. She compared the balance graphs of both problems, showing that one had a constant increase and the other a constant decrease. She also drew the daily transactions graphs for both situations, saying that a constant deposit would show as a positive horizontal line and a constant

decrease as a negative horizontal line. Then, she showed that you can derive the transaction graph from the balance graph. After finishing drawing the graph, she told the students they should be able to tell by looking at a daily transactions graph whether [the balance graph] would have an increasing slope, a zero slope, or a negative slope. Even with this more explicit introduction, students still had problems in drawing the balance graph from a transaction graph without the computer. Some students wanted the first transaction to be the initial balance, even though the problem stated what the initial balance was. Teresa recalled that this was a transaction graph, so it represented how much they were depositing or withdrawing from the account. After doing the balance graph, she asked if she could connect the different points and then asked when they were going to have a positive slope, a negative slope, and a zero slope.

In the follow-up interview, she said she was disappointed that she lost track of the task and that if she were to do it again, she would focus more on slope from the beginning. She also commented on her surprise about the level of difficulties that students experienced. She thought if they understood what a transaction and balance were, they would have no trouble relating them. After working with students, she realized that students need experience and discussion to develop the interrelationships and to use the idea of slope as a tool for analysis. She recalled the meeting between teachers and researchers, in which there was a debate whether graphs of velocity vs. time and position vs. time should be taught simultaneously or sequentially. She reconsidered this question in light of her use of Bank Account. She mentioned she wished she still had the graphs produced in the qualitative graphing tasks. The qualitative graphing tasks involved qualitative graphing position-time and velocity-time graphs. She would have liked to help students relate Bank Account with qualitative graphing. She concluded with the insight that the transaction corresponds to the velocity graph and the balance corresponds to the position graph. She also commented that she thinks that velocity, time, and position-time should not be taught separately, because it is important to understand what is going on with both graphs simultaneously. When asked about the role of technology, she said it was important because students were involved in producing the graphs. She also commented that the ID was interesting because it was already set up as a task. She mentioned that to do this in a spreadsheet would take longer because students would have to learn how to set up the values, and label the graphs.

Discussion

She was surprised and intrigued that such a simple contextual task could lead to such deep mathematical ideas. She had unexpectedly encountered two critical topics: how rates of change and accumulation are reciprocally related (later this becomes the basis of the Fundamental Theme of Calculus); and how changing slopes can be treated through piecewise analysis. Though critical topics in a modeling-based curriculum, neither topic is typically well treated in standard curricula, so it is not surprising that her experience had not prepared her to address the issues.

What we consider most important in this episode is the way she acted professionally. First, she was aware that in the second set of tasks, she had lost her sense of direction. Before teaching it again that day, she reflected on the material, found a more satisfactory way to think about it, and revised her practice. Furthermore, even after instruction, she made further connections as she linked Bank Account to the qualitative graphing and reexamined a faculty debate on how to approach position-time and velocity-time. This relation is significant as it represents a high level form of transfer. Not only is there a switch in context (balance to position; transaction to velocity) but there is a reversal in conventional direction (position vs. time to velocity vs. time) as compared to velocity vs. time to position vs. time.

What is witnessed in this episode is how teaching is strengthened by a teacher reconstructing and deepening her understanding of content within her practice. We see this as a critical element in the improvement of mathematics and science education and argue that without such reflective practice, where content improvement is accomplished, we will not succeed in reform. We point to the teachers' personal values, the use of the interview as an occasion to reflect, and the reflection of teachers' group discussions as critical elements in this process. Furthermore, we believe the use of technology and the design of the IDs were also essential elements. First of all, we believe there is evidence that students suffered from the loss of the technology on the second day. However, we hasten to point out that requiring them to predict graphs by hand permitted difficulties to surface that could have been unseen if the ID was not used with appropriate tasks. Thus, our first point is, that with appropriate curricular and technology design, effective learning can be supported.

Secondly, we suggest that the IDs, small Java applets, are excellent transitional tools towards a deeper, fuller use of new technologies. This applet brought relatively neglected but significant content to students and teachers. It was manageable for the teachers and it led to excellent connections to other important topics. If

increased student learning is to be achieved, we see the issues of appropriate and transitional technological design and effective professional development as critical.

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Acknowledgments

This research was supported by a grant from the National Science Foundation (RED 9453876.) and a grant from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq 200863/95-9). All opinions and findings are those of the authors and not necessarily those of the foundations.

Web-Based *Mathematica* Projects for Calculus

Robert J. Clasen
Department of Mathematical Sciences
United States Air Force Academy
United States
clasenrj.dfms@usafa.af.mil

Deborah L. Hall
Department of Mathematical Sciences
United States Air Force Academy
United States
halldl.dfms@usafa.af.mil

Abstract: We incorporated web-based *Mathematica* projects into our Spring 1998 offering of a first-semester calculus course. This abstract describes our projects, which were based on famous battles from history. The projects are provided at www.usafa.af.mil/dfms/projects/math141/spring98. Suggestions for adapting our projects to other computer algebra systems and disciplines are included.

Background

The United States Air Force Academy has utilized *Mathematica* in its first-semester freshman calculus course for the past five years. All students are required to complete or validate this course regardless of intended major. Annual enrollment is approximately 750 students. Before beginning freshman classes, every student purchases a computer that has full network capabilities and *Mathematica* version 3.0 installed.

Our goal is that all students gain a functional knowledge of *Mathematica* before entering their upper-level technical courses. This functional knowledge includes basic syntax skills in a manner that supports major calculus concepts (Hall 1997).

The premise that today's entering student is computer literate appears untrue. The majority of students have a cursory computer background (i.e., no formal training in any software language), and some have no computer experience. Therefore, it has not been surprising to us that students initially have difficulty with *Mathematica* syntax. Because we have come to understand the growing pains associated with learning syntax, we try to teach basic skills using a building block approach. It is our experience that students better handle the frustration of learning new syntax if it is placed in the context of an interesting, motivational example. For this reason, we placed our projects within the context of a "real life" application. Because of the fascination most entering freshmen have with surfing the internet, web-based projects seemed to be a logical extension of our students' interests.

The Projects

We chose famous historical battles as our "real life" application, and the battles we used as themes for our projects were Gettysburg, Agincourt, and Verdun. The homepage for the *Mathematica* projects is shown in Fig. 1. All three projects utilized the same basic format. First, an overview page introduced the project to the students and described what they were expected to accomplish. Second, the students read a short historical summary of the battle and answered a few written questions about the battle. Third, the students used *Mathematica* to answer calculus questions related to some mathematical aspect of the battle. Lastly, there was a page containing links to sites with more information related to the battle so those who were interested could

easily explore the topic further. A more detailed description of the four web pages that made up each project is given in the following paragraphs.

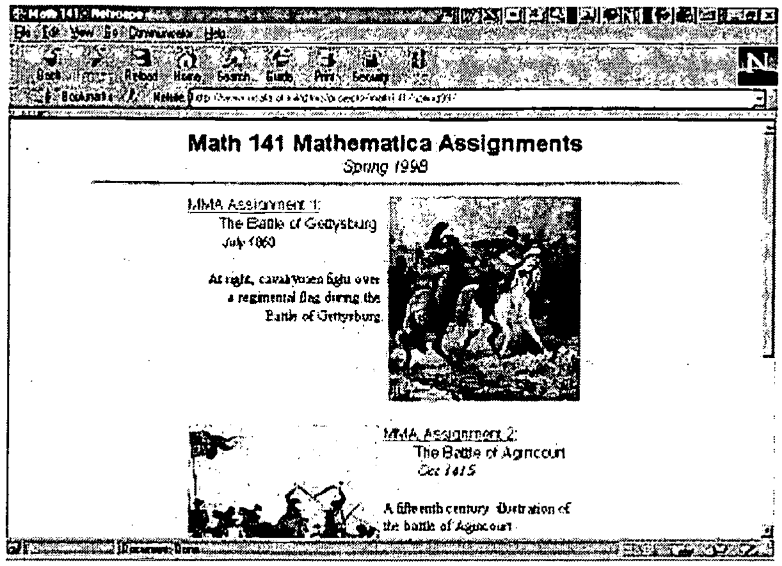

Figure 1: Mathematica Projects Homepage

Overview Page

The overview page was the starting point for each project. This page introduced the battle to the students and explained what the project entailed. This is where we covered some of the administrative details, such as the project's due date, files that needed to be downloaded, etc. The overview page used for the Battle of Verdun project is shown in Fig. 2.

Battle Page

The first part of each project was an historical portion, which contained no mathematics. The intended purpose was to expose the students to basic military history (an important goal at a military academy) and also to decrease math and computer anxiety by not immediately focusing on the calculus and the *Mathematica* syntax. The students read a summary of the battle (about three or four screens of information) and then answered some questions about the battle. These questions ensured the students actually read the description of the battle and accounted for twenty percent of the project's total points. Because the Academy encourages character development in all academic disciplines, the historical questions were sometimes ethical in nature. For example, one question from the Battle of Agincourt asked whether or not it was appropriate for Henry V to give the order to kill the unarmed French prisoners of war.

To give you an idea of the other types of questions we asked for this section, the questions used for the Battle of Verdun project are given below:

1. What was the German strategy going into the Battle of Verdun?
2. Who took over command of the French forces at Verdun after the disastrous first few days of the battle?
3. Why was it difficult for the French to get reinforcements to Verdun?
4. Why did the French have time to reorganize after they lost Fort Vaux?
5. What event caused the Germans to divert troops away from Verdun, effectively ending their attempt to take the city?

All technical departments at the Academy support "writing across the curriculum," and this section of our projects gave us a manageable format for grading short written responses easily.

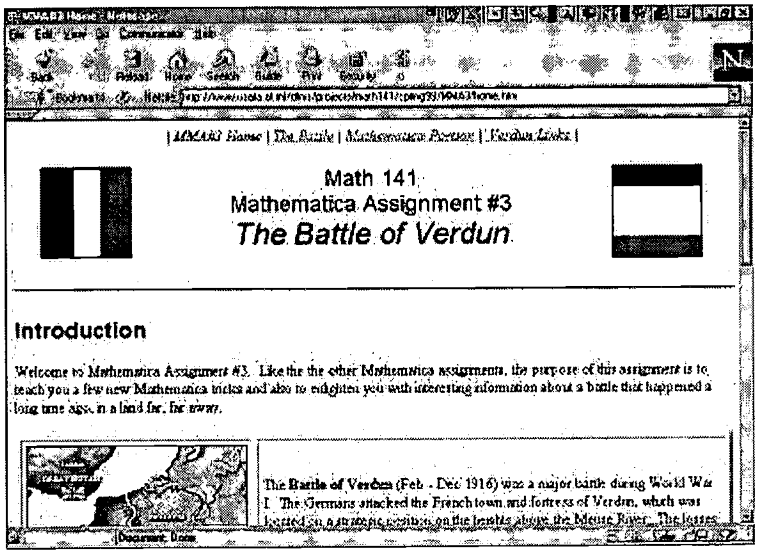

Figure 2: Overview Page for Battle of Verdun Project

Mathematica Page

All calculus concepts were contained in the *Mathematica* portion of each project. We tested the students' understanding of calculus concepts, as well as their ability to use technology as a problem-solving tool. Mathematical questions were linked to the battle. For example, a key weapon in the English defeat of the French at Agincourt was the longbow. The students were given a function (based on actual data) that provided the height of an arrow shot from a longbow. They were asked to plot the function, interpret the plot of the height to get information about the velocity, calculate average and instantaneous velocities of the arrow, and determine how long the arrow was in the air. *Mathematica* was used to answer the questions and students turned in a printout of their *Mathematica* notebook for a grade.

The *Mathematica* portion of the Battle of Verdun project was based on a function for the vertical velocity of a shell fired by the German gun known as Big Bertha. After a little web-based research, we came up with a fairly realistic velocity function, and then asked the students to use *Mathematica* to answer the following questions:

1. Graph the velocity function from $t = 0$ to $t = 100$ seconds and be sure to appropriately label your axes.
2. Estimate the net vertical distance traveled by the shell using Riemann sums:
   a. Use a left-hand sum with 1000 subintervals to approximate the net distance traveled during the first 100 seconds.
   b. Use a right-hand sum with 1000 subintervals to approximate the net distance traveled during the first 100 seconds.
   c. Use the average of the left-hand sum and right-hand sum to approximate the net distance traveled during the first 100seconds.
3. Use *Mathematica* to verify the Fundamental Theorem of Calculus by showing that the definite integral of velocity gives the net change in position:
   a. Use the Integrate command for a definite integral to determine the net change of the height of the shell during the first 100 seconds.

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b. Next, use the Integrate command for an indefinite integral to find an equation for the height, $h[t]$ of the shell at any time t.
c. Plot your height function from $t = 0$ to $t = 100$ seconds and be sure to appropriately label your axes.
d. Determine the change in height of the shell by subtracting $h[0]$ from $h[100]$. Your answers from part a) and part d) should be about the same.

4. Find the acceleration of the shell at $t = 5$ seconds.

It is our experience, based on past *Mathematica* projects, that students in a basic calculus course do not have the academic maturity and understanding of mathematical concepts to be able to readily utilize the on-line help features that *Mathematica* provides. To help ease the syntax burden, we created a tutorial notebook that explained the *Mathematica* commands required for the project. This tutorial aided the students in bridging the gap between general Mathematica commands and specific syntax necessary to solve the problems given in each project.

Links Page

Each project had a page of links to other web pages which contained information related to the battle. This made it easy for curious students to find out even more about the history surrounding each battle. There are some fantastic resources on the internet (as well as some terrible ones), and the purpose of this page was to quickly steer the students toward some of the better ones. For the Battle of Verdun project, we provided links to a couple of great World War I sites, as well as to a site that featured photos of how the battlefield looks today. In addition, we had a link to a page that contained Carl Sandburg's thought-provoking poem "Grass," which has a reference to the battle.

Summary

These projects required the use of two technologies. The first was use of the internet, which was nice but not essential for a math course. It made the project more appealing through the use of pictures and multimedia (we used a video clip of actual footage from the trenches of Verdun). Plus, the page of related web links made it very easy for those who wanted to explore further aspects of the battle to do so. However, the historical content could have been conveyed through the use of a handout in the event students do not have web access. For those who can easily create and post web pages, it seems worth the effort to use the internet since today's students are great web surfers and love flashy pages.

The second use of technology was *Mathematica*. We wanted to show the students how computer algebra systems can make their lives easier by eliminating the tediousness of long calculations and by easily plotting functions to help visually understand a problem. Since many of our students pursue technical majors, we wanted them to use technology early and often throughout their academic career. The format of our projects can be implemented with any available computer algebra system, to include programmable calculators.

We chose historical battles for this particular semester. Other disciplines that immediately came to mind include famous philosophical issues, literary events, and scientific scenarios.

The feedback from the students about these projects has been very positive. Though many complain about *Mathematica* being "picky" concerning syntax, they seem to realize they will be using technology throughout their careers and that they need to be comfortable with its use. They also seemed to enjoy learning about the battles while at the same time learning basic calculus concepts.

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Interactive Diagrams to Address Key Student Conceptions in Mathematics

Jennifer Wilhelm
Jwilhelm@astro.as.utexas.edu

Jere Confrey
Jere@mail.utexas.edu

Jose Castro-Filho
Jacf@mail.utexas.edu

Alan Maloney
Questmsm@texas.net

Systemic Research And Design Center
for Mathematics, Science and Engineering Education
The University of Texas at Austin
United States of America

Abstract: This paper discusses how an interactive diagram (ID) called "Bank Account," which is a Java applet, can aid development and intuition of the idea of rate of change. Exploration with this ID helps to facilitate an informal understanding of derivatives and integration in calculus and their relationship. The study involves clinical interviews documenting two Algebra I students' understanding of both constant and varying rates of change. It is shown that through instruction with this ID, students are able to predict, model, and check their ideas.

Introduction

This study investigates whether a deeper conceptual understanding of rate of change can be developed in students through use of computer-based technology, namely, interactive diagrams (Confrey, Castro-Filho, & Maloney 1998). These interactive diagrams consist of forty-five Java applets designed to engage students in algebra through precalculus in exploring fundamental mathematical ideas (Confrey & Maloney in press). The applets are designed as a focused tool to address topics that students typically experience difficulty in learning, such as, rate of change. Using the resources of the dynamic medium, students are invited to explore the idea and are given a variety of suggested tasks to stimulate this exploration. The interactive diagram used in the study is called "Bank Account." It is designed to assist students in relating concepts of rate of change (transactions) with accumulation (balance in the account). Students are provided a series of challenges. At first, they work to understand the impact of a variety of different patterns of transactions with the curve shape of the balance. Once they understand the process in the forward direction (predicting balance curves from transaction curves), they are asked to reverse it, to investigate how to create different balance curves by specifying sequences of transactions. This is a critical topic in preparing students to understand derivatives and integrals in calculus, while embedding them in a familiar context. It prepares students to see that the relationship between velocity-time and position-time can be derived symmetrically. Most students have a relatively limited experience of describing rate of change from a position-time graph (an informal derivative) and no experience on reversing this process. The use of rate of change of a variable is prevalent in secondary mathematics and includes a wide variety of subjects and applications. It is also the precursor to more complex problems that deal directly with differential and integral calculus. It is therefore crucial to a student's mathematical advancement to develop an intuitive understanding of this topic. Previous studies investigating comprehension of rate of change have shown that students have difficulty understanding, applying, and modeling this type of problem (Monk 1989; Nemirovsky & Rubin 1991; Thompson 1994).

The Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics 1989) state that instruction of rate of change along with limit, slope of a tangent line, and area under a curve shall be highly exploratory and that it shall capitalize on both calculator and computer technology. Instruction that capitalizes on technology, namely, graphing calculators and computers can be developed to model behavior that involve rate of change (Doerr 1997; Roschelle, Kaput, Stroup, & Kahn 1998; Smith & Confrey 1993; Stroup 1998). This can also help aid in higher level thinking skills (Kaput 1986). Focusing students' attention on underlying conceptions (rate of change and accumulation) rather than exclusively on calculating an expression (a lower level thinking skill), can result in advancement beyond what is typically expected (Thompson 1994).

Tool-based technology like computerized motion detectors helps students understand symbolic expressions of position versus time (Nemirovsky, Tierney, & Wright 1998). For example, Nemirovsky et al. (1998) did a study of two students exploring position versus time graphs using motion detectors which involved graphical responses to body motion. The computer-based technology allowed the students to make sense of graphing by exploring and experiencing the ideas of speed, time, and acceleration, which also enabled them to predict and distinguish between possible and impossible graphs.

Graphical analysis can be used to answer the following questions. How fast? How slow? What's changing? What's not changing? What's the physical meaning of the y-intercept? What's the physical meaning of the slope? What don't I know? "Many researchers are beginning to believe the use of some kind of real-time graphing environment is a key feature of having learners make sense of rate (how fast) concepts" (Stroup 1995, p. 16). Computer microworlds are often used to help formulate understanding of distance, time, and speed. One such microworld is called Over & Back (Thompson 1990). It displays a turtle and rabbit running along a number line where both can be given speeds with which to run. A timer shows the amount of time it takes each animal to run. Thompson and Thompson (1996) use this program to help develop conceptual subtleties about the image of speed.

Kaput (1994) discusses position-time graphs with their corresponding velocity-time graphs that are obtained using his computer simulation called Mathcars. He examines how one can make a graph of change-in-velocity, namely, an acceleration approximation which is a second derivative of the position as a function of time. The velocity approximation can be obtained by a first derivative of the position versus time function (Kaput 1994, p. 150). Ratios can be used in place of the derivatives giving us the informal calculus. The process can be reversed to find the anti-derivative using an area under a curve interpretation.

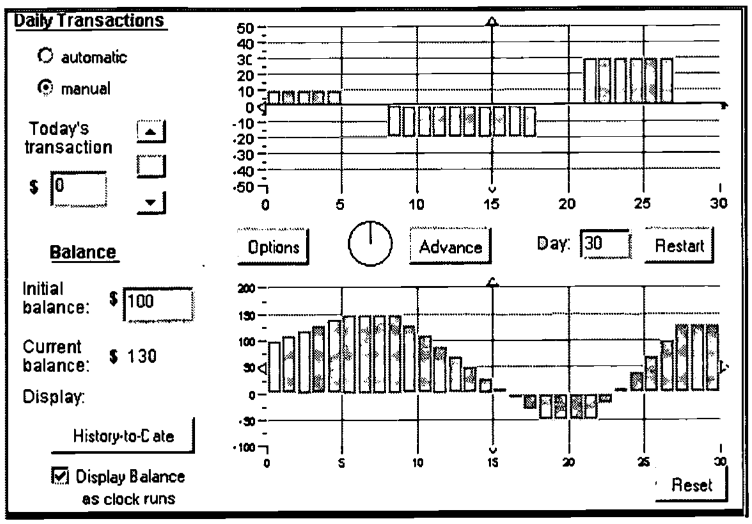
There is much literature in discussion of speed as a rate of change, less on other topics. This leads to our research study where another real world rate of change is explored. The rate that will be examined in terms of student understanding deals with change in money.

The Study

The study took place at Tree High School, an inner-city school which serves approximately 1,720 students and employs 101 teachers. The student body is diverse, consisting of approximately 72% Hispanic students, 14% white students, and 14% African American students. The study involved two separate 90 minute videotaped and audiotaped clinical interviews of two students. The students were selected by their Algebra I teachers due to their ability to stay on task. Ellie (age 14) and Gary (age 16) were selected, both are in grade nine. Both students had already received instruction exploring velocity, time, and acceleration using computer-based motion detectors. They had also explored the interactive diagram called "Bank Account" for a time period of one to three days (90 minutes each day). The interview was designed, in part, to assess the impact of the instruction. The Bank Account screen (see Figure 1) displays both a daily transaction graph and a balance graph. The user can set the initial balance to anything he wishes, and control the amount of money added or subtracted to the bank account each day.

The first two tasks given to the students involved having them make predictions of a daily transaction graph and its corresponding balance graph. After the students predicted the two graphs on paper, they were asked to model the savings account using Bank Account. This allowed the students to see if their prediction matched the model and to explain any discrepancies. These first two tasks involved constant daily transaction graphs and linearly increasing and decreasing balance graphs. The first question posed to the students was to consider a bank account that already existed that contained $100, and for seven consecutive days, a $50 deposit was made each day.

Figure 1 – Bank Account Screen



Ellie first placed what was a balance graph of this situation on her daily transaction graph, but quickly realized that she had done this and switched the two. On Ellie's daily transaction graph, she placed her first point at a value of \$100/day on day zero, and then continued to plot points of \$50/day at days one through seven. For her balance graph, she began with an initial value of \$100 on day zero and increased the value of each consecutive point by \$50 producing a linear graph with a slope of \$50 per day. Ellie then ran Bank Account and checked her predictions against it. She noticed that everything was the same except for the first point at day zero on the daily transaction graph. Ellie had it at \$100/day whereas on the Bank Account screen no point was displayed. Ellie was then asked the same question except now the daily deposit is doubled. She first predicted it and then modeled it using Bank Account. She was then asked about graph shape.

J: Great, ok. How would you describe the graph shape of the daily transaction graph there?
E: Going straight across.
J: Straight across. And how would you describe that graph shape of the balance graph?
E: A kind of steep slope.
J: A kind of steep slope, are you able to tell me what that slope is?
E: What do you mean?
J: When you say a steep slope, can you assign any kind of value to that steep slope?
E: No.

Ellie was unable to specify the value of the slope of the balance graph to be \$100 per day. Gary was asked a similar question except the balance is halved instead of doubled. He discussed what the graphs would look like even before he graphed his predictions.

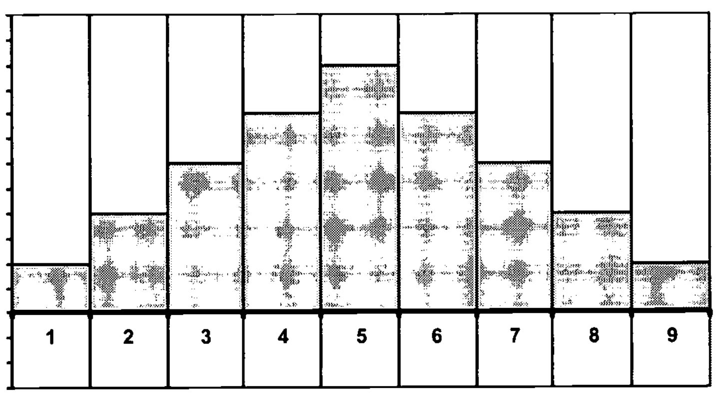
G: It'd be a lower steps.
J: Lower than what?
G: Lower than the \$50. It would be half of that.
J: It would be half of that?
G: Yeah.
J: What do you mean it would be half of that?
G: (inaudible), instead of \$50 daily transaction it'll go half way.
J: It'll just go half way?
G: Yeah.
J: Can you tell how much money you'll have in the end, without doing the graph?

G: $275.
J: Ok, and how did you get that?
G: Because, um, seven days is $175 plus what you started with $100, so $275.

Gary seemed to be more directly quantitative, constantly assigning numerical values to everything and even stating the final value of the balance before he graphed it. Gary's explanations were facilitated by his choice of the term, step, as contrasted to slope. The language involving steps, which is perfect for a discrete graph, could be viewed as a precursor to slope because of the implicit constant Δx. Ellie might have been able to come up with the slope if she had been asked to describe the steps. Ellie seemed initially to be more qualitative[1] in her approach to answering the questions, for example, discussing steepness without assigning a numerical value to it. More of this will be shown in the following task.

The third task involved a pre-drawn daily transaction graph, where the student was asked to predict the corresponding balance graph (see below). The purpose was to examine student thinking involved in finding a balance graph from its daily transaction graph. This method of going from a rate graph to its accumulation is designed to help students develop the same kind of intuition that typically develops about the reverse – predicting a rate of change graph from a position-time graph.

Daily Transactions

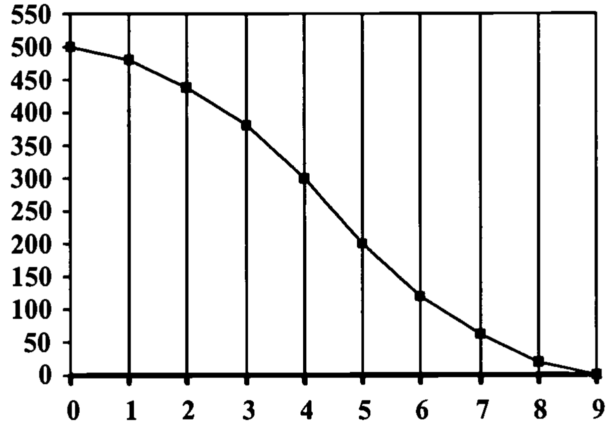


After Ellie predicted the balance graph, she was asked questions about how she obtained it. Ellie chose to have each step on the daily transaction graph go up by $20 per day per day. She realized that one cannot tell what the initial balance is from the daily transaction graph and chose her initial balance to be zero. Ellie stated that she began with zero balance and then after the first daily transaction added 20. After the second daily transaction she added 40 to the 20 giving her 60. She then proceeded to add the following amounts to her balance: 60, 80, 100, 100, 80, 60, 40, and 20 to obtain the points on her balance graph. Ellie made a mistake of adding 100 twice. When she checked her predictions against "Bank Account," she quickly saw her error in adding the $100 daily transaction in twice. Ellie basically was adding up the areas of each of the rectangles of the daily transaction graph, thus finding the area beneath the curve (an informal anti-derivative) to obtain her balance graph.

Ellie was then given a similar task except this time the daily transaction is reflected about the x-axis, which means that there will now be withdrawals from the account. Ellie wanted to know how much money she should start out with in the account and was told that she could choose. She chose $500, which seemed to indicate that she took the final amount in the balance from the last task to use. Ellie demonstrated her ability to conceptually see the informal calculus when she described her predicition of the balance curve.

[1] Note: In qualitative graphing, we assume there are concepts of more, less, steeper, and slower.

Balance



J: Ok, ah can you describe the shape of that curve?
E: It's going down.
J: It's going down?
E: It starts out going down, like not as steep and then it gets steeper, and then it kind of doesn't, isn't as steep anymore.
J: Can you point on here, what you just got done saying, can you point on here where you are talking about?
E: It's like right here it's not very steep, and then it goes down steep, and then right here it gets less steep.
J: Ok, how does that correspond to the daily transaction graph, do you know, is there any kind of relation going on here?
E: Um the more you take out the bigger the steepness is.
J: The more you take out the bigger the steepness is?
E: Yeah, you see right, you only took out 20, and then 40 and 60, and then as you go down (inaudible) to 100.
J: So that's where it's steeper?
E: Yeah.

Ellie seemed to see that the rate of change is greatest where the slope of the tangent line to the curve is steepest. She could derive the numerical values from her qualitative sense of steepness. Ellie seemed to have made the connection between the daily transaction graph and the balance graph.

When Gary did the first part of the third task, where there were deposits being made, he began with $100 initially in the account and also chose to have each step on the daily transaction graph go up by $20 per day per day giving him an ending balance of $600. Gary, like Ellie, seemed to have no difficulty producing a balance graph by taking an informal anti-derivative of the daily transaction graph. When he was asked to describe the shape of this balance curve, he described it as steps that were not exactly even and that the steps got bigger as you went up and lower as you went back down. When asked how the daily transaction graph and the balance graph were related to each other, Gary stated that on the first day the deposit displayed an increase of 20 (in the balance graph) and the second day an increase of 40, showing a bigger increase at 40 than at 20. Although Gary did not discuss any kind of steepness, he demonstrated the process of taking an informal antiderivative along with describing quantitatively the varying rate of change in the balance graph.

Discussion

Through this example, we hope to have convinced the reader that the context of banking provides a rich opportunity to relate ideas of rate of change and accumulation. By doing so, we can make intuitive understanding

of these ideas accessible to students well before formal and heavily symbolic encounters in physics or calculus. Furthermore, we have provided some evidence that the ID was effectively used in instruction, especially for students who stayed involved in the task. The discrete case also seems effective at bridging the gap between qualitative and numerical reasoning as the students worked with the language of steps, slopes, and steepness. Finally, we have illustrated the potential of the computer-based medium to support such conceptual development through its potential to allow students to easily predict, model, and check their ideas.

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Acknowledgments

This research was supported by a grant from the National Science Foundation (RED 9453876.) All opinions and findings are those of the authors and not necessarily those of the foundation.

Instructional Technology Initiative for Developmental Mathematics Students

Donald R. Coscia
Associate Dean for College Instructional Technology
Suffolk County Community College
United States of America
cosciad@sunysuffolk.edu

Abstract: Suffolk County Community College (SCCC) has embarked on a three-year pilot project using multimedia learner-centered environments to deliver developmental mathematics. The project's outcome assessment model will measure the effectiveness of this delivery system, as well as student achievement in mathematics courses. New initiative funding was invested in college-wide faculty development producing over 70 staff members as participants in this project. Moreover, this venture capital supported the design, acquisition, and construction of three multimedia mediated-learning classrooms that can accommodate over 1200 mathematics students in a semester. This paper and M/SET 99 presentation explores the development and design of this project.

Background

In the Fall 1995 semester, SCCC Strategic Planning Committee focused on various aspects of College activities that would improve retention and recruitment of students while using efficient methods to deliver College services. In particular, attention was focused on the methods the College used to deliver developmental mathematics - specifically our three-contact hour MA01 Basic Mathematics course. Professors primarily lecturing to classes of size 15 teach arithmetic concepts. This course is follow by a second developmental course, a traditionally taught four-contact hour Algebra I (MA07). The Mathematics Department felt that a more seamless approach to these courses could be developed allowing students to move more quickly and acquire the necessary mathematical skills to be successful in credit bearing courses. Attempting to meet these goals, MA06 - PreAlgebra and Algebra I, a combination of MA01 and MA07, was developed. Qualified students would be able to complete MA06 in one semester. This approach was not complete.

In the Spring 1996 semester faculty members, while attending the New York State Mathematics Association of Two Year College's (NYSMATYC) conference, discovered a product entitled *Interactive Mathematics* that was being developed and marketed by Academic Systems, Inc. This multimedia software and accompanying books could be used in teaching MA07, MA27 - Algebra II, and MA61 - College Algebra with Trigonometry courses. Academic Systems visited SCCC to present *Interactive Mathematics* to the Vice President Academic Affair, Deans of Instruction, Area/Divisional Deans, and the Mathematics Department Heads. The Mathematics Department formed a college-wide faculty committee and an administrative group was charged by the Academic Vice President to investigate the use of this product in delivering MA01, MA07, and MA27 course material.

Investigation

The faculty committee visited a local college where *Interactive Mathematics* was being used and discussed the product with their colleagues. The Committee met during the summer of 1996 to draft a method to use this software in developmental mathematics courses initially to promote a seamless approach to these courses. The Committee decided that a completely new approach must be devised. A classroom that contains multimedia computer technology for the student, collaborative workspace for the learner and instructor, and a mediated-learning approach to be incorporated by the teachers was envisioned. They agreed that a learner-centered environment is what was needed! The administrative group encouraged the faculty to pursue a NSF grant to fund the build of three mediated-learning classrooms with an eye on matching funding from SCCC.

Developing the Plan

The faculty committee proposed that the mathematics mediated-learning approach would need a LAN, a room with thirty multimedia pentium clients, a collaborative work area, a ceiling mounted multimedia projection system, software licenses, furniture, and require two faculty members (a teacher and a professional assistant) present for each class meeting.

A financial model was created that was used to explore the impact of funding this project. The model revealed that if a 7% increase in retention occurs through a mediated-learning in MA01 and MA07, SCCC could realize over a three-year period, additional revenue to financially support the project. Furthermore, the President, along with the Vice Presidents for Planning and for Academic Affairs requested that an outcomes model be designed to measure student retention rates, graduation rates, and mathematics achievement levels for those students using a mediated-learning approach as compared to the traditional class approach that students follow at SCCC throughout the project.

Preparing the Funding Rationale

The faculty effort in pursuing NSF funding was not successful but enabled them to solidify their ideas through the grant development process. Through a series of two smaller VATEA grants, the faculty were able to participate in a mentor development project employing *Interactive Mathematics*. These projects entitled *MathStar I & II*, began the acquisition of faculty multimedia computers, faculty training in learner-centered technology-based activities, and the formation of mentor relationships. Faculty went through a series workshop ranging from *Learning Windows95*, *Selecting Mathematics Software*, and *Developing a HomePage*, to *What it takes to Mentor*, and *Successful Learner-Centered Modalities*. During AY9697 faculty and students reviewed the *Interactive Mathematics* product. SCCC partnered with Academic Systems to develop materials for MA01, entitled Fundamentals *of Mathematics*, and sent an administrative and faculty team to visit several community college sites that used *Interactive Mathematics* extensively. Furthermore, the mathematics mediated-learning project became part of the College's new initiative proposal for AY9798 and was considered as a venture capital project. A series of presentations was made to Suffolk County officials to familiarize them with the mathematics mediated-learning concept as a cutting-edge initiative and an investment in developmental mathematics teaching. In June 1997, the County approved $325,00 for the Mathematics Mediated-Learning new initiative project for AY9798.

Preparing the Faculty and the Facilities

Through the help of a Mathematics Mediated-Learning Committee-at-Large (Vice President of Academic Affairs, Executive Deans, Deans of Faculty, Area/Divisional Deans, Department Head of Mathematics, Mathematics Faculty, and Academic Systems Inc.) within a seven-month period (July 1, 1997 - January 1998) the stage was set to begin teaching MA01, MA07, and MA27 using this approach. Job descriptions for the professional assistants were developed. Two three-day faculty-training sessions were held with over 110 faculty attending and over 70 completing the training. The Director of Instructional Research developed an outcome assessment plan that was approved by the Committee-at-Large. College-wide syllabi were agreed on and tests were developed. New initial rosters were developed containing student's mathematics placement and achievement information. New final grade reports were created and College software was altered to handle the reporting of the grades. Student Advisement software needed to be altered to reflect the seamless approach being taken. Counselors were trained on the meaning of the new approach in mathematics. The first semester is completed! The faculty at SCCC are much more technologically literate. We will begin to see the initial outcomes by January 1999.

Figure 1: Fall 1997 faculty training session

Designing the Outcome Assessment Tools

Three quasi-experimental studies (Napoli 1997) are proposed which will lend support for the differential effects of Academic Systems Mediated Learning (ASML) courses in Interactive Mathematics (MALA, or MAL1 or MAL2) versus the regular Developmental Math courses (MA 01 or 07) on basic arithmetic and algebra skills of two year community college students. Study 1 will use a regression-discontinuity design to test the effects of the ASML arithmetic and algebra course and the corresponding regular developmental course on grades in a succeeding first level college math course (MA 21, 22, 23, 27, 41, or 47). Standardized math test scores and Mathematics Department Placement Test scores will be regressed against subsequent grades in a first level college math course for students whose College Placement Test (CPT) -Mathematics (a composite score based on the CPT Arithmetic and Elementary Algebra tests) test scores place them in either a regular developmental math course or in the ASML course. The regression findings for the classification variable should show a significant effect for instructional group suggesting a differential direct effect of the type of developmental course on grades in first level college math. The impracticality of random assignment necessitates the use of nonequivalent control groups and statistical control of potential confounding variables. Possible *mortality* bias will be ruled out in Study 2 using a nonequivalent control group design. The covariates to be addressed will include measures of skill and motivation (high school gpa; grades/scores in Sequential 1, 2, & 3; Verbal & Math SAT scores; CPT-R scores; educational goals; regular computer usage; recency of Sequential courses) and demographic variables (age, sex...). Study 3 will use a pre-test/post-test design to assess the effectiveness of the two instructional approaches on improving arithmetic and algebra skills. Significant pre- to post-test gains should be found, and a greater differential gain for either group would indicate the superiority of that program. These results will form a critical multiplism indicating a differential overall effect for the type of developmental program should one exist.

Psychometric Analysis of the Mathematics Post-Test

Overall the study of SCCC's Institutional Research Department (IRD) (Napoli, 1998) establishes that scores on the Tri-Campus Mathematics Post-Test continuum can be reliably equated to some relevant cognitive or behavioral skill, specifically arithmetic and algebra skills. This allows the test user (instructor, department, or administration) to appropriately deploy the tests as evaluative tools for designated courses. To accomplish this goal we assessed the Tri-Campus Mathematics Post-Test in terms of: 1) Inter-Item Reliability - a score referring to the degree of consistency among item scores within a test of a unitary factor, 2) Inter-Rater Reliability - a score allowing for the statistical examination of the adequacy of a scoring rubric, and 3) Construct and Concurrent Validity - a measure of the representativeness of the test in terms of the domain it was designed to assess and the comparability of the test scores with scores on other tests purporting to assess similar skills.

IRD found high inter-item reliability. This indicates high consistency or homogeneity across items, and allows for the claim that the tests are a reliable measure of mathematics proficiency. Additionally, we found high inter-rater reliability. Thus we established an interchangeability of judges. Moreover, we confirmed that the scoring rubric was sufficiently defined to eliminate the subjective influence of scorer bias. Finally, we determined that the Tri-Campus Mathematics Post-Test have content, construct, and concurrent validity. Therefore we can claim that the tests do measure the arithmetic and algebra skills they purport to measure.

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Iterative Tangents of Third Degree Polynomials

Tilak de Alwis
Department of Mathematics
Southeastern Louisiana University
Hammond, LA 70402
USA
FMAT1117@SELU.EDU

Abstract: The tangent lines of cubic polynomials possess many unique properties not satisfied by other type of polynomials. For example, let f be a cubic polynomial with three distinct zeros a, b and c. Pick any two of these three zeros, say a and b. Then the tangent line to the graph of f at $x = (a + b)/2$ passes through the third zero at $x = c$. We discussed this remarkable property in (de Alwis 1997b). In this paper, we will uncover yet another remarkable property of cubic polynomials involving areas bounded by iterated tangent lines. To perform many of our calculations and form conjectures, we extensively used the computer algebra system *Mathematica*.

1. Introduction

Consider the simple cubic polynomial given by $f(x) = x^3$. Let $A = (t, t^3)$ be an arbitrary point on the graph of f, different from the origin, where t is a real number. Suppose the tangent line to the graph of f at A meets the curve again at the point $B = (s, s^3)$ where s is a real number and $t \neq s$. Now consider the tangent line to the curve at B, and suppose this tangent line meets the curve at $C = (u, u^3)$ where u is a real number and $s \neq u$. We are interested in computing the ratios of the areas bounded by these iterated tangent lines and the curve $f(x) = x^3$.

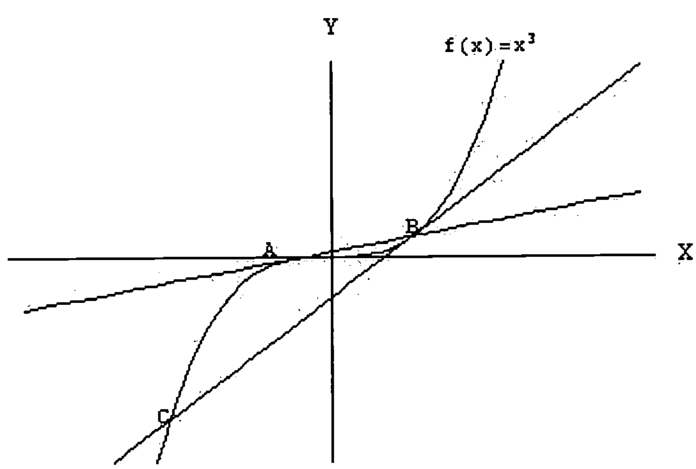

Figure. 1: Iterated Tangent Lines of the Cubic $f(x) = x^3$

To be specific, let A_1 be the area bounded by the line AB and the graph of $y = f(x)$ and let A_2 be the area bounded by the line BC and the graph of $y = f(x)$. We want to get information on the ratio of the areas A_1 / A_2. Our first proposition achieves this.

Proposition 1.1 Suppose that the points $A=(t,t^3)$, $B=(s,s^3)$, $C=(u,u^3)$ and the areas A_1, A_2 are as defined above. Then the ratio A_1/A_2 is independent of the value of t, and is equal to $1/16$.

Proof. The slope of the tangent line to the graph of f at $A=(t,t^3)$ is given by evaluating the derivative of f at t (Anton 1992; Larson et al. 1998; Stewart 1994). Therefore, the slope of the tangent line AB is equal to $f'(t)=3t^2$. Then the equation of the line AB is given by the point-slope form $y-t^3=3t^2(x-t)$. When simplified, this yields the following:

$$y=3xt^2-2t^3 \tag{1}$$

Recall that the equation of the curve is given by

$$y=x^3 \tag{2}$$

However, the graphs given by equations (1) and (2) intersect at the point $B=(s,s^3)$. Hence we obtain the following equation:

$$s^3=3st^2-2t^3 \tag{3}$$

The above equation (3) was obtained by considering the tangent line to the graph of f at $A=(t,t^3)$. Similarly, by considering the tangent line to the graph of f at $B=(s,s^3)$ one obtains the equation

$$u^3=3us^2-2s^3 \tag{4}$$

But A_1 is the area between the graphs of equations (1) and (2) between $x=t$ and $x=s$. Therefore, using the area interpretation of the definite integral of a function (Anton 1992; Larson et al. 1998; Stewart 1994), one obtains

$$\begin{aligned} A_1 &= \left|\int_t^s (3xt^2-2t^3-x^3)dx\right| = \left|\frac{3}{2}t^2(s^2-t^2)-2t^3(s-t)-\frac{1}{4}(s^4-t^4)\right| \\ &= \left|\frac{(s-t)}{4}\left[6t^2(s+t)-8t^3-(s^2+t^2)(s+t)\right]\right| \\ &= \left|\frac{(s-t)}{4}(5st^2-3t^3-s^2t-s^3)\right| = \left|\frac{(s+3t)(s-t)^3}{4}\right| \end{aligned}$$

Therefore, we have

$$A_1=\left|\frac{(s+3t)(s-t)^3}{4}\right| \tag{5}$$

Similarly, one can obtain the equation

$$A_2=\left|\frac{(u+3s)(u-s)^3}{4}\right| \tag{6}$$

The equations (5) and (6) imply

$$\frac{A_1}{A_2} = \left| \left(\frac{1+3\frac{t}{s}}{\frac{u}{s}+3} \right) \left(\frac{1-\frac{t}{s}}{\frac{u}{s}-1} \right)^3 \right| \tag{7}$$

Therefore, the ratio A_1 / A_2 can be computed once the ratios t/s and u/s are known. This is exactly where the equations (3) and (4) will come into play. By writing $t/s = \alpha$, the equation (3) is equivalent to the following:

$$2\alpha^3 - 3\alpha^2 + 1 = 0 \tag{8}$$

But observe that $2\alpha^3 - 3\alpha^2 + 1 = (\alpha - 1)^2(2\alpha + 1)$. So the solutions of equation (8) are $\alpha = 1$ or $\alpha = -1/2$. However $\alpha = 1$ cannot be true, because this would imply $t = s$. Therefore, $t/s = -1/2$. The same argument applied to the equation (4) yields, $s/u = -1/2$, so $u/s = -2$. Finally, plug the values $t/s = -1/2$ and $u/s = -2$ in equation (7) to obtain $A_1 / A_2 = 1/16$. This proves the theorem.

Q. E. D.

2. Experimenting with other Types of Cubic Polynomials

In the above we considered the most elementary cubic polynomial, i.e. $f(x) = x^3$. A natural question to ask is whether, a similar result would hold for other types of cubic polynomials, such as $f(x) = 2x^3 + 1$, $f(x) = x^3 - 2x^2 + 3x + 4$, etc. The general cubic polynomial can be written as $f(x) = ax^3 + bx^2 + cx + d$, where a, b, c, and d are arbitrary real numbers with $a \neq 0$. One can use a computer algebra system (CAS) such as *Mathematica* to compute the ratio A_1 / A_2 of the areas associated with different types of cubic polynomials.

Mathematica is a general purpose CAS. It can be used as a numerical or symbolic calculator, a visualization system to analyze data, a high level programming language, or even as a tool for creating interactive documents to combine text, animations and sound. Some good references on *Mathematica* are (Wagon 1991) and (Wolfram 1991). For the uses of *Mathematica* as a powerful problem solving, pattern recognition and a conjecture forming tool, the reader can refer to (de Alwis 1993a, 1993b, 1994, 1995a, 1995b, 1997a, 1997b, and 1998).

The following *Mathematica* program enables one to compute the ratio A_1 / A_2 of the areas for different values of the coefficients a, b, c, and d, and for different values of t. Before executing the program one must pick values for a, b, c, d, and t. The variables a, b, c, and d stand for the coefficients of the general cubic polynomial $f(x) = ax^3 + bx^2 + cx + d$. Therefore, one can pick a, b, c, and d arbitrarily as long as the leading coefficient a is nonzero. However one must be careful in picking t. Recall that t stands for the x-coordinate of the initial point A on the graph of f, as described in Section 1. In the present case, the point A has the coordinates $(t, f(t))$. However, if A is a point of inflection of the graph of f, then the tangent line at A does not meet the graph at a point other than A. Just to ensure that this will not happen, we will require A not be a point of inflection of f. Now, the inflection points of f are obtained by solving the equation $f''(x) = 0$ (Stewart 1994). Since the second derivative of f is given by $f''(x) = 6ax + 2b$, this implies that $f''(x) = 0$ if and only if $x = -b/(3a)$. Therefore, choose t as any real number such that $t \neq -b/(3a)$.

Program 2.1

```
Clear     d, f
a = 2;
b = - 1;
c =
d =     35
f          3 + b x2          d
t = 2    M     sure               to        a
list1  = x   . NSolve                            1
s = Cases          , x_Real                   10 6
list2  = x   . NSolve                            1
u = Cases            x   eal      ;           10 6      ;
a1 =
a2 =
a1
--
a2
```

The output for the above input lines is equal to 0.0625, i.e. 1/16. This means that for the values $a = 2$, $b = -1$, $c = 13.5$, $d = -2.35$, and $t = 2$, the ratio of the areas A_1 / A_2 is equal to 1/16. The reader can experiment with various other values for $a, b, c, d,$ and t only to find out that the output is equal to 1/16 each time! This leads to a beautiful conjecture on the areas bounded by the iterated tangent lines of a general cubic polynomial. The conjecture holds true, so we will state and prove it as a theorem in the next section.

3. A Generalization

Theorem 3.1 Consider the general cubic polynomial $f(x) = ax^3 + bx^2 + cx + d$, where $a, b, c,$ and d are arbitrary real numbers with $a \neq 0$. Let t be any real number such that $t \neq -b/(3a)$. Suppose that the tangent line to the graph of f at $A(t, f(t))$ meets the curve again at B, distinct from A. Suppose that the tangent line to the graph of f at B meets the curve again at C, distinct from A. Let A_1 be the area bounded by the line AB and the graph of f and let A_2 be the area bounded by the line BC and the graph of f. Then the ratio A_1 / A_2 is independent of the value of t, and is equal to $1/16$.

Proof. One can write the point B as $(s, f(s))$ and the point C as $(u, f(u))$, where s and u are real numbers with $t \neq s$ and $s \neq u$. Using the same method as in Proposition 1.1, the equation of the tangent line AB is given by

$$y = x(3at^2 + 2bt + c) - 2at^3 - bt^2 + d \tag{9}$$

Similarly, the equation of the tangent line BC is given by

$$y = x(3as^2 + 2bs + c) - 2as^3 - bs^2 + d \tag{10}$$

However, the point $B(s, f(s))$ lies on the tangent line AB given by equation (9). This implies the following:

$$as^3 + bs^2 + cs + d = s(3at^2 + 2bt + c) - 2at^3 - bt^2 + d \tag{11}$$

After simplification, the equation (11) is equivalent to the new equation $(-s+t)^2(b+as+2at)=0$. However, since $t \neq s$ this implies the following relationship between t and s:

$$b + as + 2at = 0 \tag{12}$$

Similarly, by considering the equation (10), one can obtain the following relationship between s and u:

$$b + au + 2as = 0 \tag{13}$$

Subtracting the equations (12) and (13) yields

$$t = \frac{s+u}{2} \tag{14}$$

We will now calculate the areas A_1 and A_2. Using the area interpretation of the definite integral of a function, one obtains

$$A_1 = \left| \int_t^s [x(3at^2 + 2bt + c) - 2at^3 - bt^2 + d - (ax^3 + bx^2 + cx + d)]\,dx \right| \tag{15}$$

Using the **"Integrate"** and **"Simplify"** commands of *Mathematica*, or simplifying by hand, one can reduce equation (15) to the following factored form:

$$A_1 = \left| \frac{(-s+t)^3(4b + 3as + 9at)}{12} \right| \tag{16}$$

Similarly, one can obtain the following expression for the area A_2.

$$A_2 = \left| \frac{(-u+s)^3(4b + 3au + 9as)}{12} \right| \tag{17}$$

Divide equation (16) by (17) to obtain

$$\frac{A_1}{A_2} = \left| \left(\frac{s-t}{u-s} \right)^3 \frac{(4b + 3as + 9at)}{(4b + 3au + 9as)} \right| \tag{18}$$

One can further simplify equation (18), using the equations (12) and (13). The equation (12) implies that $b = -as - 2at$. At the same time, the equation (13) implies that $b = -au - 2as$. Plug these in equation (18) to obtain

$$\frac{A_1}{A_2} = \left| \left(\frac{s-t}{u-s} \right)^3 \frac{(-4as - 8at + 3as + 9at)}{(-4au - 8as + 3au + 9as)} \right| = \left| \left(\frac{s-t}{u-s} \right)^3 \frac{(-as + at)}{(-au + as)} \right| = \left(\frac{s-t}{u-s} \right)^4$$

$$\frac{A_1}{A_2} = \left(\frac{s-t}{u-s} \right)^4 \tag{19}$$

However, according to equation (14), $t = (s + u)/2$. Plug this in equation (19), and simplify to obtain $A_1 / A_2 = 1/16$. This proves the theorem.

Q. E. D.

One can now ask whether the above theorem can be generalized to higher degree polynomials. A good way to investigate the issue is to experiment using a *Mathematica* program similar to Program 2.1. It appears as if a similar result is true for a certain class of odd degree polynomials. However, because of the space limitations of this paper we will not include further details.

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Acknowledgements

The author wishes to thank a certain participant of the Tenth ICTCM Conference in Chicago, USA, November 1997. This paper was born because of his valuable comments.

Doing Mathematics with *MathEdu*

Fernando Díez.
Escuela Politécnica de Ingeniería
Universidad Antonio de Nebrija
and
Departamento de Ingeniería Informática
Universidad Autónoma de Madrid
Spain
fdiez@dii.unnet.es

Roberto Moriyón
Departamento de Ingeniería Informática
Universidad Autónoma de Madrid
and
Instituto de Ingeniería del Conocimiento
Spain
Roberto.Moriyon@ii.uam.es

Abstract: In this paper we present the *MathEdu* problem solver, an interactive tool based on *Programming by Example* for the construction of programs that allow students to solve interactively problems of Mathematics. The problems handled by *MathEdu* are those that involve computations and symbolic manipulation of mathematical expressions, like computing derivatives or integrals. *MathEdu* is built on top of the *Mathematica* system. *MathEdu* programs can be embedded as part of a course that incorporates both theory and practice, together with mechanisms to navigate among them. The designer of the set of exercises, a Mathematics teacher that has some knowledge of *Mathematica* programming, can define resolution methods for different classes of problems in a simple way. This information is used in order to establish an intelligent dialogue with the student, by asking him questions about the different possible resolution paths that are coherent in the exercise being solved or in similar ones.

Introduction

During the last years there has been an enormous growth of activity in the development of computer assisted tutoring systems, and tools to develop computer based courses. This growth has taken place in all the aspects of the technologies related to this field, and especially in those related to the amount of intelligence included in the applications and to the richness of the media that can be used. But the growth has been comparatively bigger at the level of generic systems and strategies than at the level of more specialized tools and techniques. In particular, the development of didactic material for the scientific and technologic areas has been restricted by the difficulties inherent to the communication of this kind of knowledge with nowadays user interfaces. All this happens at the same time that the enormous growth of Internet through the World Wide Web is leading us to a culture of distributed information at very cheap costs, long distance education being supposed to be more accessible to people. Consequently there is a growing need for more interactive, and deeper tutoring applications in scientific fields.

In this paper we present the *MathEdu* problem solver, a tool for the construction of programs that allow students to solve interactively problems of Mathematics. The problems that can be handled by *MathEdu* are those that involve computations and symbolic manipulation of mathematical expressions, like computing derivatives or integrals. *MathEdu* programs are highly interactive, and they are able to deal with the student's acquisition of concepts and procedures up to a deeper degree than present technologies allow. On the other hand, *MathEdu* is a tool, so the development of this kind of applications can be done in a relatively simple and systematic way. The *MathEdu* interactive tool is based on the *Programming by Example* paradigm (Cypher, 1993) that allows the designer to work in an environment that is similar to the one where the student will work. *MathEdu* programs can be embedded as part of a *MathEdu* course that incorporates both theory and practice, together with mechanisms to navigate among them according to the work done by the student.

In spite of the fact that the most advanced current interactive mathematical educational materials are considerably better and deeper than they used to be not long ago, the degree of interactivity achieved in applications conceived to teach Mathematics is very poor. In the best cases, the student can represent geometrical constructions using different values for parameters on which they depend, s/he can represent some dynamical processes like solutions to Differential Equations by means of animations, or s/he can introduce mathematical expressions to answer to specific questions. But almost nothing that can be considered as a true and deep dialog between the student and the system has been achieved. Moreover, there is almost no tool that simplifies the development of interactive courses or sets of problems in Mathematics.

There are essentially two kinds of programs for mathematical education: on one hand, there are interactive courses and problem solving systems, like *Wiley Web Test* (Orr, 1996), *Calculus@Mathematica* (Uhl et al, 1998), and the related *Internet Calculus Program* (Manfredi et al, 1998), and *Calculus Wiz* (Stroyan, 1998), that help students to step through different aspects of traditional mathematical learning, either by posing problems and validating the students answers or by giving interactive support for more global aspects of the learning process. Some of the above systems can be used through Internet. On the other hand, *PAT OnLine* (Corbett et al, 1998) and *PAT* (Corbett et al, 1998, b) are Algebra tutors based on *ACT-R,* a theory of cognition (Anderson, 1983), (Anderson, 1993), that represent a significant step both in the direction of the deepness of the interaction with the student at the semantic level, and the simplicity of the development of materials by means of an authoring tool. In the next paragraphs we give a brief description of the computer-based systems for Mathematics teaching cited above.

The *Wiley Web Test* offers a high variety of exercises related with derivatives and integrals. The key feature of the tests is that students can take them over the web for practice as many times as they need in order to develop skill and confidence, before coming to the computer lab to take the test for credit. However, the functionality of the system is very limited, since all the students can do is just answering simple independent questions, like computing specific integrals.

Calculus@Mathematica uses *Mathematica* software to help students to step through the routines of traditional mathematical learning, while the related *Internet Calculus Program* teaches Calculus over the Internet to students willing to learn independently in an organised manner. Both systems constitute nowadays a well-established paradigm for Mathematics tutoring. The amount and diversity of courses on different areas of Mathematics based on this paradigm that are available is growing very rapidly.

Calculus Wiz is also built on top of *Mathematica* as a package of notebooks that can help to solve most of the problems of the traditional first-year calculus course. This course makes it possible for the students to solve calculus problems simply by clicking a computer button and filling in information. It is probably the most advanced computer based course in Mathematics from the interactive point of view, but it is not a tool. It can not be used through the web, although this might change in the future, as www capabilities of *Mathematica* evolve.

Both *PAT* and *PAT OnLine* allow students to introduce variables related to an algebra problem and relations among them, as well as their values found by solving the corresponding equations. Their usefulness is enhanced by the Problem Situation Authoring Tool, which provides a method for entering and editing problems used in both systems. *PAT OnLine* is an experimental web-based system similar to the classroom version of *PAT*. This family of systems is fairly deep from the point of view of the part of the semantics of the problems that is under their control, and from this point of view it represents an outstanding step forward with respect to other systems, but it has serious limitations from the point of view of the user interface. Both PAT systems are limited to a very specific (but very important) kind of problems.

A comparison of *MathEdu* with the previous systems and courses shows that its domain of application is closer to those in the first group. Besides this, it includes a prototype authoring tool, like *PAT,* and it allows the development of materials and courses with a higher degree of interactivity and semantic deepness.

The rest of this paper is organized as follows: in the next section a simple but representative example of the kind of problems that can be addressed by *MathEdu* is introduced, and the way in which a student interacts with the system in the resolution of this problem is explained. After this, the same example is used in order to illustrate the design process using the *MathEdu* prototype authoring tool. Finally, some conclusions are drawn.

An example

In this section we shall show how a student interacts with a typical program developed using *MathEdu*. This will be done by means of a simple example of a problem to be solved by the student, namely

Problem: Compute

$$\int x^2 \cos 3x \; dx.$$

Both the information shown by programs developed with *MathEdu,* and the overall program behavior depends on the inputs from the student. In this case, the student is first asked to solve the above problem, and s/he gets a list of possible resolution strategies, like *Integration by parts, Change of variable and Algebraic simplification.* He can also indicate that the integral can be computed *directly (Immediate integral).* The system knows which are the strategies that make sense for each specific problem. In our case, the system knows that the integrand is the product of a polynomial by a simple trigonometric function, and so it can be solved using integration by parts, while the other available methods of integration are not useful. This part of the knowledge is embedded into the program by making extensive use of the symbolic capabilities of the underlying system, *Mathematica.* The use of *Mathematica* also simplifies the interaction with the student, who can work all the time with expressions in the standard mathematical format.

The designer of the set of exercises can decide which action to take in case the student gives a wrong answer. For example, s/he can decide that, in case the student chooses *Change of variable* for a problem like this one, the following sequence of things would happen: a) the description of the corresponding method should be shown to him/her; b) s/he would be asked for a choice of an expression that satisfies the criteria needed in order for it to define a reasonable change of variable; c) s/he would be allowed to answer that there is no such expression, in which case the problem resolution would continue at the point of the mistake, and an indication would be given to the student that *Change of Variable* is not a correct choice. Similarly, in case the student chooses another wrong answer, like *Algebraic simplification,* s/he might be allowed to continue making decisions, like choosing the kind of simplification he wants to perform, until s/he acknowledges that the conditions for his/her choice are not accomplished. Finally, in case the student chooses *Immediate integral,* s/he might be asked to introduce the expression that s/he assumes is the correct value of the integral, and s/he might then be asked for the value of the derivative of this expression. In this case there would be three possibilities: a) the value keyed in for the derivative is wrong. Then a corresponding message might appear, indicating the mistake, and giving the right derivative; b) the value is right, but it does not agree with the integrand. Then the definition of integral would be shown, and the problem resolution process would continue at the point of the mistake; c) the answer is all right. Then, the system would show the student a message telling him that, although s/he gave the right answer, it has not been obtained in a systematic way, so s/he should solve the problem again choosing a different strategy.

In case the strategy chosen by the student is correct, s/he has to select once more the correct description of the actions to take among a list of descriptions of the actions to be taken for the different possible methods of integration (this is also a possible option in case the strategy he chooses is not correct). In this way, s/he collaborates actively in the introduction of the information needed for the next steps in the resolution process in a natural way. Hence, if the student chooses in our problem to use *Integration by parts,* one of the possible choices will be: *Two expressions u and v have to be chosen in such a way that: a)* $x^2 \cos x = u.v$*; b) the integral of v, let us call it V, is simple to calculate, and c) the integral of u'.V is simpler than the original one.* Once the student has chosen this alternative, references to u, v and V can be made during the next steps of the resolution process in a clear scope.

Following with our example, once the student has chosen the right explanation of the strategy to be used, s/he is asked to introduce the values of *u* and *v*. The system knows once again, thanks to the use of *Mathematica* behind the scenes, how to compute both expressions, so it can check their values, and act accordingly, in case the student does not give correct answers. Finally, the system asks her/him whether s/he has to compute next the integral of u'.V, or s/he has to accomplish any of the steps that would correspond to other resolution methods. This dialog continues until the student finds out the value of the integral. During this process, other intermediate problems have to be solved, like, in this case, the computation of a new integral.

The type of dialog between the student and *MathEdu* has some important advantages that can be summarized as follows:

- The student has a clearer idea of the different choices, expressions, and magnitudes that should be considered at each step in the resolution process and about the consequences of them in terms of actions to be taken.
- The student has a clearer idea of the reasons by which some decisions are wrong.
- The system can accumulate deep information about the kind of difficulties the student is having at the different resolution steps. For example, the system might notice that the student does not remember how to differentiate cos *3x*, and then make him/her practice on derivatives of this kind.

Design in *MathEdu*

A fundamental aspect of *MathEdu* programs is that they can be designed using an interactive tool. By means of this tool the designer specifies sets of problems and, simultaneously, s/he designs the students interface. The *MathEdu* design tool uses the *Programming by Example* paradigm (Cypher, 1993) in order to allow the designer to work on the same interface the student will use while solving problems. In this way, teachers with a standard knowledge of *Mathematica* programming are able to design there own problem sets in a relatively simple way. In order to design a set of problems, a teacher has to accomplish three steps:

- Specific problems have to be stated and solved in the format of a standard *Mathematica* notebook; a formal semantics has to be attached to each problem.
- More general types of problems, that share a common problem statement except for some specific data, are defined by means of problem generalization.
- Some parts of the notebook that includes the problem resolution can be used to define resolution rules.

In the next paragraphs we shall show these three steps in the context of the example introduced in the previous section.

First of all, the statement of a problem is specified through a *Mathematica* cell. In the case of the problem introduced in the previous section, its semantics, a *Mathematica* expression, will be

compute[Integrate[x^2 Cos[3 x], x].

The symbol *compute* is a *MathEdu* reserved symbol that prevents the evaluation of its arguments. The designer of the course can also define her/his own reserved symbols. As part of the semantics specification, the designer has to indicate that the integral that appears in the statement is a mathematical formula. As a consequence of this, the appearance of the expression in the semantics is linked to its representation in the main notebook.

In order to generalize a problem the designer has to decide which expressions that appear inside mathematical formulae can have different values in different problems of the same general type. These expressions are called *MathEdu metavariables*. In our case, the problem is generalized to a generic *simpleComputation* problem by specifying that *Integrate[x^2 Cos[3 x]]* is a metavariable. The designer gives a name to each metavariable; in this case, the metavariable that represents the expression to be computed can be called *expression.*

Rules represent procedural knowledge about how to solve different types of problems. This knowledge includes both mathematical computations and decisions that have to be made on the basis of mathematical considerations, and also computational knowledge about how the student is supposed to specify his computations and decisions.

When defining a rule the designer first has to specify conditions on the metavariables that correspond to a problem generalization under which the same method can still be applied. For example, in our case the designer has to specify that the *integration by parts* strategy can be specified for the generalization of our problem if the expression to be computed is of the form *Integrate[integrand, var],* where the metavariable *integrand* is the product of a *polynomial in var* by a *simple trigonometric function in var*. It is at this point where the designer needs a reasonable knowledge of *Mathematica* programming, since a Boolean function that recognizes this specific kind of functions has to be implemented. The designer can also specify functions that generate automatically random acceptable values for the metavariables, so that the final program can pose different problems of similar types to the students.

MathEdu rules have the form *If pendingProblemSemantics matches XXX then use strategy YYY.* Strategies include information that has to be shown to the user, and requests for metavariables to be given a value by the user. These requests can have associated conditions for the values to be accepted, and associated pending problems that have to be solved in order determine the corresponding values. In our example, the *integration by parts* strategy includes a description that indicates that *two new expressions u and v have to be chosen in such a way that: a) the integrand equals u.v; b) the integral of v, let us call it V, is simple to calculate, and c) the integral of u'.V is simpler than the original one.* Moreover, in our example the *integration by parts* strategy will accept the values given by the student for *u* and *v* if *u* is the *polynomial part* of the *integrand* and *v* is the *trigonometric part* of it. Finally, the strategy specifies that the student has to find the value of two new metavariables, *U* and *V,* that must solve corresponding derivation and integration problems, and that the new problem to be solved is a new *simpleComputation* problem, the metavariable *expression* defined three paragraphs above having the value *Integrate[U V, var].*

The use of predefined notebook *Mathematica* cells that ask for input from the user simplifies the definition of strategies by the designer. Defining rules involves using *Mathematica* pattern matching in a non trivial way, while the specification of matching conditions and values to be accepted usually involves working at the symbolic level with mathematical formulae. The designer has very high flexibility about how to accomplish

the design task. For example, once s/he has started the resolution of a problem, s/he can define a rule associated to the part of the resolution s/he has specified before finishing its specification. The *MathEdu* development environment simplifies the definition of problem resolution rules by allowing the designer to specify variable expressions, conditions on them, and other associated information in the same graphical context used to specify the resolution of specific problems. For example, the designer just has to select a mathematical expression that appears in the resolution notebook in order to specify through a menu item that this expression can be generalized. S/he is then prompted for a name for the expression, and after this s/he is asked to give a pattern and a condition to specify the degree of generalization allowed. This is done by just declaring those expressions that can be generalized.

After having introduced several types of problems by the above mechanism, the designer can ask *MathEdu* to create automatically a corresponding problem solving program. This program classifies the different types of problems into groups of similar ones according to the specification of their semantics, and the patterns associated to corresponding variables. For each type of problem, the strategies that have been specified for similar types of problems are considered as alternative strategies to be shown to the student when solving a specific problem. The design tool creates then sets of apparently reasonable alternative strategies for each type of problem in an automatic way. When solving a problem, by choosing among the strategies that are shown to him/her, the student sends instructions to a rule interpreter to go ahead in the interactive problem resolution.

Acknowledgements

This work has been funded by the National Research Plan from Spain through the *InterEdu* project, project number TEL97-0306.

Conclusions

In this paper we have presented the *MathEdu* environment, an interactive versatile tool based on *programming by example* that can assist in the design of active problem sets without much programming effort, and the corresponding problem solver, that automatically poses alternative resolution paths for problems and guides the student through the resolution process. The problem sets allow an intelligent dialog between the student and the system. Some of the advantages of using *MathEdu* are the following:

- Designers can build in a simple and systematic way and with a high degree of generality problem sets that include self-assessing tasks.
- The student has a clearer idea of the different choices, expressions and magnitudes that should be considered at each step in the resolution process, and about the consequences of his decisions.
- The student has a clearer idea of the reasons by which some decisions are wrong.
- The system can accumulate deep information about the kind of difficulties the student is having at the different resolution steps. For example, the system might notice that the student does not remember how to differentiate cos $3x$, and then make him/her practice on derivatives of this kind.

There are several tasks that have to be undertaken in order to convert *MathEdu* into a tool available for general use; the design of wider sets of problems and its systematic use in the classroom are the most essential ones.

As future work, we are also planning to add a model of the student, so that *MathEdu* can take global decisions by itself in order to guide the student through a whole course. Other ambitious goals in the long term are the enrichment of the degree of interactivity on the part of the student, and the development of a generic framework in which systems like PAT and *MathEdu* can be included.

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Computer Assisted Geometric Proofs

John J. Edgell, Jr., Ph.D., Professor Mathematics/Mathematics Education, Southwest Texas State University, USA, je02@swt.edu

Michael Brown, Professor Mathematics, Austin Community College, USA, browns@centuryinter.net

Sally Birkenfeld, Undergraduate Instructional Assistant/Student, Southwest Texas State University, USA, sb27747@swt.edu

Conjectures do not just occur as a result of intense, focused thinking. The following conjecture/theorem happened while sharing geometrical ideas with fifth graders and while guiding university students through a historical development of mathematics several years ago. The fifth graders were fast becoming confused and frustrated with a myriad of seemingly unrelated formulations involving ostensibly obscure attributes for measuring geometrical regions. The university students had briefly reviewed Heron's (or Archimedes) formula for the area bounded by a trigon and had become aware of a formula by L. N. M. Carnot for the volume bounded by a tetrahedron. Both of these formulations are about constructs (points, line segments, trigons, tetrahedrons, pentatopes, $\boxed{C_n}$) in terms of the distances between the vertices. The idea of measurement, counting the real number of unit cubes (points, unit line segments, unit regular quadragons, unit regular hexahedrons, unit regular octatopes, $\boxed{u^n}$) that tessellate a geometric region, doesn't seem like a particularly complex idea. When one realizes that constructs tessellate or closely tessellate geometric regions then the idea of measuring tessellating constructs and summing those measures to understand the measure of a region, $\boxed{g_n}$, becomes reasonable, $\boxed{m(g_n) = \quad m(C_n) = x}\ \boxed{u^n}$. Heron and Carnot, though separated by thousands of years, had sowed the seeds of formulating the measure of a construct in terms of the distances between the vertices, which are well delineated and not very obscure attributes at all. So, it would seem that one could merely tessellate a region with constructs, measure the distances between the vertices (edges) of each construct, calculate the measure of each construct, and the measure of the region is the sum of the measures of the tessellating constructs. This strategy doesn't seem particularly confusing or frustrating. Heron and Carnot had already done most of the work. The challenge became to come up with rather simplistic formula for the measure of a construct in terms of the edges. Inspiration seems to be a rather elusive state, but it sure does help. The experiences, knowledge, challenge and inspiration combined to produce a formulation that in a short while evolved to the following: $\boxed{m(C_n) = (\frac{1}{n!})((\frac{1}{2^n})|a_{ij}|)^{\frac{1}{2}}}\ \boxed{u^n}$, where $\boxed{a_{ij} = (Nd_{0i})^2 + (Nd_{0j})^2 - (Nd_{ij}d)^2}$ and $\boxed{Nd_{ij}}$ represents the numerical part of the distance between vertices $\boxed{V_i}$ and $\boxed{V_j}$, $\boxed{d_{ij}}$, see the following figure, (Fig. 1).

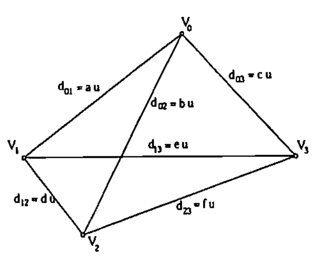

Figure l: A tetrahedron, $\boxed{C_3}$, in terms of vertices and distances between vertices.

Becoming aware of a conjecture and proving such are not always simultaneous. In this instance the formula is easily verified for n = 0 (define $\boxed{|a_{00}| = 1}$), n = 1 and n = 2. Verification for n = 2 can involve analytical

geometric analysis and techniques and provide hints for an analytic geometrical proof for n = 3, the scope of this paper. Also, one discovers a reasonably ready acceptance of $\boxed{m(C_2) = \frac{m(B)\,m(h)}{2}}$ and one can usually convince students that $\boxed{m(C_3) = \frac{m(B)\,m(h)}{3}}$. When n = 3 one could also apply linear algebra/vector analysis techniques which may be applicable for some secondary/undergraduate students. Alternately, one could use techniques which are well beyond the usual secondary/undergraduate abilities and prove the general formula for which n = 3 is a restricted application but completely mystify the theorem for students, which happens all too often.

Students tend to react rather well to analytical geometrical derivations. Such approaches allow for rather specific alpha numeric assignments to attributes, coordination in 3-D space and an opportunity to capitalize upon relationships between attributes which can be formulated as in systems of equations. Unfortunately these systems sometimes invoke lots of algebraic terms and students can get frustrated through minor errors and sometimes fail to analyze the structure because of the details. Deriving $\boxed{\frac{1}{3!}\sqrt{\frac{-1}{2^3}\left|a_{ij}\right|}^{\,1/2} u^3}$ from $\boxed{m(C_3) = \frac{m(B)\,m(h)}{3}}$ involves systems of equations which at a crucial point hinges upon a simplified equation of twenty-two terms. An essential purpose of technology is to free the mind from routine, though difficult, manipulations. Consequently, the following comprises a computer assisted, Maple, proof. Consider the following figure (Fig. 2) as a basis for formulating an analysis that results in a system of equations without loss of generality.

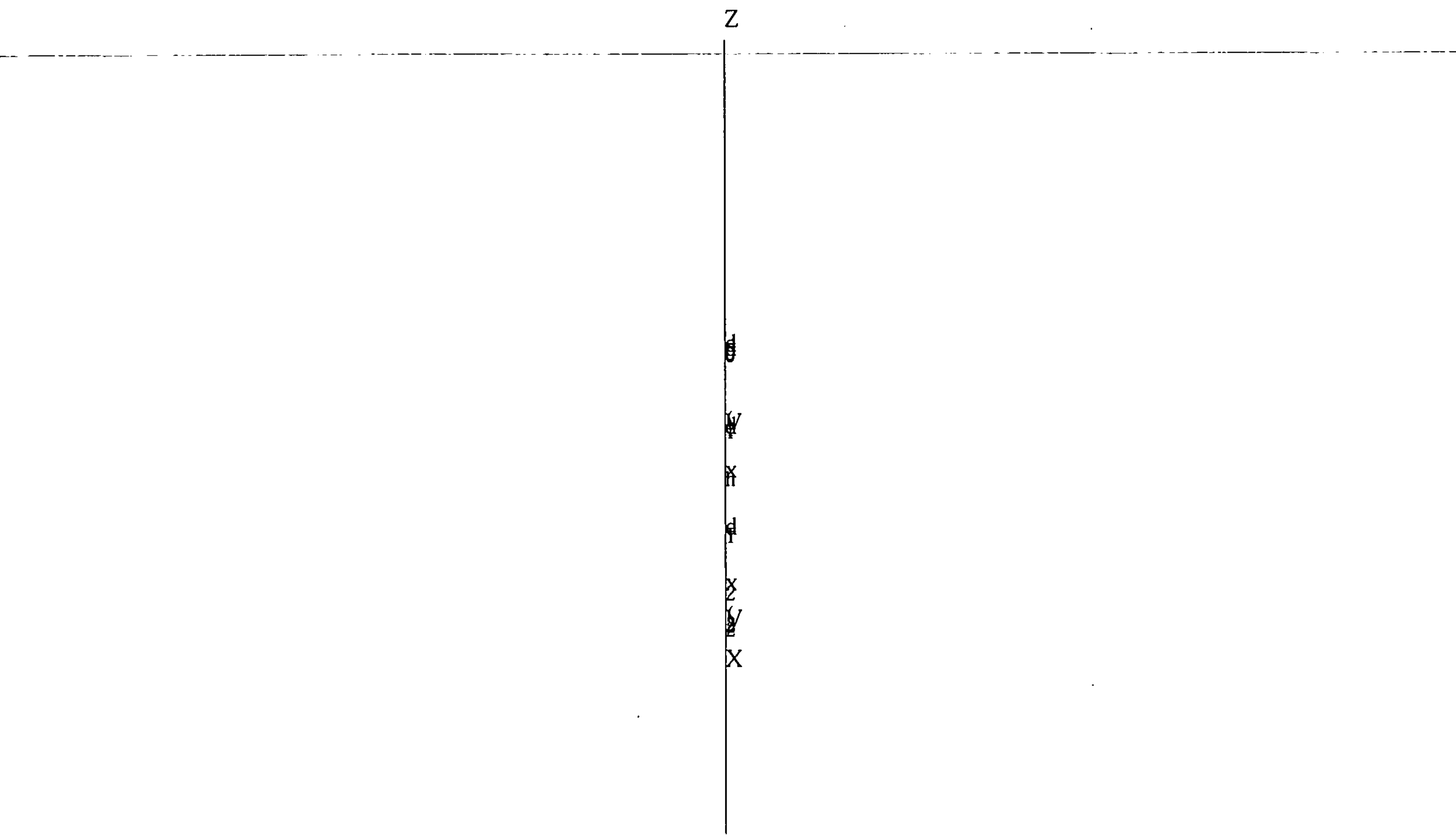

Figure 2: A tetrahedron related to a 3-D coordinate system.

$m(Base) = \frac{ex_2}{2}$ u^2 since e u can be the length of the base of the trigonal face in the XY plane and x_2 is the height of that trigon. h u is the measure of the height of the tetrahedron so $m(C_3) = \frac{ex_2 h}{6} u^3$. We need to show $\frac{ex_2 h}{6} = \frac{1}{3!}\left(\frac{1}{2^3}|a_{ij}|_{3x3}\right)^{1/2}$.

From the diagram with the imposed Cartesian coordinate structure it should be clear that:

$d_{V_1B} = (x_h^2 + y_h^2)^{\frac{1}{2}}$.

$d_{V_2B} = [(x_2 - {}_h)^2 + (y_2 - y_h)^2]^{\frac{1}{2}}$.

$d_{V_3B} = [x_h^2 + (e - y_h)^2]^{\frac{1}{2}}$.

Since h is perpendicular to the designated base and as a result of the imposed coordinate system:

$(x_h^2 + y_h^2)^{\frac{1}{2}}$, h, and a are edges of a right trigon and so, $x_h^2 + y_h^2 + h^2 = a^2$, Eq 1.

$((x_2 - x_h)^2 + (y_2 - y_h)^2)^{\frac{1}{2}}$, h and b are edges of a right trigon and so $(x_2 - x_h)^2 + (y_2 - y_h)^2 + h^2 = b^2$,Eq 2.

$(x_h^2 + (e - y_h)^2)^{\frac{1}{2}}$, h, and c are edges of a right trigon and so $x_h^2 + (e - y_h)^2 + h^2 = c^2$, Eq 3.

x_2, y_2, and d are edges of a right trigon and so $x_2^2 + y_2^2 = d^2$, Eq 4.

$x_2, (e - y_2)$, and f are edges of a right trigon and so $x_2^2 + (e - y_2)^2 = f^2$, Eq 5.

Eq 1 and Eq 2 result in Eq 6: $x_h = \frac{e(x_2^2 + y_2^2 + a^2 - b^2) - y_2(e^2 + a^2 - c^2)}{2x_2 e}$.

Eq 1 and Eq 3 result in Eq 7: $y_h = \frac{e^2 + a^2 - c^2}{2e}$.

Substituting Eq 6 and Eq 7 in Eq 1 yields Eq 8:

$4x_2^2e^2h^2 = 4x_2^2e^2a^2 - [e(x_2^2 + y_2^2 + a^2 - b^2) - y_2(e^2 + a^2 - c^2)]^2 - x_2^2(e^2 + a^2 - c^2)^2$.

Recall that $m(C_3) = \frac{ex_2 h}{6} u^3$ or $[m(C_3)]^2 = \frac{e^2x_2^2h^2}{36}$ u^6 or $144[m(C_3)]^2 = 4x_2^2e^2h^2$ u^6.

So, from Eq 8 and the proceeding we know

$144[m(C_3)]^2 = 4x_2^2e^2a^2 - [e(x_2^2 + y_2^2 + a^2 - b^2) - y_2(e^2 + a^2 - c^2)]^2 - x_2^2(e^2 + a^2 - c^2)^2$ u^6, Eq 9.

Eq 4 and Eq 5 result in Eq 10: $x_2^2 = \frac{4d^2e^2 - (d^2 + e^2 - f^2)^2}{4e^2}$ and Eq 11: $y_2 = \frac{d^2 + e^2 - f^2}{2e}$.

Substituting Eq 10 and Eq 11 into Eq 9 yields Eq 12:

$144[m(C_3)]^2 = 4\frac{4d^2e^2 - (d^2 + e^2 - f^2)^2}{4e^2} e^2a^2 - e\frac{4d^2e^2 - (d^2 + e^2 - f^2)^2}{4e^2} + \left(\frac{d^2 + e^2 - f^2}{2e}\right)^2 + a^2 - b^2 - ($

$$-\frac{4d^2e^2-(d^2+e^2-f^2)^2}{4e^2}(e^2+a^2-c^2)^2 \quad \boxed{u^6}$$

Eq 12 simplifies to:

$$144\,[m(C_3)]^2 = (-a^4f^2 - a^2b^2c^2 + a^2b^2c^2 + a^2b^2f^2 + a^2c^2d^2 - a^2c^2e^2 + a^2c^2f^2 + a^2d^2f^2 + a^2e^2f^2 - a^2f^4$$

$$-b^4e^2 + b^2c^2d^2 + b^2c^2e^2 - b^2c^2f^2 + b^2d^2e^2 - b^2e^4 + b^2e^2f^2 - c^4d^2 - c^2d^4 + c^2d^2e^2 + c^2d^2f^2 - d^2e^2f^2)$$

$\boxed{u^6}$

Since both members of the proceeding are greater than or equal to zero:

$$m(C_3) = \frac{1}{12}(-a^4f^2 - a^2b^2c^2 + a^2b^2c^2 + a^2b^2f^2 + a^2c^2d^2 - a^2c^2e^2 + a^2c^2f^2 + a^2d^2f^2 + a^2e^2f^2 - a^2f^4$$

$$-b^4e^2 + b^2c^2d^2 + b^2c^2e^2 - b^2c^2f^2 + b^2d^2e^2 - b^2e^4 + b^2e^2f^2 - c^4d^2 - c^2d^4 + c^2d^2e^2 + c^2d^2f^2 - d^2e^2f^2)^{\frac{1}{2}}$$

$\boxed{u^3}$

This expression can be modified:

$$m(C_3) = \frac{1}{3!}\;\frac{1}{2^3}(-2a^4f^2 - 2a^2b^2c^2 + 2a^2b^2c^2 + 2a^2b^2f^2 + 2a^2c^2d^2 - 2a^2c^2e^2 + 2a^2c^2f^2 + 2a^2d^2f^2$$

$$+2a^2e^2f^2 - 2a^2f^4 - 2b^4e^2 + 2b^2c^2d^2 + 2b^2c^2e^2 - 2b^2c^2f^2 + 2b^2d^2e^2 - 2b^2e^4 + 2b^2e^2f^2 - 2c^4d^2 - 2c^2d^4$$

$$+ 2c^2d^2e^2 + 2c^2d^2f^2 - 2d^2e^2f^2)]^{\frac{1}{2}} \quad \boxed{u^3}$$

and, the expression can be further modified:

$$m(C_3) = \frac{1}{3!}\;\frac{1}{2^3}\begin{vmatrix} 2a^2 & a^2+b^2-d^2 & a^2+c^2-e^2 \\ a^2+b^2-d^2 & 2b^2 & b^2+c^2-f^2 \\ a^2+c^2-e^2 & b^2+c^2-f^2 & 2c^2 \end{vmatrix}^{\frac{1}{2}} \quad \boxed{u^3}$$

$$= \frac{1}{3!}\;\frac{1}{2^3}\left|a_{ij}\right|_{3x3}^{\frac{1}{2}}, \; a_{ij} = (d_{0i})^2 + (d_{0j})^2 - (d_{ij})^2 \quad \boxed{u^3}$$

$$= \frac{1}{3!}\;\frac{1}{2^3}\,D_{3x3}^{\frac{1}{2}} \quad \boxed{u^3}.$$

Consequently, in measuring a polyhedronal region one merely tessellates the region with tetrahedrons using the vertices, measures the edges of each of the tessellating tetrahedrons, calculates the volume of each of the tetrahedrons, and the measure of the polyhedronal region is the sum of the measures of the tessellating tetrahedrons.

The proceeding leads one to conjecture that $m(g_n) = (\frac{1}{n!})((\frac{1}{2^n})\,D_{nxn})^{\frac{1}{2}}$, which has been proven.

Abstract: Proof, the heart of mathematics, should be an essential aspect of secondary mathematics and not limited to geometry. Historically, Heron expressed the area of a trigon, $\boxed{C_2}$, and Carnot expressed the volume of a tetrahedron, $\boxed{C_3}$, in terms of edges.

One suspects that the measure of any construct, $\boxed{C_n}$, can be in terms of edges. Constructs tessellate (or closely tessellate) geometric regions. These properties lead to a measurement/construct perspective of geometry which is all too often glossed over in students conceptualizing/applying geometry. A simplified application of this perspective is to tessellate a geometric region, $\boxed{g_n}$, with constructs, $\boxed{C_n}$, measure the edges of each construct, calculate the measure of each construct, $\boxed{m(C_n) = (\frac{1}{n!})((\frac{1}{2^n}) D_{nxn})^{\frac{1}{2}}}\boxed{u^n}$, and sum the measures, $\boxed{m(g_n) = \quad m(C_n)}$. The scope of this paper is to develop a proof of the formula for a tetrahedron with the assistance of a computer technique, Maple.

Acknowledgments

Many thanks to those fifth grade students and personal communications with Howard Eves in discussing Carnot's formula. Thanks to Merilee (Adams) Sommers for insights into Escher's tessellations. Many thanks to my fourth, fifth, and sixth grade student group who applied these results while using programmable calculators. Many thanks to Mike Brown for his continued interest in this idea and to his secondary students for applying such. Thanks to Joyce Donahoe for her interest and vector analysis insights. Thanks to Eugene Curtin for his interest, his insight and eventual proof of the general theorem. Many thanks to my teacher preparation students and many teacher inservice workshop participants who have applied these results. A big thanks for the assistance of Naomi Driskell for spending several hours in assisting me in getting this paper on e-mail. Thank to my wife Lucy for her patience with this and many other projects.

Preparing Teachers to Use Technology in the Mathematics Classroom

Mary C. Enderson
Mathematics Department, Indiana University of Pennsylvania
Indiana, PA, 15705, USA
email <enderson@grove.iup.edu>

Abstract: Teachers are presently having to confront the technological revolution in their classrooms on a regular basis. Effectively using technology in the mathematics classroom may present challenges and obstacles for new and senior teachers alike. This is not uncommon since many have had little to no experience or preparation dealing with content and/or pedagogy issues requiring use of technology. This paper addresses how teacher education programs have a responsibility to prepare and support mathematics teachers, at all levels, to work with technologies in an exploratory and content-rich manner. Presenting situations that require teachers - pre- and inservice - to explore, analyze, verbalize, and verify their mathematical findings must become part of their own learning experiences so that they will be better prepared to offer such environments to their own students.

With the fast pace of the technological revolution occurring in school districts around the country, teachers are having to face the reality of how to use such technologies effectively in their classrooms. For beginning and experienced teachers alike, many do not know how to use technological tools, let alone receive training in how to use them for classroom instruction. In order to better prepare teachers to deal with this revolution, Teacher Education programs need to offer opportunities and support for incorporating technology into mathematics coursework, fieldwork, and professional development seminars and workshops.

Heid and Baylor stated, "A wholehearted incorporation of computing technology in high school mathematics suggests changes in mathematical content as well as in the methods and nature of teaching and learning mathematics" (1993, p. 198). Thus, it is crucial for teacher preparation programs - at all levels - to address not only mathematics content issues with the technology, but also pedagogy issues. By introducing teachers to learning environments enhanced by technology, their own motivation and curiosity about the "how's" and "why's" of mathematics often emerge. This in turn may initiate discussions revolved around teaching strategies that can be adopted in their own classrooms.

Manouchehri et al.(1997) highlight the point that teachers must have opportunities in their collegiate courses to do mathematics in ways that are different from their previous experiences. One way of carrying this out is by using technology as a tool to engage present and future teachers in their own mathematical investigations to help them construct conceptual understandings of the mathematics for themselves. Research studies have suggested that the use of interactive software assists learners in making mathematical abstractions and generalizations within algebraic and geometric domains (Edwards, 1991; Jiang, 1993; Manouchehri, 1994; Pagnucco, 1993). This is a positive step for teacher preparation in having the potential to pose dynamic and stimulating mathematical situations for teachers to engage in.

In working with preservice and inservice teachers at all levels, elementary, middle/junior high, and senior high, it is not unusual to find a number of individuals who are lacking in their mathematics content knowledge. Some of these uncertainties are associated with little understanding of concepts, lack of problem solving expertise and poor communication skills. Preservice and inservice teachers need exposure to mathematical situations that require them to explore, conjecture, test, validate, and reflect upon the mathematics they are doing and the mathematics they will be teaching. While such visions are professed in the NCTM *Standards* (1991, 1989), teachers need support in trying to achieve such practices in the classroom. One method of accomplishing this is through the use of technology, more specifically the computer with interactive software. With such technology available, the learner has the power to reason, problem solve, connect concepts, conjecture/question, test, receive feedback on actions, and communicate findings from carrying out such activities. Colleges and universities have to take on a leadership role to help educate and prepare teachers to implement such visions in their own classrooms.

Much of my own work has been directly involved with teacher preparation, both at the elementary and secondary levels. With the push for adopting and promoting the mathematics reform movement doctrine, using technology in content and pedagogy courses has become instrumental in posing problem situations for teachers to tackle. In what follows are three different situations that have been used in content and/or pedagogy courses at my university. Although technology can take on a variety of different forms, the focus here is on using interactive computer software to explore mathematical concepts.

The first situation is an open exploration that allows students to investigate the mathematics in a non-predetermined manner. This may be interpreted as having no limitations to the mathematics students use to attack or resolve the problem. A statement of the problem situation follows:

Develop a set of directions that a friend can follow to construct a regular hexagon. Is it possible to generate the hexagon in more than one way? If so, how? If not, why not?

This situation is an excellent opportunity to explore mathematical concepts using the dynamic software, *Geometer's Sketchpad* (GSP) (Jackiw, 1995). The ease of using the software along with its instant feedback to the actions of the user are amazing.

This software also provides students with an environment to explore the hexagon task at "their own" level of

understanding as well as their own pace. As part of the hexagon situation, students share their responses and in the process, discover that there are a number of ways to "attack" and/or resolve this problem. Through the course of the investigation, students had to confront various mathematical concepts and ideas some of which included: construction versus draw, polygons and their interior and exterior angle measures, lines and points of symmetry, rotations, and reflections. The situation is accessible to a wide audience since it is designed as an open exploration. How and what mathematics students use to solve it, depends on how they interpret it and what mathematics they believe GSP supports in this process.

The second situation can be described as a semi-structured activity, which is an activity designed with specific mathematical goals in mind as well as to motivate students to use particular tools of the software (Manouchehri, Enderson, & Pagnucco, 1998). A statement of the problem (Wilson, 1997) is as follows:

If square ABCD is 2 inches to a side and G, H, K, and L are midpoints, what is the area of region QRST? (see Figure 1)

Figure 1: Area of QRST Problem Situation

This problem is also a prime situation to explore using GSP (Jackiw, 1995). Students may work within a preconstructed environment or they may generate their own environment with a square fitting the given criteria. GSP allows the user to make adjustments to the figure while maintaining its appropriate characteristics. This permits the user to test an infinite number of cases out in a matter of seconds. This traditionally has not been the case with paper and pencil explorations or software that is not dynamic and interactive.

Student responses to this problem typically focus on a symbolic manipulation. While this technique is valid, it is often one that loses sight of trying to find the area of the interior square. Pagnucco and Hirstein (1995) found similar results when presenting the same problem to a mathematics methods class. In carrying out the numerical manipulation, it might also be noted that it does not take "full" advantage of the capabilities of GSP. This is part of what I want my students to experience. As a consequence, they are placed in a situation where they now must rely on the workspace rather than the numbers. One way of accomplishing this is to focus on the transformation menu and its rotation feature. Students quickly realize that they can rotate the pieces into five small squares. This ultimately helps answer the question and achieves meeting the objectives, but in this process, a number of additional questions surface. This often becomes a crucial part of the interactive technology exploration. Questions such as, "What if the midpoints are not used - but rather any point on the sides?"; "What if we begin with a quadrilateral that is not a square?"; "What if we have a polygon that is not a quadrilateral?" All of these questions became important in a number of ways. Students wanted to find out if there were any generalizations that could be made about the relationship of the interior area to the other pieces or to the entire figure and whether or not this held for any polygon or any point used on the side of the polygon. This initiated a great deal of investigation and dialogue that is traditionally not present when one explores and generalizes using paper and pencil or non-interactive software. This is a component of teacher preparation that needs attention if mathematics teachers are to be prepared to teach as the *Standards* (1991, 1989) envision teaching.

The third situation is an independent exploration involving a bit of problem solving and critical reasoning (For a detailed discussion of independent exploration, see Manouchehri et al., 1998). The situation, finding the volume

of a box, was presented in a dual-level mathematics course for elementary/middle school teachers who were studying a unit on functions. First, students used grid paper to cut and fold up sides to create boxes for finding the maximum and minimum volumes. The task then took a different direction by incorporating computer software, *Algebra Xpresser* (William K. Bradford Publishing), into the investigation. At this point, the situation turned to trying to make sense of how the numerical and graphical data for the volume of a box related to each other (For a more detailed discussion of this situation, see Enderson, 1997). Most students had a grasp on the volume formula, "length x width x height," but did not have a sense of how this product related to the graph of the function. They also had very little expertise in dialoguing about such mathematical concepts. The problems for students to investigate using the technology were posed as follows:

Describe what the graph represents with respect to the actual box.
Is there more than one box that holds the maximum volume?
Is there more than one box that holds the minimum volume?

The value of this mathematical situation was not only in the exploration itself, but also in the additional questions that were student-generated and investigated on a long-term basis. Once students realized how the function related to the graph, they then began to ask other questions about the situation. This is where the independent exploration comes in - students begin raising some of their own personal questions and concerns and using the technology to explore them. Some of the questions that were raised included: "What if the grid paper we began with was square rather than rectangular? Would anything about this investigation be different?"; "Is it possible for the volume graph of two different boxes to look similar? Why or why not?"; "Is it possible to generate a graph for the volume of any box that does not have a curve similar to the one(s) we explored?" Another natural extension of this investigation was its connection to polynomial functions and finding their roots/zeros.

In these particular episodes, the interactive technological environment allowed a much deeper exploration of mathematical concepts than was previously explored from a symbolical perspective. Representing mathematical concepts in various forms is an area that many teachers, novice and expert, need to experience. They need to investigate mathematics that is challenging for themselves by conjecturing, testing, analyzing, verifying, and reformulating mathematical tasks. For a number of teachers, this challenge was lacking in their own education. Thus, exposure to such situations prior to making attempts at presenting such activities into their own classrooms must occur. Teacher Education programs have a responsibility to provide an avenue to help teachers teach for the 21st century. This means using technology in exploratory and investigative ways to better prepare all students mathematically, K-12, to work and live in the ever-changing society of today and of the future.

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The Impact of Web-Based Instruction on Performance in an Applied Statistics Course

Robert J. Hall
Department of Educational Psychology
Texas A&M University
United States
bobhall@tamu.edu

Michael S. Pilant
Department of Mathematics
Texas A&M University
United States
mpilant@math.tamu.edu

R. Arlen Strader
Department of Educational Psychology
Texas A&M University
United States
strader@tamu.edu

Abstract: Forty-one graduate and undergraduate students enrolled in Summer or Fall sections of an applied statistics course self-selected into one of three groups. Group 1 subjects (n = 11) took chapter pretests online and printed out results. Subjects in group 2 (n = 18) printed copies of the pretests but did not take tests online. Group 3 subjects (n = 12) did not access the pretests. Pretests for exams 1 and 3 were made available through a class website using online-testing software developed by the authors. Demographic information (educational background and course learning and performance goals) and prerequisite math skills scores were collected on the first day of class. Groups could not be distinguished, *a priori*, on the basis of either demographic data or math skill scores. There were, however, statistically significant differences among groups on exam performance, favoring students in the online-pretest group. Factors influencing student performance, as well as issues for future study, are addressed.

Overview and Purpose

The area of human-computer interaction combines information from several academic areas (i.e., computer science, education, and psychology). For example, concepts inherent to technology such as flow, feedback, formatting, detail, organization, and consolidation have been relevant to cognitive psychology and to instructional design for a number of decades. According to Dillon and Zhu (1997), technology has "enhanced our ability to apply these [learning] principles over distributed learner populations with higher fidelity than previously" (p.223). One major component of instructional design and one of the more difficult areas in Web-based instruction to verify is "effectiveness" (Reeves & Reeves, 1997). Several key questions related to effectiveness must be considered in order to document how Web-based instruction affects academic performance. Questions related to course orientation (i.e., for-credit, not-for-credit, workforce related), learning objectives (i.e., factual, algorithmic, strategic), and nature of instruction (i.e., skills-based vs. general problem solving) highlight important issues facing developers of Web-based courses and instruction. The issue of concern for this study, however, is assessment and exploring how technology can add to our understanding of human learning and performance and whether carefully designed web-based supplemental study-aids can be shown to impact on classroom performance as measured by course exams. In that regard, we are interested in questions such as "How will performance metrics for a Web-based course be defined?" and "Will assessment focus primarily on pre-testing (for diagnostic purposes), post-testing (to determine subject mastery), or both?"

These issues are inter-related in a complex manner and make questions about assessing the effectiveness of Web-based instruction challenging ones. The purpose of this study, then, is to evaluate the impact of online pretesting and feedback on outcome performance as measured by in-class multiple choice and workout exams in educational statistics.

Method

Subjects. This study focuses on two cohorts of graduate and undergraduate students enrolled in a first semester course in applied statistics for the behavioral sciences. The first cohort included 19 students (13 females, 6 males) enrolled in a five-week session during the summer of 1998. The second cohort includes 22 students (16 females, 6 males) enrolled in the same class during the fall of 1998. The same instructor taught both courses.

Procedure. On the first day of class, students were given a password and student ID that enabled them to access the class website. All course materials including HTML versions of the in-class lecture slides (*Microsoft* (R) *PowerPoint*), problems, assignments, announcements, threaded discussion groups, class rosters with e-mail links, *JAVA*-based statistics applets, and chapter pretests were made available to students through the website. All but one of the 41 students participating in this study reported owning a computer and only one student who owned a computer did not have a modem. In addition, there are many open-access labs at the University housing hundreds of computers with high-speed Ethernet connections. In other words, access to a computer should not have been an issue for any student taking this course.

Students were given a math prerequisite exam on the first day of class (59 questions) that covered basic arithmetic, advanced arithmetic, complex problems, and simple algebra skills. Students were not allowed to use calculators to answer any of the questions on the test. The math prerequisite test was used to compare math skill levels across treatment groups. Results for the three groups are summarized in Table 2. During the first week of class, students were required to fill out an online demographic questionnaire made up of 36 questions. Tables 3 and 4 summarize results from questionnaire data by treatment group. Finally, three days prior to each exam, chapter pretests were made available to students.

Instrument. The authors have developed an assessment tool that addresses some of the issues outlined in the introduction. A series of linked components make up the online testing instrument. The first is an "administration" or "authoring" component that is web-based and password protected. In this environment an instructor can build or modify questions and exams and create classroom databases. A second component provides students access to the actual interactive testing. Finally, the third part is the database itself, which uses the program *Microsoft* (R) *Access*. Note, although *Microsoft* (R) *Access* is used for data storage, it is completely hidden behind a web front-end and therefore can be used by Unix and Mac systems.

One of the unusual features programmed into the online testing tool is the ability to capture information related to motivation through use of sliders that measure student's "familiarity" with content objectives prior to testing, and "confidence" about response accuracy as the test proceeds. This provides students and instructors with information regarding depth of preparation, level of skill, and degree of uncertainty. Each question is timed transparently to the student. The format of the questions is unstructured - any valid HTML code can be included. Question types currently supported are true/false, multiple choice, short workout, and detailed workout. Questions can be interactive (through embedded *JAVA* applets), and can contain graphics and multi-media. Responses are recorded and a printable summary of the students' work - including computer-graded questions (true/false and multiple choice), explanations, time spent answering individual questions, reported confidence and help, and reported familiarity with learning objectives - is returned when all questions have been answered. Students review one question at a time and once questions are submitted, they cannot be revisited. If there is not enough time to complete a pretest, a bookmark feature allows the student to return to the test at the point where he/she stopped. Using this tool, instructors can maintain question, exam, student, and class databases, and link questions to categories and/or objectives to individual questions. The authoring tool is completely accessible through the Web (although it is password protected for security reasons).

Results

Design. On the basis of the amount of time spent engaged with the online chapter pretests, students were placed into 1 of 3 groups. The first group, *Pretested Online* (n = 11), spent at least 20 minutes online working on

each chapter pretest (15 to 18 multiple-choice questions and workout problems per test). The second group, *Download Only* (n = 18), was made up of those students who visited the test sites but only took enough time to print out the test. These students averaged less than five minutes with each pretest. The third group, *No Access* (n = 12), did not access the pretests, choosing instead to study for the exams without benefit of these study aids.

Analysis. A split-plot analysis of variance was used to analyze data from this study. The design had one between-subjects factor, *Pretest Group* (3 levels; Pretested online/Download/No Access) and two within-subjects factors, *Exam* (3 levels; Exam 1/Exam 2/Exam 3) and *Question Type* (2 levels; Multiple Choice/Workout). All three main effects and one interaction effect, *Exam* x *Question Type*, were statistically significant. For *Pretest Group*, $F_{(2,38)} = 6.31, p < .004, \eta^2 = .25, \omega^2 = .21$, power = .87. For *Exam*, $F_{(2,76)} = 21.98, p < .001, \eta^2 = .37$, power = .1.00. For *Question Type*, $F_{(1,38)} = 173.99, p < .001, \eta^2 = .82$, power = 1.00. For *Exam* x *Question Type*, $F_{(2,76)} = 8.60, p < .001, \eta^2 = .19$, power = .96. Table 1 summarizes means and standard deviations for the different cells in the design.

Online Pretest Group		Ex. 1 MC%	Ex. 1 WO%	Ex. 2 MC%	Ex. 2 WO%	Ex. 3 MC%	Ex. 3 WO%
Pretested online (n = 11)	Mean	81.55	96.62	78.16	95.64	71.00	90.68
	S.D.	9.27	4.02	11.99	4.83	14.02	7.74
Downloaded pretests (n = 18)	Mean	76.56	88.18	78.35	89.26	64.71	85.19
	S.D.	12.52	14.05	13.74	12.93	13.33	12.35
No access (n = 12)	Mean	69.17	80.44	65.50	82.81	53.57	79.24
	S.D.	9.87	11.26	13.43	10.60	13.38	16.27
Total	Mean	75.73	88.18	74.54	89.09	63.14	84.92
	S.D.	11.72	12.66	14.16	11.46	14.81	13.09

Table 1: Descriptive statistics for exams by question type and group. MC - Multiple Choice; WO - Work Out

Discussion

In this study, we were interested in whether students who took pretests online (OT) and then reviewed printed answers and explanations would outperform, on in-class exams, students who only downloaded (DO) pretests and/or students who did not access (NA) pretests. Statistically significant differences, separating the OT group from the NA group were obtained. Moreover, there were consistently observed, but not statistically significant, differences between the OT and DO groups and between the DO and NA groups. On the basis of this analysis, we are tempted to conclude that results from this study can be interpreted to indicate that taking Web-based pretests resulted in better performance on the exams given in class. At best, however, this conclusion is preliminary.

Students were not randomly assigned to treatment groups but rather self-selected into the respective groups. Thus, systematic bias tied to individual differences (i.e., ability, motivation, and educational background) inherent to the self-selection process could be cited to account for the better performance of the OT group. Clearly, one factor that might promote the observed differences in performance would be general math ability. All students were given a math prerequisite exam on the first day of class. Table 2 summarizes exam results for each of the treatment groups.

Wilks'-Lamda F for a one-way multivariate ANOVA testing for group differences among the four dependent math skill measures was not statistically significant ($F_{(8,70)} = 1.01; p = .434$). Hence, students in the three treatment groups could not be distinguished, *a priori*, on the basis of their general math ability as measured by the prerequisite test scores. Given that the groups did not differ in general math ability, we turned to investigate factors, other than online pretesting, that might account for the observed group performance differences. Tables 3 and 4 summarize findings from the demographic questionnaire by treatment group.

Table 3 presents frequency counts for variables related to educational background and course goals by treatment group. Proportional representation for the variables gender, class cohort, year in school, and number of hours employed during the semester was approximately the same for all groups. Similarly, almost all students reported grades of A or B in their high school algebra courses with the ratio of A's to B's about 2 to 1. All but 1 student reported owning a computer and when asked how comfortable are you working with web browsers to obtain information, the least comfortable group was OT (61/100) followed by DO (74/100) and NA (77/100). Most students had not taken a computer course of any kind and all students indicated that their grade goal for the class was an A or B. Primary learning goals reported for the OT and NA groups were conceptual understanding but all

three groups placed importance on developing computational skill. Finally, in all groups, most students anticipated that they would spend 7 to 12 hours a week studying for the class. Information summarized in Table 3, then, might be interpreted to argue more for homogeneity rather than heterogeneity across groups.

Next we looked to see if measures related to general motivation (e.g., confidence, importance, ability, or effort) might form a basis for differentiating groups, thus undermining the conclusion that the online testing experience was a major factor in determining exam performance. Table 4 summarizes the descriptive statistics that address questions tied to motivation. Univariate one-way ANOVAs were used to test for group differences for each of the rating measures. None were statistically significant. In sum, even though students were not randomly assigned to treatment groups, the only reliable difference among groups that we could establish to account for differences in exam performance was the nature of the interaction that students had with the chapter pretests.

Online Pretest Group		**Basic arithmetic (30 pts)**	**Advanced arithmetic (14 pts)**	**Complex arithmetic (11 pts)**	**Simple algebra (4 pts)**	**Total score (59 pts)**
Pretested online (n = 11)	Mean	28.59	10.91	8.55	2.86	84.85
	S.D.	2.55	2.63	2.38	1.57	13.07
Downloaded pretests (n = 18)	Mean	29.06	10.97	8.50	3.50	86.71
	S.D.	.87	2.50	1.90	.92	8.01
No access (n = 12)	Mean	28.21	10.96	9.29	3.42	86.46
	S.D.	1.72	2.49	1.08	.67	7.97
Total	Mean	28.68	10.95	8.74	3.30	86.14
	S.D.	1.70	2.47	1.84	1.08	9.39

Table 2: Prerequisite math score descriptive statistics by online pretest group.

	Pretest Group (n = 41)								
Survey Question	**Tested Online (n = 11)**			**Download Only (n = 18)**			**No Access (n = 12)**		
Gender	Male		Female	Male		Female	Male		Female
	3		8	5		13	3		9
Class Cohort	Summer 98		Fall 98	Summer 98		Fall 98	Summer 98		Fall 98
	6		5	9		9	4		8
Year in School	Undergrad		Grad	Undergrad		Grad	Undergrad		Grad
	4		7	8		10	5		7
Hours Employed	None	< 20	> 20	None	< 20	> 20	None	< 20	> 20
	3	3	5	4	2	11	3	5	4
HS Algebra Grade	A	B	C or <	A	B	C or <	A	B	C or <
	5	3	3	9	4	4	8	4	0
Own a Computer?	Yes		No	Yes		No	Yes		No
	11		0	16		1	12		0
Web Browser Use	< 1 wk	1-2 wk	Daily	< 1 wk	1-2 wk	Daily	< 1 wk	1-2 wk	Daily
	2	6	3	7	5	6	4	3	5
Computer Course?	Yes		No	Yes		No	Yes		No
	4		7	6		12	5		7
Grade Goal	A	B	Other	A	B	Other	A	B	Other
	10	1	0	15	2	0	8	4	0
Primary Learning Goal [a]	Comp.	Concep.	Prep.	Comp.	Concep.	Prep.	Comp.	Concep.	Prep.
	5	7	3	11	4	10	8	11	4
Anticipated Study Hours	< 6	7 - 12	> 12	< 6	7 - 12	> 12	< 6	7 - 12	> 12
	2	8	1	7	10	0	3	9	0

Table 3: Demographic survey results summarized by pretest access group. [a] For primary learning goals, the numbers indicate "yes" responses. Students could check more than one area. Key: *Comp* = Computational skills; *Concep* = Conceptual Understanding; *Prep* = Future course preparation.

Further support for the impact of the pretests comes from student feedback. When asked "how helpful were the online chapter pretests in preparing you for the exams?" students who took advantage of the Web-based pretests responded with either a 5 or 6 (out of a possible 6) on a Likert scale rating instrument. In addition, many students provided written comments indicating that the online pretests (and the student reports generated from the pretests) helped them to focus their study efforts and to prepare for the in-class exams. Others reported that the online tests provided an experience comparable to the actual test in that there was no immediate feedback regarding whether their answers were right or wrong and that they felt anxious about their performance like they would on an exam. For some students, then, the pretests helped to focus their final preparation for the in-class exams.

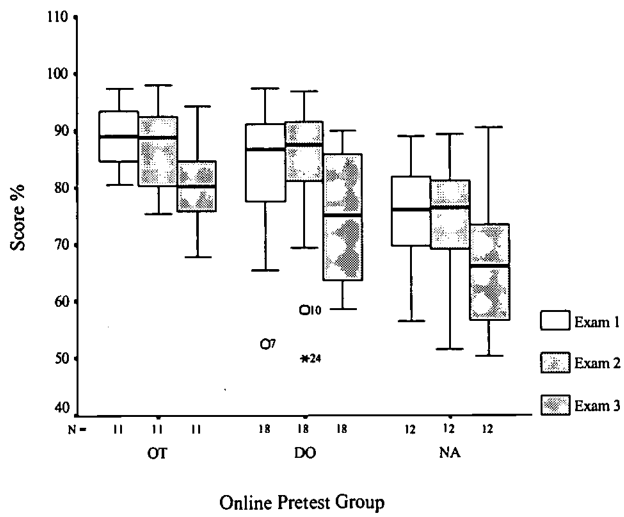
	Tested Online (n = 11)			Pretest Group (n = 41) Download Only (n = 18)			No Access (n = 12)		
Rating	$\bar{X}$	**S.D.**	**n**	$\bar{X}$	**S.D.**	**n**	$\bar{X}$	**S.D.**	**n**
Grade Goal Importance [a]	84.10	15.55	10	90.71	9.98	17	89.11	12.11	9
Grade Goal Confidence [b]	74.40	16.21	10	80.29	9.83	17	79.33	14.40	9
Learning Goal Import. [c]	81.40	17.14	10	77.24	15.36	17	85.00	17.49	9
Learning Goal Confid. [d]	74.90	16.29	10	82.81	11.14	16	80.29	13.83	9
Math Ability for "B" [e]	72.80	9.65	10	62.62	18.06	16	66.44	7.73	9
Math Abl. for Lrn. Goal [f]	71.11	5.80	9	63.56	15.29	16	64.00	6.71	9
Personal Math Ability [g]	58.44	9.63	9	63.13	22.27	16	66.44	21.31	9
Effort for "B" [h]	79.00	11.61	10	75.75	10.48	16	69.56	16.79	9
Effort for Learning Goal [i]	78.67	11.54	9	73.38	13.97	16	70.11	15.65	9
Personal level of Effort [j]	91.00	9.74	10	84.25	15.82	16	82.22	13.57	9

Table 4: Confidence, importance, and ability ratings (scale = 1 to 100) summarized by pretest access group. [a] How important is the final grade in this course to you? [b] How confident are you that you can attain your goal for the course grade? [c] How important is your primary learning goal to you? [d] How confident are you that you can obtain your primary learning goal for this course? [e] How much mathematical ABILITY do you think it would take to obtain a grade of at least a B in this course? [f] How much mathematical ABILITY do you think it would take to acquire the computational skill and conceptual understanding for this course needed to prepare you for future courses and/or your career? [g] How much mathematical ABILITY do you think you have? [h] How much EFFORT do you think it would take to obtain a grade of at least a B in this course? [i] How much EFFORT do you think it would take to acquire the computational skill and conceptual understanding for this course needed to prepare you for future courses and/or your career? [j] How much EFFORT do you intend to devote to this course?

In contrast were those students who chose not to access the online tests and those who accessed the tests but chose only to print out the questions and explanations. The latter group faired better on the in-class exams than students who did not access pretests, but their performance, on average, was almost a full grade (8%) lower than the group who took full advantage of the online testing package. Some students in each group did well on the exams, but one interpretation is that just looking at questions and answers apprises students of specific information that might be asked on an exam but does not prime them to search through networked information. These students are not faced with producing reasonable responses within a time frame or with identifying areas of uncertainty that when resolved might result in more in-depth understanding of concepts and facts.

At this point, evidence for the impact of online pretesting on performance is suggestive, not conclusive. Students from two classes, taught by the same instructor covering material in basic statistics, self-selected into treatment groups. Group members differed in how they chose to prepare for in-class exams. Although reasons for their choices are not known, we do know that those students who took online pretests outperformed those who did not. Moreover, no differences in the self-selected groups based on educational background, grades, computer literacy, or ability to do basic math or simple algebra could be established. Student motivation as reflected in self-rated effort, ability, and course learning and performance goals also did not distinguish the groups nor did the amount of time that students reported studying for the exams. In other words, the groups, although not randomly populated, appear similar with respect to many of the individual difference variables that often are cited as major factors influencing classroom performance (Mayer, 1999). The only reliable difference among groups in this study was in the online aids that students chose to help them prepare for the in-class exams. Nonetheless, our explanation of findings places too great an emphasis on a retroactive search for limits to the interpretation of the observed treatment effect. A more proactive posture, providing upfront control (i.e., random assignment from a well-defined pool of subjects), is advocated for future research. One final piece of information, however, is noteworthy.

Figure 1 depicts exam-score distributions across groups. Pretests were available only for exams 1 and 3. With the treatment effect withdrawn for exam 2, it might be argued that the groups should regress to some common level of performance. Clearly that does not happen. Group 3's performance remains generally inferior to that of the other two groups. This suggests a more generalized difference among groups not captured in the data that we collected. But, there is also indication for an online testing effect, one that impacts performance in ways different from just studying using copies of pretests (e.g., Group 2). For the OT group, the group that took most advantage of pretest materials, the interquartile range (IQR) of scoring expanded about 50% when there were no pretest study aids (exam 2). When pretests were again available, exam 3, variability within the IQR returned to exam 1 levels. Note, too, the consistency of IQR ranges across groups on exam 2. Moreover, in terms of median performance, the OT



and DO groups are similar across exams, but the DO group evidences much greater variability on exams 1 and 3 than does the OT group. The DO and NA groups differ in terms of median scores but the respective IQRs are similar. What does all this mean?

Figure 1: Total-test score distributions.

It may well be that reduced variability is the real impact of the online pretesting experience. That is, students in the OT group were more densely packed into a narrower scoring range than were students in the other two groups. In summary, work to this point looks promising. There is a robust and powerful test-authoring tool that affords the capability of collecting speed, accuracy, confidence, and familiarity data on students placed in test-like conditions. Observed performance differences reflect a treatment effect, but the sample, although homogeneous, is small. For these reasons, work in this area needs to be extended to include more subjects placed in experimental groups controlled by experimenters rather than in self-selected groups based on subject choices. From this study, however, further work in this area appears justified.

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Acknowledgements

This project was supported by a grant from the Academy for Advanced Telecommunications and Technology, College of Science, Texas A&M University.

Mathematical Experience within Cabri-II Microworld : Construction and Interpretation of Algebraic Expressions

HOYOS, V., Univ. Pedagógica Nacional (Mexico). E-mail: vhoyosa@correo.ajusco.upn.mx
CAPPONI, B., Lab. Leibniz-IMAG/UJF (France). E-mail: Bernard.Capponi@imag.fr

Abstract: We present results about the set up of scenarios on the learning of algebra whitin Cabri-II microworld. We started our teaching experiment in a french highschool with a tenth grade school class (16 years old), introducing the simulation in Cabri-II of machines to draw curves (see Hoyos et al. 1998). Here, we worked searching the establishment of connections between the geometrical properties and their corresponding algebraic symbolization. Afterwards, we inquired about the state of these connections by solving tasks of algebraical inequality. The results of the test that we designed supported one hypothesis of the present paper: in the execution of techniques and procedures based on the literal calculus one of the principal difficulties to overcome is the construction of means of control for the algebraical executions involved. Also, these results indicated a necessity of approach our work within Cabri-II to the graphical interpretation of algebraic expressions.

Introduction

In this paper we present results of a research project about the set up of scenarios on the learning of algebra within Cabri-II microworld. This research project was born after carrying out a wide theoretical observational study performed with students of approximately 17 years of age (who where studying the second year of high school in Mexico City); this study was inscribed in the inquiry about the construction of meaning of the lineal equations with two unknown values (see Hoyos 96, 97 and 98). Therein we sought to identify what the links that students established among the operational uses of algebraic variables were, which these take place in the tasks of translating from the geometric field to the algebraic one (analytical uses). Also we reported some of the difficulties which high school students present in the execution of algebraic tasks of syntactic manipulation.

In April 1997, we began our learning experiment in a French high school with a tenth grade school class (16 years olds). We started introducing the simulation in Cabri-II of machines to draw curves (see Hoyos et al. 1998). We chose Cabri-II microworld because some characteristics of this microworld incite pupils to the perception of geometrical invariant properties: *"nous faisons l'hypothèse que l'ordinateur peut guider l'élève dans l'exploration de dessins en l'incitant à repérer des invariants entre plusieurs dessins, invariants pouvant déboucher sur la mise en évidence de notions et propriétés géométriques générales. En effet, ... il peut proposer plusieurs dessins répresentant un même ensemble de données théoriques."* (See Bellemain 1992).

The activity in the scenario of simulation developed round the modeling of mechanisms of tracing of curves, the subsequent visualization of the curve(s) obtained and the task of finding the corresponding equation(s). Our hypothesis was that this would allow the pupil to establish connections between the geometrical properties and their corresponding algebraic symbolization.

Afterwards, we inquired about the state of these connections by solving tasks of algebraical inequality. The results in the application of the test that we designed (we present some of the items we included, below) indicated the existence of a very low level of success in the algebraical manipulations which, nevertheless, is usual in the school grade in question. These results supported one hypothesis of the present paper: in the execution of the techniques and procedures based on the literal calculus (as in the procedures which are carried out to solve an equation, or in the algebraical treatments to reach factorization or quotients of linear terms) one of the principal difficulties to overcome is the construction of means of control for the algebraical executions involved. Also, these results indicated a necessity of the approach our work within Cabri-II to the graphical interpretation of algebraic expressions.

Finally, in sense mentioned by Confrey (see 1993: "*... technologies -that is, any significant tool- necessarily alter the character of knowledge.*"), probably we have evidences that our accomplishments within Cabri-II are significant tools for analytical uses of algebra.

Theoretical Underpinnings

The Computer: A Tool for the Construction of Meanings

One of the principal points of the theoretical framework sustaining this research is the conception of the construction of mathematical meaning within a differentiated support, or assistent to learner's system, of which the structure promotes the establishment of connections with other nomenclatures, with other mathematical domains. Within a system of this class (Noss and Hoyles 1996), the meaning's construction idea appeals to the presence of a structure over which the students may be able to construct and reconstruct, in the ways that they choose as the appropriate to their elaboration of the mathematical meanings in discussion effort's, with a support (real or virtual).

Indeed, these authors (Noss and Hoyles 1996) conceive the computer as integrating an educational support system in which elements are knowledge, student(s), teacher and the environment. They think of it as a system with several components that make it very advantageous: a) the fluid and flexible computational or informatical environment, that is under the control of the pupils; b) the possibility to indicate various trajectories to use instead of pointing to a unique and directed goal; c) there is a local support structure, to which the student has access and that is a product of his comprehension as well as a cultural product about it, built by others; d) there is a global support structure, that happens to be comprehended by the user, and that emerge of connections that become performed by him while he uses it.

Scenarios on the Learning of Algebra within Cabri-II Microworld

The microworld Cabri-II allows the integration of an educational support system of this kind because its characteristics of direct manipulation promote in students the perception of invariant geometrical properties (see Bellemain 1992).

In fact, the solid mathematical structure with which Cabri-II provides the student is a factor that promotes his advance in the construction of knowledge. Such a structure (see Noss and Hoyles 1996) is a determinant factor in the development of mathematical meaning: *"It is the web of relationships and objets offered by the computer that can act both as a support for developing new meanings, as a means for transcending that support. For by manipulating objets and articulating the relationships between them, a dual action /notational framework is developed which can begin to be a new resource, one which is not so dependent on the medium for its expression."* (Noss & Hoyles 1996)

Mathematical Experience and the Introduction of History's 'Voices' in the Classroom

Finally, another aspect that we have included for the design of the scenarios, it have been to introduce 'voices' of the history in the classroom -the Descartes'voice in this case, like else additional factor that would make possible to pupil the establishment of links between the voice and his/her own interpretations: *"Each of these expressions conveys a content, an organization of the discourse and the cultural horizon of the historical leap. Referring to Bachtin (1968) and Wertsch (1991), we called these expressions 'voices'. Performing suitable task proposed by the teacher, the student may try to make connections between the voice and his/her own interpretations, conceptions, experiences and personal senses (Leontiev, 1978), and produce an echo, i.e. a link with the voice made explicit trough a discourse."* (Boero, et al. 1997-98)

According to Boero et al., there exist cultural expressions that represent – from a deep communicative point of view – important leaps in the evolution of mathematics and science. It is through the execution of adequate tasks ("a game of voices and echoes") posed by the teacher, that the student may try to establish connections between this introduced 'voice' -the notational Cartesian geometrical-algebraic system, in this case, and his own interpretations. All the produced voices would contribute to produce an echo or link with the introduced voice.

Our Teaching Experiment in the 10th Grade Class

Simulation of Drawing Machines within Cabri-II

We began by introducing the simulation on Cabri-II of Descartes' machine, to plot hyperbolas. This machine is made of a mechanism, composed of a system (RSQ) of a fixed slope that slides vertically and of a shaft (AF) tied to this system. This shaft is also articulated to a fixed point (F) on a horizontal axis (see Descartes 1637). By introducing the simulation on Cabri-II of the mechanical construction of the plots, we wish to get close to the fundamental elements of Descartes'analysis situations in order to obtain algebraic equations. This teaching experiment was complementary to the normal mathematics course of the first year of high school (tenth grade class). We set it up by constituting three sessions of practical work of one hour each.
The first task's sequence was: 1) Modeling the machine; 2) Algebraic characterization of the straight line's families that step in the plot of Descartes'hyperbolas; 3) Obtaining the equations.

Our Test: Solving Tasks of Algebraical Inequality

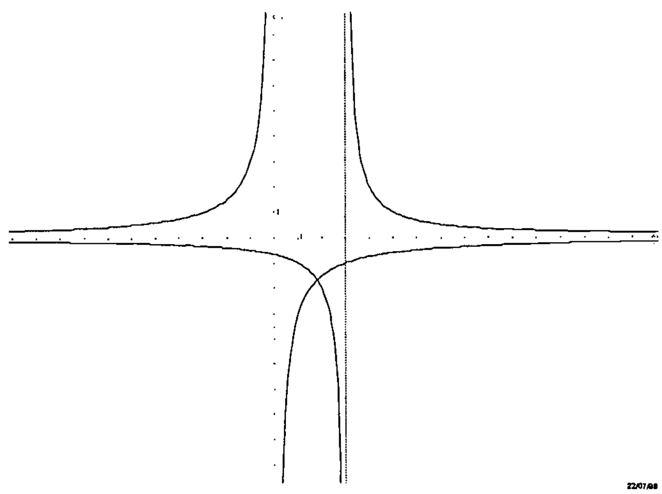
Following the scenario of simulation of Descartes'Machine, we applied a test. Some of the items in the test that we applied to our students were the following:

1. Résoudre les inéquations suivantes en donnant l'ensemble des solutions sous forme d'intervalle ou de réunion d'intervalles.

a) $(5x+2)(5-x) > 0$; b) $(x-2)^2 < (2x-3)^2$; 3) $1+(x-1) < 5$

...

4. (Attention les axes sont identifiables par les graduations: le repère n'est pas normé).
Sur ce graphique il y a deux représentations graphiques qui sont des hyperboles.



La première correspond à la fonction f définie par $f(x) = -3 + x$
la deuxième à la fonction g définie par $g(x) = 2 + (x-3)$
- Tracer en rouge la représentation graphique de f et en bleu celle de g.
- Résoudre graphiquement l'équation $f(x) = g(x)$ (encadrement(s) à 0,5 près)
- Résoudre graphiquement l'inéquation $f(x) \quad g(x)$

5. En utilisant la calculatrice graphique, résoudre l'inéquation $x^2-2 \quad -2x+3$
Tracer la graphique obtenu sur votre feuille et marquer en couleur l'ensemble des solutions sous forme d'intervalle ou de réunion d'intervalles. »

In our test, only 27% of our students succeeded in obtaining the algebraic inequalities presented in exercise 5. Also, the results concerning exercise 4 indicated that the students had reached the new curves they had studied with certain familiarity -the hyperbolas: the students correctly used their calculators to finger, identify and color the functional expressions given. However, the students did not succeed in discerning -based on graphic tools given by their calculators- what was happening with regard to the functional variation mentioned by members of algebraic inequality. From the results of the application of said test, we concluded in the necessity of expanding our teaching experiment with a practical work on the graphical representation of algebraic expressions.

Graphical Representation of Algebraic Expressions

The scenario of learning about the graphic representation of algebraic expressions which we elaborated, incorporates the use of old and new tools of the Cabri-II microworld: the dragging of any given point with the visualization of the change of its values; the use of a calculator of the proper microworld; the transfer of measurements; the tracing of curves through the track of the variable; and the geometric locus. Our hypothesis in accomplishing one scenario about this graphic representation was that the tools that the Cabri-II microworld provides for the graphical representation of functions permits the accomplishments of the cognitive actions which follow: dynamic perceptions of the elemental algebraical variables from different frames of representation -symbolical, graphical and numerical; recognition of the importance of the ortogonality on images-values of algebraic expressions -that we ask to pupils to denote with f(x), in the Cartesian graphical representation of variables; dynamic perception of the print of variable point P(x, f(x)); dynamic perception of the functional dependence between x and f(x).
The sequences about the graphical representation within Cabri-II were carried out during two extra-class practical work sessions, which amounted to two hours of directed work with the pupils. Only 7 volunteering pupils participated during the second. The two directed work sessions were completely videotaped and analyzed.

The Results: Mathematical Experience of the Pupils within Cabri-II Microworld

On the Modeling of Descartes'Machine

We asked pupils to simulate in Cabri-II the Descartes'machine. Indeed, the students (placed in Cabri-II) were committed in the proposed experiment. Several pupils were close to obtaining the equation of the curve. During the timed session, approximately 50 mins., despite its interest and the planned guidance, the students were only able to stablish the proportionality relations asked for. It was outside the class, later, that we asked advanced pupils to finish that task. After reworking approximately ten minutes, they wrote the equation in question: 1/x-2+x = y.

Graphical Treatment of Algebraical Inequalities within Cabri-II

Here we identified two principal actions that are not spontaneous for the student in his/her eargeness to obtain the graphic representation of a given algebraic expression: a) the dragging of the point M (the variable point (x,0)); and b) the simultaneous visualization in the screen of the movement of M and the effect that this provokes in the f(x).
We believe that these actions are subject for to learn and when the pupils exert them, become fundamental elements in the understanding of the functional dependence of the values x and f(x).
Also, this research work showed us the differences between the use of Cabri-II software and the usual graphical calculators: Cabri-II was revealed as a convenient microworld in the construction of means of control for the algebraic manipulations which the high school students usually carry out when solving algebraic inequalities. In other words, the graphication tools available in a usual graphical calculator provide us with finished graphical representations. Therefore, the students have difficulty in perceiving the variation of the values of the algebraic expressions, i.e., of the function; a perception that occupies an imminent role to succeed in the solution of the inequalities presented in our test.

Conclusions

It is probable that the set of actions executed by the students within Cabri-II has turned fundamental for the establishment of the connections sought, because the accomplishment of this practical work conducted the pupils to the revision of their own syntactical procedures of solution about algebraic inequalities; and it gave them a chance to validate their usual algebraic manipulations.

Also, we think that this working perspective for the learning of algebra contribute with a formulation of the problem of establishment of links between graphical and algebraical representations, like a problem of mathematical experience supported in the construction and interpretation of algebraical expressions by a dynamic draw of curves within Cabri-II, the description of their invariant geometrical properties, and the graphical representation of algebraical variables.

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Teaching Abstract Algebra with Involvement of Students' Research

Aihua Li

Department of Mathematics
Loyola University New Orleans
USA
ali@loyno.edu

Abstract: This article addresses my experience in teaching Abstract Algebra classes during the past several years. Motivated by the idea of "learning through research," I incorporated student research projects into my classes. Through working actively and cooperatively, students gained a better understanding of the algebraic structures, experienced "discovery" learning by formulating and attempting to prove their own conjectures, and experienced what it is like to engage in mathematics research. The paper will discuss the student project design, show several detailed sample projects, and address students' achievement through the experiment. The result of this research reflects the effectiveness of learning through research in attracting and retaining students, in supporting their development of self-confidence, and in mastering the mathematical concepts involved.

I. Introduction

Abstract Algebra has been a topic that frustrated students and instructors because it contains many abstract concepts, and because the logic and processes of building algebraic structures are not similar to the way people commonly process information. Research shows that students learn and retain mathematics better if they explore it on their own, passing from specific examples to general principles. Motivated by this idea of "learning through research," I incorporated student research projects into my classes. Through working actively and cooperatively, students gained a better understanding of the algebraic structures, experienced "discovery" learning by formulating and attempting to prove their own conjectures, and experienced what it is like to engage in mathematics research. This was reflected in students' achievement, their overall enjoyment of the class, and their satisfaction with the course. The result of this research also demonstrates the effectiveness of learning through research in attracting and retaining students, in supporting their development of self-confidence, and in mastering the mathematical concepts involved.

II. Student Project Design

Based on basic concepts in Abstract Algebra, I designed research projects for students to work on cooperatively. Some of them are computer-based problems requiring students to use computer algebra system *Mathematica* for investigating and constructing mathematics ideas. Selected samples are shown below.

(1) (Computer work required) Study groups U(n) (see Gallian 1994) for 20 or more integers. List group elements, orders, and multiplication tables.
   (a) What can you find out about the relationship between the number of elements of U(n) and the order of each element in U(n)?
   (b) Are there any interesting outputs when n is a prime number? Make your conjecture.
   (c) What can you say about the number of elements of a specific order?
   (d) Attempt to prove the conjectures derived.

(2) (Computer work required) For $1 < n < 100$, use the computer to determine whether U(n) is cyclic. When U(n) is cyclic, list all of the generators and all of the subgroups. Run your program for n = 8, 9, 16, 18, 20, 25, 30, 32, 36, 49, 50, 60, and 64. Make conjectures on the conditions of U(n) for which U(n) is cyclic or non-cyclic. Try to prove your conjectures.
(3) (Error-Detection) Study the methods of assigning identification numbers by using weighing vectors (refer to several research papers), prove the relevant theorems (see Gallian 1994). Find examples of these methods on campus.
(4) (Subgroup diagrams) Study the structure of subgroups of a group. This can be illustrated with a subgroup lattice of the group. Draw the subgroup lattices of well-known groups like Z_n, U(n), and the Dihedral groups. Investigate properties of subgroups from the diagrams and attempt to prove your results. Refer to several research papers.
(5) Study a computational method used to decide the number of subgroups of Dihedral groups which was described in a student research paper.

Project (1) and (2) encourage students to take the advantage of computer technology to investigate many examples of groups, find patterns, make conjectures, and try to prove what they have found. Project (3) focuses on the applications of Group Theory in the real world, especially on campus. It leads students to realize the usefulness and beauty of mathematics. Project (4) and (5) encourage students to gain deeper insight into the theorems involved by reading mathematics research papers. Most of the papers assigned in the projects were from student researchers, so they were written at a level that can be understood by students. The goal of these projects is to involve students in the "discovery learning" process, and to encourage them by doing mathematics and by being active and cooperative learners.

III. Students' Achievement

The value of student research in learning at the undergraduate level is increasingly recognized by educators. It is also strongly apparent in my own teaching experience. My students showed considerable interest in the assigned projects and the cooperative approach. The projects using computer technology especially attracts many students. By examining the data collected with the aid of computers, students made interesting conjectures, some of which were theorems they were going to learn later. They became interested in finding solutions for their conjectures and began to construct their own concepts. One group of students conjectured that the number of order-3 elements in a group is even, and gave an elementary proof. They also conjectured that the individual orders had to be factors of the group order, which is a part of the Lagrange's Theorem. Although they didn't prove the whole conjecture, they approached the proof of a special case with little help. Other students chose to study the groups U(n). They were approaching the famous Euler function $\varphi(n)$, which is the order of the group U(n). They also investigated the conditions on the number n such that U(n) is cyclic. A nice conjecture and a simple proof were derived: U(n) is not cyclic if n is a power of 2. They were quite excited about their discovery, in fact, one student wrote: "my project really gave me a lot of experience with cyclic groups that helped me learn the concepts better." She chose the cyclic group as her favorite concept in this class. Students investigating campus applications discovered that the campus library card identification number was assigned using Group Theory. An interesting aspect is that the librarians did not understand the instruction sheet describing the assigning process, and they had difficulties applying it. My students working on this project studied the theoretical part of the method, and wrote a clearer instruction sheet for the library. They were very excited to see practical applications on campus and how their mathematics knowledge applied to their daily lives. Every student in this class was involved in a research project and presented his/her results in class or the department seminar. For most of them, this was their first experience in mathematical research.

Computer technology is a big aid for student research. It made it possible for students to produce many examples and investigate the data which lead students to "deductive thinking." Some students had already found the patterns before the theorems were addressed. For example, by playing with the computer-produced data, one student group brought up the conjecture that $U(2^m)$ is non-cyclic for all positive integers m. They also developed a proof for it. By doing this, they achieved much better understanding of structures of cyclic groups and non-cyclic Abelian groups. On the other hand, it was much easier for me to address

other related theorems later, such as, $U(p^m)$ is cyclic if p is a prime number other than 2. In this way, theorems came out and were accepted naturally. It made the abstract concepts concrete, therefore better understood by students, and it made my lectures much clearer.

IV. Conclusion

My experiment shows that involving students in research projects encourages them to construct mathematics ideas in their own minds and to become active participants in their class rather than passive learners. Through teaching this class, I realized the effectiveness of learning through research in attracting and retaining students, in supporting their development of self-confidence, and in mastering the mathematical concepts involved. Through working on the research projects, students feel the abstract concepts are more approachable and joyful. This was reflected in students' achievement, their overall enjoyment of the class, and their satisfaction with the course. One student continues his research project even after the class is over.

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An Internet-Based CAL Software for Solving Trigonometric Problems

Janet Mei-Chuen Lin*, Jie-Yong Juang**, and Ponson Sun*
*Department of Information and Computer Education
National Taiwan Normal University
Taipei, Taiwan 106
(02) 2362-2841
mjlin@ice.ntnu.edu.tw

**Department of Computer Science and Information Engineering
National Taiwan University
Taipei, Taiwan 106
(02) 2362-5336
juang@csie.ntu.edu.tw

Abstract: This paper describes MathCAL, an Internet-based computer-assisted-learning (CAL) system that provides a distance-learning environment for learners to do exercise on math problems in an exploratory style. The design of MathCAL hinges on provision of a set of domain-specific mathematical rules for learners to apply in each step of problem solving. Each time a learner selects a problem from the built-in problem set and starts working on it, MathCAL dynamically keeps track of a learner's problem-solving process and is capable of giving appropriate hints to guide the learner. Learners can also get help from other users of the system through synchronous or asynchronous network functions provided by the system. Currently MathCAL allows students to solve problems requiring the use of trigonometry.

Introduction

The Agenda for Action published by the National Council of Teachers of Mathematics (1980) asserted that the acquisition of problem-solving skills should be one of the goals of school mathematics instruction. Even though there may have been various perspectives on teaching mathematical problem solving (Kilpatrick, 1985), few mathematics educators will deny that practice in solving many problems is a necessary condition for improving one's problem-solving abilities.

Mathematical problem solving involves using mathematical concepts and principles in seeking the answer for a particular problem. Starting with a word problem, a student first has to extract given facts from the problem statement. They then try to figure out how to derive more facts from the known facts. If the student is on the right track in his/her solution, the process should lead the student closer and closer to the solution until the solution is finally included among the known facts. Each derivation of new facts from known facts is based on the application of a certain mathematical rule. A mathematical rule dictates specific relationships between a set of facts. For instance, the rule which says that the three angles of a triangle sum to 180 degrees specifies the relationship between angles α, β, and γ of a triangle. Therefore, when a rule is given certain known facts as the input conditions, it will generate new facts according to the relationships specified by the rule. For example, given that α is 30 degrees and β is 60 degrees, the rule will generate the new fact that γ is 90 degrees.

Based on the above concepts, if we want to implement a software system for students to practice problem solving, the system should include at least the following four components:

(1) a set of mathematical rules for students to choose from and apply in each step of problem solving,
(2) a set of stored problems for students to practice on,
(3) a mechanism for students to input known facts, and
(4) an area for displaying the currently known facts.

In the remainder of this paper, we describe how our system, named MathCAL, has been constructed to provide a mathematical problem-solving learning environment by incorporating the above-mentioned four components as well as other supporting features. We first discuss our design philosophy and some design considerations and then

explain how learners are to interact with MathCAL. The central part of the paper describes the internal structure of MathCAL, which is followed by our concluding remarks.

The Design Philosophy and Considerations in the Implementation

Since the authors' expertise is in computer science rather than mathematics education, we approach the development of MathCAL from a software engineer's viewpoint. That is, we define the ultimate goal for our "product" to be *a domain-specific calculator* which provides not only the keys for simple addition, subtraction, and so on, but also such macro functions for performing complex computations for a specific domain in mathematics. Similar to a pocket calculator which people use for making simple mathematical calculations, our product has been targeted at middle-school students who will use MathCAL as a powerful calculator to assist them in solving more complicated mathematical problems. Our basic assumption is that when students learn mathematical problem solving, they should concentrate on thinking about concepts and rules to apply rather then being bothered with tedious computations. For example, if a student knows that, at a certain step of problem solving, the Pythagorean theorem should be applied to obtain the measure of the third side given the lengths of the remaining two sides of a right triangle, there should be a tool to do the computation for him/her. We are not implying that solving equations is not an important ability in itself, what we mean is simply that equation solving in general is a different thing to learn and should not be a major concern in using the Pythagorean theorem here.

Besides being a computational tool, MathCAL has been augmented in several respects to capitalize on the computer's power. With the availability of computer's enormous memory capacity, MathCAL has been designed as a tool with abundant knowledge. Such knowledge includes the correct solution path(s) for system-provided problems, a learner's problem-solving procedures during an interactive session as well as his/her past learning history, the record of who has solved which problems, and the instructional knowledge of how to apply concepts and rules in solving each system-provided problem. Having been equipped with such knowledge, MathCAL is capable of observing the learner and giving appropriate suggestions or hints. This is done by matching a student's problem-solving procedure against that of the correct solution in order to identify the learner's problem spot. The student can also ask for help from teachers or someone who, according to the record kept by the system, has successfully solve the problem before. Such human help was made possible with network functions such as on-line chatting and e-mail exchange. The provision of built-in guidance as well as alternative human assistance through network has transformed MathCAL from a mathematical tool into a computer-assisted learning environment.

To summarize, the usefulness of MathCAL is as follows:

(1) to provide students with a *high-level tool* such that students may focus their attention on the application of concepts and rules rather than complex calculations during problem-solving,
(2) to provide a friendly environment for students to sharpen their abilities in problem-solving without the pressures of time, fear of failure, and anxiety about one's performance, etc.,
(3) to provide a supportive learning environment in which interactions between teachers and students and between students themselves are supported either synchronously or asynchronously, and
(4) to provide teachers with a tool for use in the classroom to demonstrate problem-solving procedures without having to waste time on tedious computations.

With reference to the four basic components explained in the previous section, it is apparent that the first component, namely provision of a set of mathematical rules, is the key component of such a system. Nevertheless, it is also the most complicated part of the whole task because it demands a thorough analysis of domain knowledge in order to ensure that the rule set is sufficient for solving any problem within the domain. In reality it will be virtually impossible to guarantee that a set of rules is sufficient for solving "any" problem within the domain. Fortunately, what a computer system stores is *closed world databases* (Date, 1990). Loosely speaking, a closed-world database is assumed to contain all true facts about the topic involved. What the *closed world assumption* implies in the case here is that the set of rules may be considered sufficient as long as all the problems stored in the system (i.e., Component 2 above) can be solved using them. This leads us to a *demand-driven* design strategy in which the knowledge engineer may go backward by compiling the set of problems first. Each time a problem is inserted into the problem set, the engineer should check if any new rule(s) need be added to the rule set. As such, the size of the rule set usually grows together with that of the problem set until it reaches a steady set that the existing rules seem capable of handling all the problems within the domain. Each of these rules is implemented as a macro function in our system.

The prototype of MathCAL has been implemented in JAVA so that it can be deployed on the Internet to provide a distance learning environment for practicing mathematical problem solving in an exploratory style.

MathCAL uses an object-oriented approach in representing its domain knowledge and the Petri-net theory (Peterson, 1981) as the modeling tool to capture the dynamic nature of problem-solving behavior. These, together with its supporting knowledge base, databases, and other utility functions, help to provide an effective distance learning environment.

How MathCAL Is Used by the Learners

(Fig. 1) shows the flow of MathCAL operations from a learner's point of view. A learner can log on to the web server hosting the MathCAL with a JAVA-enabled WWW browser. When the learner is ready to work with MathCAL, MathCAL will set up a learning environment suitable for the learner according to the information stored in the system's database about the learner. The learner's background, his progress in acquiring knowledge in a particular domain, and his previous performance can all be taken into account in the setup procedure. Then the learner can start doing exercise by selecting a problem by himself or letting the system select one for him. The learner has the alternative of asking the system to demonstrate how a particular problem is to be solved step by step, or he may also ask MathCAL to coach him. In the latter case, he will be required to analyze the problem statement and translate it into a set of known conditions. Based on the set of known conditions, he can choose a proper subset and use it to 'fire' a macro function by simply clicking on the corresponding routine name provided in a menu list. MathCAL will then execute the macro function and output its results. The newly generated results now become known conditions and are added to the existing set of known conditions for the next iteration of firing another macro function. These steps are performed interactively until a correct answer is finally found. When the learner gets stuck somewhere and is unable to proceed any further, the system will generate appropriate hints to guide him towards the solution. If the learner decides to seek help from other users of the system, he may activate the 'chat' or the 'e-mail' functions provided by the system. These features will be described in details in the next section.

The Internal Structure of MathCAL

The internal structure of MathCAL consists of six major components as shown in (Fig. 2). In the following we briefly explain the purpose of each component and how it is implemented.

(1) *The System Kernel*:

At the system kernel is a package of macro functions which are learners' computational resource kit for solving problems. Since the repertoire of macro functions provided by the system is highly content-dependent, we currently concentrate on the contents of the topic of trigonometry covered in a standard high-school textbook used in Taiwan. We analyzed the typical problem types and came up with approximately twenty functions. Each function is characterized by its input and output arguments. When the learner selects a function for use, MathCAL will prompt the user for necessary input conditions and then perform the required computation.

In order to capture the dynamic nature of problem-solving, we employed the Petri-net theory as our modeling tool. With mathematical problem solving, the transitions and places of a Petri-net map to the built-in routines and the known conditions respectively. The functions and the input/output conditions associated with the use of each function during a problem-solving process can be fully recorded with a Petri-net. Such a Petri-net remembers not only the individual steps of the learner's behavior, but also the sequence in which the functions are applied. In other words, the learner's solution strategy has been properly recorded and it can be analyzed for the purpose of diagnosing the learner's misconceptions or missing conceptions.

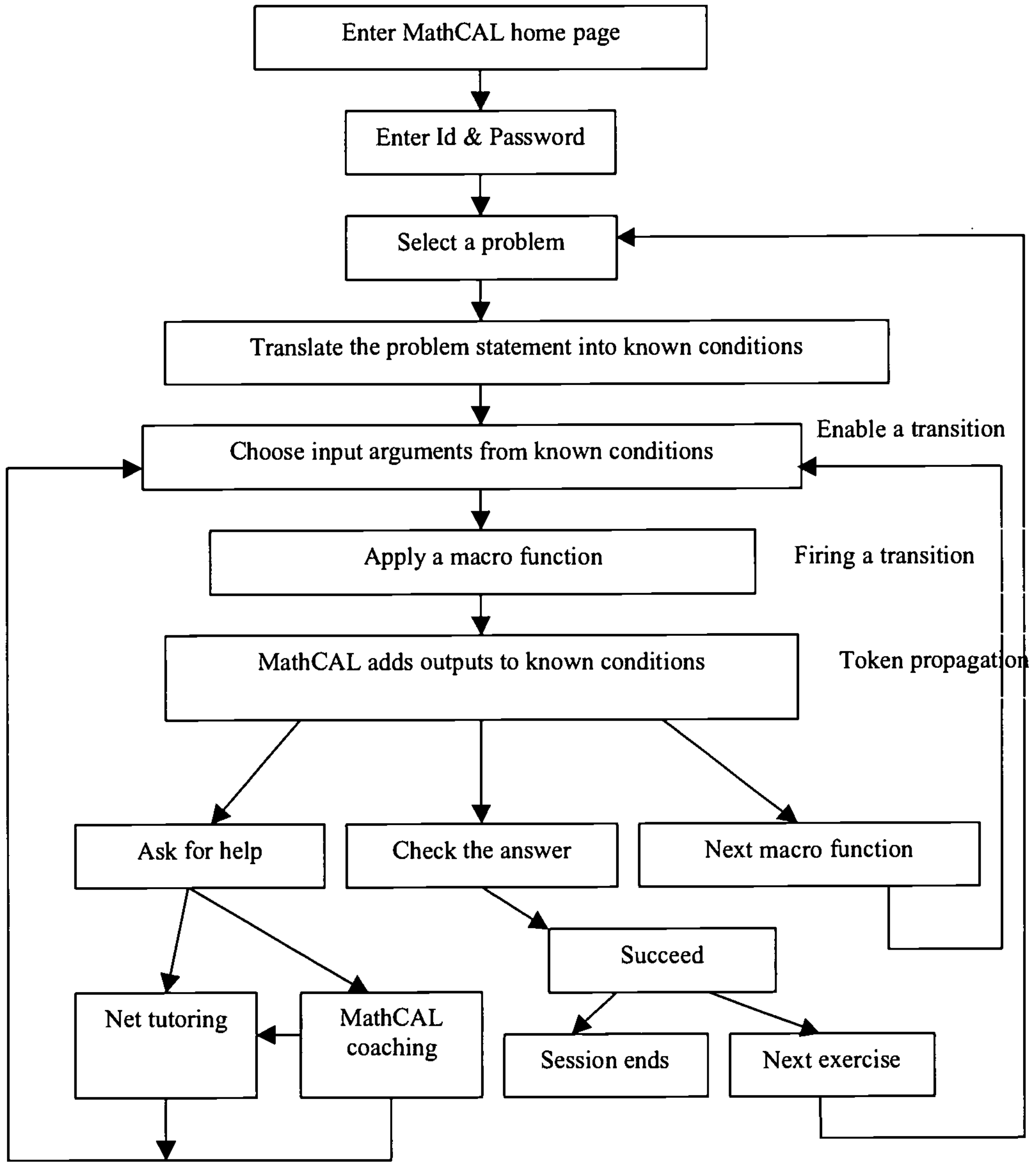

Figure 1: The Operation Flow of MathCAL from a User's Viewpoint

(2) *The Problem-Solving Coach*:

Since MathCAL stores the correct solution path(s) of each problem in its database, a user's problem-solving steps may be compared with the correct solution paths. By analyzing the difference between a learner's solution and the correct solution, the system then determines the adequate hints to be given to the user. The hint generated by the system is dynamically determined based on the learner's current state in solving a particular problem, rather than being hard-wired with the problems or the correct solutions. Internally, the solution path(s) are recorded as Petri-nets. As we mentioned before, Petri-nets carry abundant information about the learner's problem solving behavior, and hence facilitates generation of hints in a more accurate and refined manner. It enables MathCAL to monitor the learner's problem solving status, and to coach the learner in a more personalized way.

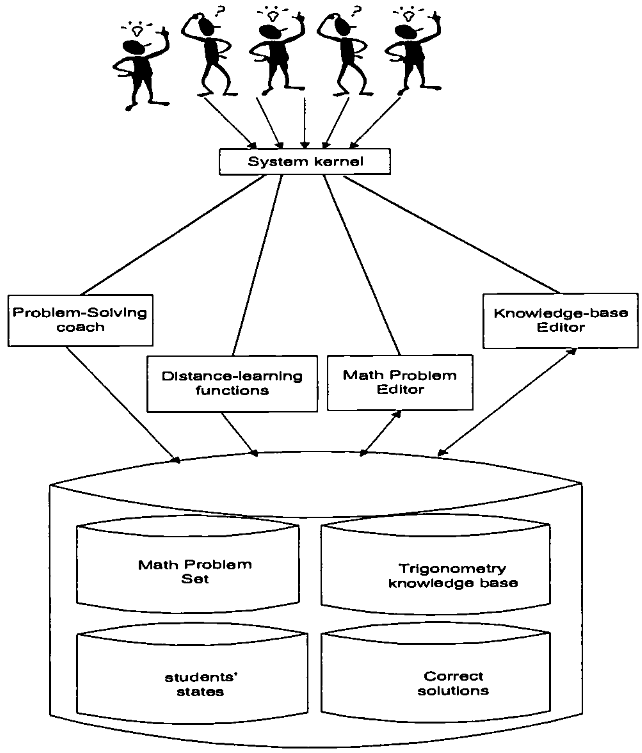

Figure 2: The Overall Structure of MathCAL

(3) *The Distance-Learning Functions*:

When a learner tries to seek human help, he may send a message over the Internet to whoever is using MathCAL simultaneously. If whoever selected is willing to offer help, the system will set up a communication channel so that the helper will be able to look at the steps that have been taken by the learner, and guide the learner from that point on. The learner may also send e-mail messages to anyone who is not on-line and ask for asynchronous help. The learner's problem-solving process will be attached to the message so that the helper understands the thought process of the learner. The solution steps recorded using Petri-nets provide an efficient way for communication over the Internet. If learners used ordinary e-mail system or chat program to communicate with the helpers, they would have to describe their problems and solutions in natural languages. This can be lengthy and complicated. For example, typing mathematical equations and transmit them in real time over the Internet is still a very difficult task. Furthermore, to describe one's problem-solving process precisely is in itself a challenge to the learner who is seeking for help, since he may not understand the problem well enough to describe it properly. Fortunately, MathCAL records automatically not only the solution, but also learner's behaviors precisely with the help of Petri-nets and the object-oriented knowledge representation scheme. It also results in a very concise packet for transmission over the Internet. The problem-solving procedure can be re-produced completely and easily by MathCAL at the helper's side. All these design features contribute to efficient functioning of MathCAL as an Internet-based learning environment.

(4) *The Math Problem Editor*:

MathCAL has been designed in such a way that an instructor or a learner may add new problems to the system as one wishes. One may use the math problem editor to enter a new problem and then solve it so that the system can record the correct solution path(s) for it. The problem may be used by other learners thereafter just like any other problem originally provided by the system. Since a problem is internally represented in text format, the math problem editor is simply a word processor for entering natural language statements of a problem. However, it will be further enhanced to handle graphical inputs and mathematical symbols. Editing a solution to a problem can be done in the same way if the solutions are to be stated in natural languages. Nevertheless, MathCAL represents a

correct solution path as a Petri-net which is constructed by organizing a sequence of macro functions fired during the problem-solving process by an expert. A solution path is in turn represented internally with a simple matrix. Using such a representation scheme, editing a solution can be done by simply solving it as a learner would do in an ordinary problem-solving process, and let the system generate the solution path in its corresponding matrix form. Therefore, no additional editor is necessary for editing solutions.

(5) *The Knowledge-base Editor*:

This editor allows an instructor to modify the instructional knowledge stored in the knowledge base. Each time after MathCAL identifies some difficulty encountered by a learner, it must consult the knowledge base to extract appropriate explanation related to the identified concept. It is worth noting that this editor is not for editing domain knowledge. Recall that domain knowledge is represented as macro functions which constitute the system kernel, and that they have to be programmed as JAVA objects.

(6) *The Databases*:

The system functions described above are supported by a database of various files, which include the file for math problems, the instructional knowledge base, the file for recording correct solution path(s) for each problem, and the file for recording each learner's learning history.

Conclusions

In this paper we described a software system, MathCAL, which has been designed for users to practice mathematical problem solving. The users are provided with an environment in which a set of domain-specific macro functions are at their disposal for solving problems step by step. The system keeps track of a user's problem-solving behavior by dynamically constructing a corresponding Petri-net internally. This Petri-net may be matched against the correct solution path(s), also stored as Petri-nets by the system, to determine the appropriate suggestions or hints to be given to the user when the user asks for help. MathCAL also provides synchronous and asynchronous network functions for users to solicit human help from other system users. Currently MathCAL is capable of handling problems typically encountered in high-school-level trigonometry, but it is being expanded to cover other topics incrementally. The experiences we gained from the development of MathCAL has convinced us that the Petri-net theory is a very useful tool for modeling a learner's dynamic problem-solving behavior. The Petri-nets constructed by MathCAL truthfully record a learner's thought process in his attempt to solve a problem. Such information is indispensable to correct diagnosis of a learner's misconceptions and/or missing conceptions. Due to space limitation we are unable to present more implementation details, especially about how Petri-nets have been represented internally and how they are used to realize the various system features.

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Acknowledgment

This research has been funded by the National Science Council of Taiwan, the Republic of China, under grant number NSC 90-2520-S-003-001.

TECHNOLOGY AND GEOMETRICAL CONCEPT LEARNING

Leping Liu
Department of Reading, Special Education, and Instructional Technology
Towson University, U. S. A.
E-mail: lliu@towson.edu

Abstract: This paper will present a case study that investigated the process of using some mathematical software packages to learn geometrical concepts. The purpose of this study was to develop possible patterns of learning geometrical concept, which may enhance children's concrete-abstract thinking and abstract-concrete thinking. The software packages used in this study were *LogoPlus* and *Geometer's Sketchpad.* Four children learned geometrical concepts with designed learning process. Their learning processes were observed. A CAC (concrete-abstract-concrete) learning pattern was summarized from this study.

Introduction

One inexhaustible source of new questions in mathematics teaching/learning is the development of technology (Davis & Hersh, 1981). The new technology not only has made calculations and graphing easier, it has changed the methods educators use to teach mathematics and the ways with which students learn mathematics (Abramovich & Nabors, 1997). As stated in *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), one of the general goals of mathematics teaching is to develop students' abilities to mathematical thinking. Therefore, a new question raised for educators would be how students' mathematical thinking abilities could be improved in the new-technology learning environment. Studies have been conducted to explore the potential of using technology to improve mathematical thinking skills in several facets: (a) programming and cognitive styles and development (Clements & Gullo, 1984; Swan, 1993; Oakley & McDougall, 1997), (b) thinking levels (Olson, Kieren & Ludwig, 1987; Clements & Meredith, 1993; Liu & Cummings, 1997), and (c) using mathematical software packages (Abramovich & Nabors, 1997; Wright, 1997; Pokay & Tayeh, 1997). These studies suggest that programming experience, especially when enriched with appropriate activities and discussions, can help children become cognizant of their mathematical intuitions and move to higher level of mathematical thinking; and that using mathematical software programs, especially with well designed learning processes, can help children develop abstract reasoning skills.

Liu and Cummings (1997) have discussed a geometrical concept learning process with *Logo* programming that would develop children's concrete-abstract (CA) and abstract-concrete (AC) thinking. The learning process consists of two sub-processes: the process of conceptualization that involves concrete-abstract thinking, and the process of application that involves abstract-concrete thinking. Mathematics learning occurs as learners develop and apply these two thinking processes. In most literature, abstract thinking and concrete thinking are discussed separately as two states of a person's thinking (Swan, 1993) referring to the classic Piagetian (Piaget, 1971) distinction between formal mental manipulations and thinking that is based on concrete objects. However, Liu and Cummings (1977) discussed, instead of the states of thinking, the thinking processes that describe the transition from one thinking state (e.g., concrete thinking) to another thinking state (e.g., abstract thinking). While their discussion stands on the theoretical dimension of this thinking process, the current study intends to develop the practical dimension. To examine whether or how the CA and AC thinking processes will benefit mathematics learning, first a learning pattern that applies these thinking skills and performs the transition process needs to be developed. The purpose of this study was to develop such learning pattern, specifically, a pattern of learning geometrical concepts, with *LogoPlus* and *Geometer's Sketchpad* as the tools of the learning pattern development.

The Methodology of Developing the Learning Pattern

The Learning Pattern

What a student learns depends to a great degree on how he has learned it. In this study, we defined the learning pattern as "*How he has learned.*" Therefore, according to the purpose of this study, the operational procedures of developing the learning pattern were to identify:

1. How does a student learn geometrical concepts?
2. How does a student apply the thinking skills to learn geometrical concepts?
3. How does a student use *LogoPlus* and *Geometer's Sketchpad* to learning geometrical concepts?

In fact, the three procedures are the three facets of the learning pattern, and cannot be separated as individual procedures. During the learning procedure, *what works* or *what works well* would be summarized as the learning pattern.

The Subjects

The subjects of this study were four children, two girls aged 8 and 10, and two boys aged 10 and 11. They had never used *LogoPlus* and *Geometer's Sketchpad* until they were taught in this study. They first learned to use the two software packages with two designed learning processes: (a) concrete-abstract process, and (b) abstract-concrete process. Then they were asked to identify a geometrical concept in different ways. The entire learning processes were observed.

Conceptualization and Concrete-Abstract (CA) Process

A concept can be divided into several basic components. For example, the basic components of the concept "rectangle" are the sides, the length of the sides, the number of the sides, the angles, the degree of the angles, the numbers of the angles. These components can be considered the "concrete" parts of a rectangle. To construct the concept "rectangle" from learning the properties of the individual concrete components is considered the process of concrete-abstract thinking.

Process one—Logo and CA Process. The programming language, *Logo*, was developed as a conceptual framework for understanding children's construction of knowledge about mathematics and problem solving (Clements & Meredith, 1993; Liu & Cummings, 1997). It has been used to investigate thinking process, cognitive processes and abstract reasoning in geometric learning (Weave, 1991; Geddes, 1992). This study used *LogoPlus* as a tool to investigate the thinking processes. The conceptualization process that employs a concrete-abstract thinking process in *LogoPlus* environment was designed as:

1. Learn commands in *LogoPlus* that will produce a shape (e.g., square).
2. Learn the characteristic properties of the shape from observing the construction of the shape.
3. Summarize the definition of the shape from the commands and the shape on screen.

For example, we can teach the following three commands to help children learn the concept "square":

Command 1: repeat 4 [forward 5 right 90]
Command 2: repeat 4 [forward 10 right 90]
Command 3: repeat 4 [forward 15 right 90]

Once the three squares are on the computer screen, students can summarize the relationship between the Logo commands and the length of the sides and degrees of the angles and develop their conceptual understanding of the shape. This entire process is a transition process from concrete thinking to abstract thinking.

Process Two--Geometer's Sketchpad and CA Process. *Geometer's Sketchpad*, an exploratory program that allows students to investigate geometrical concepts and discover relationships among concepts (Pokay & Tayeh, 1997), was also used in this study. The concrete-abstract process in *Geometer's Sketchpad* environment was designed as:

1. Provide students figures of the same shape but different sizes (e.g., squares).
2. Ask them to measure the sides and angles
3. Ask them to summarize the definition of the shape with the measurements.

In this study, if the subjects can perform the two processes with *LogoPlus* and *Geometer's Sketchpad,* it is assumed that they have performed a concrete-abstract thinking, and have learned the concepts with a concrete-abstract learning pattern.

Application, Re-Conceptualization, and Abstract-Concrete (AC) Process

After developing the concrete-abstract thinking skills and learning about certain geometrical concepts, the next level of thinking is abstract-concrete thinking (Liu & Cummings, 1997). Abstract-concrete thinking is not simply the

reverse of concrete-abstract thinking. It is, instead, a higher form of thinking that depends n more advanced abstract and logical reasoning abilities but that is grounded in the concepts and rules derived from concrete-abstract learning. The abstract-concrete process is a process of application and re-conceptualization that uses the obtained knowledge of concept to solve new problems or develop new concepts. This study included this process to investigate whether students can perform complex multiple thinking process.

Process Three—Logo and AC Process. The process of application and re-conceptualization that employs a abstract-concrete thinking process in *LogoPlus* environment was designed as:

1. Provide students the shape that can be developed from the concepts they already know.
2. Ask them to write the *Logo* code to produce the shape.
3. Ask them to summarize the definition of the shape.

For example, after students summarize the concept "square," provide them a rectangle shape, and ask them to write the code to produce the rectangle and summarize the concept "rectangle."

Process Four--Geometer's Sketchpad and AC Process. The abstract-concrete process in *Geometer's Sketchpad* environment was designed as:

1. Calculate the sides and angles of the given shape (e.g., triangle).
2. Draw the shape according to the calculated size.
3. Summarize the definition of the shape.

If the subjects can perform the two processes with *LogoPlus* and *Geometer's Sketchpad,* it is assumed that they have performed a abstract-concrete thinking, and have learned the concepts with a abstract-concrete learning pattern.

Problems for Concept Learning in the Four Processes

According to the designed steps described in each process, the following problems were used for concept learning in the four thinking processes:

1. Problem for process one (*Logo* and CA process) was to summarize the concept "square" by following the three steps in this process.
2. Problem for process two (*Geometer's Sdetchpad* and CA process) was to summarize the concept "square" by following the three steps in this process.
3. Problem for process three (*Logo* and AC process) was to summarize the concept "rectangle" based on the knowledge of the concept "square," and the code that will produce a rectangle.
4. Problem for process four (*Geometer's Sdetchpad* and AC process) was to summarize the characteristic properties of a right triangle with the size-proportion of 3:4:5.

The criteria for the answers were:

1. The definitions of the concept should be correctly described?
2. The Logo code should be correctly written (for process one and three).
3. The sides and angles should be measured or calculated correctly (for process two and four).

Each of the four subjects worked on the four problems. Their problem solving processes were observed and their answers to these problems were analyzed.

Summary and Learning Patterns

The answers of the four subjects to the four problems were summarized as the following:

1. All four subjects defined the concept "square" correctly for problem one and two. They all wrote correct *Logo* code for problem one and measured correctly for problem two. This means that they constructed the concept from the basic concrete components of the concept.
2. Three subjects (except the 8-year-old girl) defined the concept "rectangle" correctly for problem three and wrote the correct code that produced the rectangle. The 8-year-old girl was not able to construct the "repeat" command for producing the rectangle; she only produced two sides of the rectangle. It seemed that she had difficulty in the abstract reasoning that requires the understanding of the process of conceptualization.
3. Only one subject, the 11-year-old boy, completed problem four with the definition that only described part of the characteristic properties of the triangle although his calculations and measurements were correct.

In summary, the subjects' performance and the results suggest that younger children may be able to perform concrete-abstract thinking in the process of conceptualization, but they have difficulty in performing abstract-concrete

thinking. When the concept was divided into the basic concrete components, it was easier for younger children to understand the process of conceptualization with *Logo* programming. It may not appropriate for younger children to use *Geometer's Sketchpad* to solve the problem that requires abstract reasoning.

The learning pattern developed from this study was a CAC (concrete-abstract-concrete) pattern. Although, *what worked well* was the first part of this pattern—CA pattern, the CAC pattern was a complete learning process. From the CA process, a learner obtains the knowledge of concept, and in the AC process he/she can rehearse and apply the knowledge he/she has learned—this is the most important part of learning. The purpose of this study was to determine the possible learning pattern that can be used in further study to investigate whether or how the CA and AC thinking processes will benefit mathematics learning. Therefore, the last part of the pattern—AC process should not be omitted.

Conclusions and Discussions

This study provided two possible learning patterns, CA pattern and CAC pattern, based on the theoretical background discussed by Liu and Cummings (1997) and the performances of four subjects. Since these learning patterns were developed with the *LogoPlus* programming software and the exploratory software *Geometer's Sketchpad*, they could be applied with other programming or exploratory software in mathematics course planning, or courseware design.

In further studies that investigate the impact of CA and AC thinking process on mathematics learning, we may first use CA pattern, and then use CAC pattern, considering children's thinking abilities of different level. Also, based on the criteria in this study, the instrument to measure students' concept learning can be developed with continuous measurement scores. Further experimental designs with larger sample size could be conducted to dig the potential of these learning patterns.

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The Teacher Education Challenge: Infusing Technology into Mathematics Methods Classrooms

Sheryl A. Maxwell
College of Education
Department of Instruction and Curriculum Leadership
The University of Memphis
Memphis, Tennessee 38152
United States of America
maxwell.sheryl@coe.memphis.edu

Katherine Abraham
College of Education
Department of Instruction and Curriculum Leadership
The University of Memphis
Memphis, Tennessee 38152
United States of America
abraham.katherine@coe.memphis.edu

Abstract: The mathematics methods classroom should mirror the current mathematics reform efforts. When mathematics teacher educators use a *constructivist* type of pedagogy and integrate technology throughout the mathematics curriculum, the preservice teachers can experience the reform's effectiveness firsthand. Several specific uses of the computer in these unique mathematics methods classroom are described as the authors depict the importance of the four components: the teacher educator, the lesson, the environment, and the students. It is hoped that the impact of preservice teachers experiencing the best practice of learning/teaching mathematics in concert with the infusion of technology use within the classroom will help further the mathematics reform efforts in future classrooms. The prospective teachers can consider incorporating similar aspects as they reflect upon their own future classrooms through class discourse.

The goal of the current mathematics reform effort is to provide the best mathematics learning for all students (NCTM, 1989, 1991). Technology can support the teaching and learning of mathematics in unexpected ways if it is used creatively by teachers within the classroom. In 1990, the Research Advisory Committee concluded that "the presence of technology has changed the discipline of mathematics: unsolved problems have become trivial, and underemphasized themes have achieved central importance. Technology allows us [educators] to emphasize different parts of the traditional school mathematics curriculum and to deemphasize others, to include mathematical topics new to the traditional curriculum and to reorganize instruction" (RAC 1990, 291). If this reform is to occur in K-12 classrooms, this transformation must include infusing technology into the mathematics methods classroom. No longer should the institutions responsible for educating preservice teachers be locked in the past linear, didactic manner that differs from society's use of technology. American education should embrace the 21st century and empower the future teachers to use technology to one of its intended purposes (Strommen, 1998).

According to the 1991 *Standards for the Professional Development of Teachers of Mathematics*, the vision of teaching can be realized when the following aspects of the professional development of teachers are addressed:

- Modeling good mathematics teaching
- Knowing mathematics and school mathematics
- Knowing students as learners of mathematics
- Knowing mathematical pedagogy
- Developing as a teacher of mathematics
- Teachers' roles in professional development.

(NCTM 1991, 6)

Consequently, the mathematics methods classes should be designed to incorporate all of these aspects. Since teaching and learning are more effective when students are actively involved, the preservice teachers taking mathematics methods classes should be engaged in well-constructed, worthwhile mathematical tasks that move them beyond practicing skills. Preservice teachers are encouraged to explore their own conjectures and to extend their mathematical ideas (NCTM, 1991). As the preservice teachers are challenged to problem solve, explore patterns, and make conjectures, technology becomes one instrument to facilitate learning. By becoming active participants in, and creators of their own learning, they can discover that technology can also be used to enhance mathematical discourse. According to the National Council of Teachers of Mathematics (NCTM) guidelines (1991), a future teacher's role is to initiate, orchestrate and use questioning and listening skills to enhance student learning. The teaching efforts, modeled by the teacher educator guiding the participants of the mathematics methods class, mirrors how mathematics should be taught within their own future classrooms. For example, preservice elementary and middle school teachers use Turtle Math™ armed with the programming language of Logo to learn how to create a regular polygon through investigating its unique attributes. Later, these future teachers follow instructions designed as a concept development activity. The four crucial aspects, explore, conjecture, test, and generalize, help to increase conceptual understanding allowing the preservice teachers to experience what it means to extend their knowledge of geometric figures. They learn that the sum of the exterior angles is equivalent to 360_ and that the sum of the interior angles follows a definite pattern. "Teachers need opportunities to revisit school mathematics topics in ways that will allow them to develop deeper understandings of the subtle ideas and relationships that are involved between and among concepts" (NCTM 1991, 134). Preservice teachers' mathematical awareness is increased as they are encouraged to think differently about the ways they approach mathematics.

Reform Efforts Penetrate Methods Classes

The current university classroom is often the last place that preservice teachers view and experience the implementation of current and relevant teaching strategies. Although college students read about incorporating technology into the classroom in their research-based textbooks and discuss the theoretical implications including the barriers to this implementation, these prospective teachers rarely experience the creative infusion of technology within their own educational classes. How technology is used in the classroom is critically important. A philosophical teaching change is needed to appropriately educate and empower children, youth, and adults for the 21st century. The guiding philosophy of *constructivism*, a theory of cognitive growth and learning, in concert with effective uses of technology, provide the possibility that the classroom can model society. The *constructivist* model should be used in the mathematics methods classroom to enable preservice teachers to experience this philosophical change that engages them in complex reasoning in an authentic context.

One foundational premise of *constructivism* is that individuals actively construct their own knowledge. Instead of simply absorbing new ideas from listening to authorities, or internalizing these by repeated rote practice, *constructivism* asserts that learners process new data by modifying existing information (Blais, 1988). Additionally, when learners collaborate, sharing the process of constructing their ideas, they reflect on and elaborate on their peers ideas. "The focus of constructivism, then, is the child [learner] as a self-governed creator of knowledge. Educational practices that follow from this focus are designed to facilitate their learning by nurturing their own, active cognitive abilities" (Strommen 1998, 3). The preservice teachers are placed in cooperative groups, pairs to groups of six, to learn more about the teaching of mathematics and how the computer can enhance learning.

The Computer in the *Constructivist* Classroom

Technology makes possible the exchange of information between classrooms; enables individual students to interact; allows instant access to databases and on-line information; and provides multimedia resources such as audio and video. However, the integration of technology into the classroom is based upon four critical factors: the teacher educator, the lesson, the environment, and the students. In a traditional college/university classroom, the teacher educator lectures regarding a particular procedure while students

remain at their desks, listening or taking notes. Later, they use the computers to complete individual assignments, proving their competence of the assigned computer procedure instructed during the didactic class. In a *constructivist* classroom, the computer is seen as a tool that is used in many contexts such as a unique writing tool, as a spreadsheet with varying equations, and as a mathematical problem-solver. With each activity, the preservice mathematics teacher is "learning by doing," is engaged in actively obtaining knowledge, and is experiencing the best practices of teaching mathematics.

The Teacher Educator

The teacher educator serves as the guide and facilitator in the preservice mathematics methods classroom, rather than being the dispenser of knowledge to passive recipients. The role of the teacher educator is to enable the learner to be engaged in the learning process through self-directed explorations. Instead of being the sole source of knowledge, the teacher educator moves around the classroom, among the various groups, assisting individuals, or small groups, questioning by using open-ended techniques (NCTM, 1991). These questions allow the student to explore his/her own understanding, potentially raising his/her mathematical level through reflecting. According to Dekker and Elshout-Mohr (1996), mathematical level raising involves the learners forming a view of a mathematical idea, reflecting upon it, using it appropriately and flexibly, communicating ideas to peers, and reflecting on another's perspective from one's own framework.

Devising good questions requires the teacher educator possess a clear understanding of the mathematics and pedagogy involved as well as a knowledge of likely misconceptions. Additionally, the teacher educator should query students to look for mathematical or pedagogical relationships. For example, using phrases like *that's the same as*, or questioning *how does this relate to the previous. . .?* , enable the students to increase their understandings of both mathematics ideas and pedagogical strategies. Throughout the course, the mathematics teacher educator models how questioning techniques help to promote mathematical knowledge, referencing these times when pedagogy discussions are being emphasized. Through recognizing questioning techniques, preservice teachers can become questioners themselves.

Additionally, the creative teacher educator who infuses technology into the mathematics methods classroom believes that technology is an integral component of this new curricular design. Classroom learning is redesigned to capitalize on student competencies, the multitude of resources available, and the vision that learning can be dynamic and exciting. Although obstacles such as prior preservice teachers' experiences and their lack of mathematical understanding exist, the teacher educator moves ahead creating tasks that include the computer within the scope of the mathematics methods to be explored. A comprehensive CD-ROM, designed as a resource tool, is available with newer mathematics methods textbooks.

The Lesson

The *constructivist* classrooms, where participants experience problem-solving adventures, can become pertinent learning experiences for preservice teachers. In this type of classroom, innovative, problem-solving experiences are highlighted. Preservice teachers are encouraged to think and reason through meaningful mathematics tasks frequently connected to a real world context (Brooks & Brooks, 1993). For example, in the secondary mathematics methods class, the teacher educator shows students how to use the calculator's and the computer's numerical and graphic tools they need to explore the data collected from the Computer Based Laboratory (CBL) light sensor. After investigating how the data arises and is interpreted in a realistic context, the students construct the theoretical framework of those ideas out of their shared experiences. The calculator and computer, used as tools of learning, challenge preservice teachers to become researchers. This task could become the model for a later assignment, or the seed idea for a future lesson involving the computer, specific software, and a concept development activity. Their designed lesson will be utilized by high school students in a clinical setting.

The Environment

The mathematics methods classroom participants should experience the 1989 NCTM *Curriculum and Evaluation Standards for School Mathematics* focusing on problem solving and the infusion of technology as a

way of learning and teaching math. Additionally, the goal of the teacher educator should be to develop a mathematical community, rather than to stress that the classroom remain a collection of individuals. Key ingredients to the developing this unique community are to involve the preservice teachers in problem solving in cooperative groups and to promote discourse about mathematics, pedagogy, and technology.

The Learning Center Approach

The teaching of mathematics in a technology-rich environment can be developed in several differing ways. In the elementary or middle school classroom, five computers are frequently placed in a unique location serving as one of many learning centers distributed throughout the classroom. The large teacher work station is used to demonstrate the general workings of the activity to the whole class, or used as a sixth computer source. Capitalizing on the various learning centers, the students rotate to one site using a prescribed design. For example, assume that the class of 30 students are arranged in groups of 5, labeled A, B, C, D, E, F. Groups A and B work at the computers where two students are assigned to each of the computers, one from Group A and one from Group B. This pairing capitalizes on the interactions among individuals as an important source of learning and development. According to Vygotsky, "social interaction allows the child [student] more easily to enter into his or her zone of proximal development and set off the internalization process" (Lemerise 1993, 28). The students work at a pre-designed mathematical activity, often a concept development activity, for 20 to 40 minutes. If the computer task is designed as a concept development activity, there exists four overlapping portions: The exploring experience, the conjecture phase, the testing aspect, and the generalization portion. In the exploring phase the preservice teachers experience the problem solving process through the use of questioning strategies, and the role of the computer as a problem-solving tool. The students are guided to state and test their conjecture(s). A final question, *Explain what you learned in this experience to an absent friend*, helps the student to generalize their results. The other students are actively involved in different mathematics centers where up to four different tasks pertaining to the same mathematical topic are presented. Each of these different mathematical tasks, one per site, encourage student exploration and clarification. The groups of students rotate to different centers at a designated time. If four math centers are used, Groups C, D, E, F work for only 20 minutes, moving to a different center at the end of the first 20 minutes. After the next 20 minutes, Groups C and D rotate to the computers, while Groups E and F become actively involved in different activities experienced by Groups C and D. Groups A and B become involved in the math tasks at locations vacated by Groups E and F. In a one and one-half hour college class, four groups can experience problem solving on the computers. On another day, Groups E and F move to the computers with Groups A, B, C and D located at the math centers not previously experienced. Figure 1 helps to clarify the rotation system. After all students have participated in the both the computer and math tasks, all participants are challenged to analyze the "learning is doing" portions. During the remainder of this class time, the students discuss mathematical concepts learned, with emphasis on how this pedagogical technique can be used by preservice teachers in their future elementary or middle school classrooms.

Time Site	ROTATION 1 (20 min)	ROTATION 2 (20 min)	ROTATION 3 (20 min)	ROTATION 4 (20 min)	ROTATION 5 (20 min)	ROTATION 6 (20 min)
Computers	A & B	A & B	C & D	C & D	E & F	E & F
TASK 1	C	D	E	F	A	B
TASK 2	D	C	F	E	B	A
TASK 3	E	F	A	B	C	D
TASK 4	F	E	B	A	D	C

Figure 1: Learning Center Approach Rotation

The Project Focus Design

Another way the computer can be used in the mathematics classroom is demonstrated in the project focus designed curriculum. For example, the secondary mathematics methods students are challenged to problem solve a particular mathematics topic using the computer as a tool. In this format, each group of two to four students utilizes one computer as they seek their unique solution. The individual mobile computer stations are positioned at the site of each working group. The preservice teachers must create a project-based lesson where technology is infused into a lesson plan. This project must have a literature review obtained through the use of internet, must use a specific technology application such as a spreadsheet, or software application such as the Geometer's Sketchpad™, Geometric Supposer™, or GeoExplorer™ to teach that lesson. Additionally, it should be designed as a concept development activity, described earlier in this paper. Although each of the applications or software has been introduced previously in the mathematics methods classroom, the group of preservice teachers, working cooperatively, deepen their mathematical understandings and knowledge of the software application throughout this assignment. The mathematics educator presents the use of this unique method to acclimate the preservice teachers to the mathematics reform movement. It is hoped that this differing educational environment that supports and encourages mathematical reasoning can have an impact on how prospective teachers think about their own role as future teachers in the mathematics classroom.

The Students

When the learner operates in the listener-follower role of the traditional classroom, the student becomes dependent, eliminating the need to think for oneself. A student exposed to this pedagogical model strengthens the habit of dependency and learns helplessness. In the *constructivist* classroom, the student is challenged to relinquish passive ways to become an active learner. One way this can be accomplished early in a mathematics methods class is through an assignment that involves a CD-ROM and internet. According to Ball (1996), "elementary teachers are themselves the products of the very system they are now trying to reform. . . those same experiences have equipped them with ideas about the teacher's role, . . ." However, these passive students who often feel mathematically inadequate, are eager to become good teachers by learning about resources that are available to them. Capitalizing on their enthusiasm, the teacher educator assigns a "Technology Surf" task, encouraging them to explore the CD-ROM connected to their textbook. Additionally, they investigate the databases available on internet, correspond with a peer in the classroom through e-mail, and examine the availability of journal articles on the World Wide Web (www). Presented with this assignment early in the semester, the preservice teachers learn that their textbook is only one of many resources. Furthermore, they have begun the process of problem solving, "learning by doing," and investigating the computer through several of its valuable purposes.

Summary

Future teachers can be challenged to modify their views of the traditional mathematics teacher and to assume the contemporary *constructivist* vision of a mathematics educator as a designer, facilitator and manager when they experience a specially designed mathematics methods course. When the teacher educator's lessons focus on a problem-solving emphasis, using the computer as a tool of learning to reach often multiple solutions, the preservice teachers begin to think differently about mathematics. Additionally, the mathematics teacher educators seek to create an environment that is multi-dimensional, simultaneously involving multiple activities that students can work on in groups to facilitate learning. The student assumes the role of a researcher, designing and finding seed ideas for lessons, creating tasks and utilizing the computer within concept development activities. Ultimately, the preservice teacher becomes technologically competent and capable of effectively using the computer in their future classroom.

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The Role of Technology in the Introductory Statistics Classroom: Reality and Potential

Maria Meletiou
Department of Mathematics Education
University of Texas at Austin, United States
email: Meletiou@math.utexas.edu

Carl Lee, Ph.D.
Department of Mathematics
Central Michigan University, United States
email: Carl.M.Lee@cmich.edu

Margaret Myers, Ph.D.
Dana Center for Science and Mathematics
University of Texas at Austin, United States
email: myers@cs.utexas.edu

Abstract: This paper compares the learning experience of a group of students from a technology based introductory statistics course, with that of a group of students from non-technology based instruction. Findings indicate that the use of technology had a positive impact on students' motivation, on their enjoyment and appreciation of statistics, and gave them increased exposure and familiarity with the practical aspects of the subject. At the same time, confusion about the nature and purpose of inferential statistics was observed in both groups, which led to some conjectures regarding possible obstacles to students' better comprehension of statistical concepts. The study makes the hypothesis that the linear and consecutive way in which the different statistical ideas are presented causes students' knowledge to become compartmentalized. Finally, it suggests the need for moving away from traditional approaches that project a static view of reality towards new, dynamic technology based approaches of teaching statistics.

Introduction

The developments in computers during the last decades have been so profound that it is not surprising they have had an immense impact on the practice of statistics. The availability of computing technology has freed statistics from many of the constraints of the past and has radically transformed the culture of practicing statisticians. The calculating power of the computer has relieved the burden of computations, and its ability to generate data from which to make conjectures and simulate the behavior of complex systems has opened new and exciting avenues. Similarly, technology has provided the opportunity to create an entirely new learning environment, it has significantly increased the range, sophistication, and complexity of possible classroom activities (Hawkins, 1997). Despite however the technology's potential to transform the culture of the statistics classroom, its real impact has been limited. Many statistics instructors still choose to completely ignore the calls for reform and the effects on student learning often dishearten others who do make some use of technology.

Having a vision of what technology can do is not the same as knowing how to take advantage of these possibilities in a teaching context (Hawkins, 1997). The amount of research done which investigates in depth whether students' conceptual understandings change as a result of using computer software and if so in what ways, is very limited. There is a pressing need for a more systematic investigation of the effect of technology on students' conceptions and beliefs regarding probability and statistics. This is especially crucial now that some colleges have finally begun to respond to the calls for reform. Educational reform decisions should be guided by continued research which helps determine the purposes for which calculators, computers, and other technologies are best suited and the ways in which they should be used by students. Software development and research on its educational effects should continuously inform each other (delMas, 1997, 83), otherwise technology will continue to have a less than optimal impact on student learning.

This paper compares the learning experience of a group of students from a technology based introductory statistics course, with that of a group of students from traditional, lecture based instruction.

By analyzing interviews conducted with students from both groups the study draws conclusions about the influence of technology on introductory statistics students' attitudes, understandings, and their ability to apply the most important statistical ideas.

Study

Individual in-depth interviews with twenty-two student volunteers who had just completed an introductory statistics course were conducted. The students interviewed were of varied mathematical backgrounds and had taken the course in one of five different departments across two campuses. Each of the twenty-two interviews, which were audio taped and transcribed, lasted approximately two hours. During the interviews, students were encouraged to use paper and pencil as needed. Although the interviews proceeded depending on students' responses, the interviewer guided the dialogue so that the majority of a list of topics covering the main ideas encountered in an introductory statistics course was brought into the discussion. A vast amount of information regarding the culture of the statistics classroom and its impact on student learning and attitudes was collected. In order to analyze the data, we looked closely to every interview and used qualitative research methods to code students' responses in order to document recurring themes or patterns in the data and develop working hypotheses. In this report names have been changed to protect the identity of the participants.

Seven out of the twenty-two students had taken a course developed by the second author called PACE (Projects-Activities-Cooperative Learning-Exercises). The nature of the intellectual activity in the PACE classroom was very different from that in the other classrooms. Whereas in the other courses the teaching of statistics was primarily lecture based –hereafter referred to, as *traditional course group*-and incorporation of technology was either minimal or non-existent, technology played an integral role in the PACE course. Students had access to calculators and computers and used them to perform calculations, to create graphical displays of real datasets, and to conduct simulations that illustrated statistical concepts such as the Central Limit Theorem and the sampling distribution of the mean.

Traditional Course Group

Our findings indicate that students from the traditional classes lacked an appreciation of statistics and were not familiar with the practical aspects of the subject. The view of statistics these students acquired seems to be a collection of isolated and meaningless techniques.

Several of the students in the traditional group described the learning environment as rigid and the activities as unreal. One of these students, John, considers the nature of statistics *" to be sort of a dry subject, or dry topic"*, though he thinks that it can still *"be presented in such a way that if it's made relevant to the student and to what they're doing and why they're studying and if the student wants it to be then it will be less dry and more interesting"*. Another student, Anna, found statistics to be boring and she blames the way the course was delivered for that: *"It was hard to pay attention when it was just regular writing on the board, problems from the book. I mean, I think it could be a very interesting course if you used it in a way that was more relative to life."* When asked to give suggestions about how to make the course more interesting and more alive, the first suggestion she gave was that of a hands-on approach using technology:

"I had a friend that was in a course, the same course, but by a different teacher at the same time. And she said that they used technology, computers and stuff to learn. And I think I would have learned much better using the technology and stuff like that rather than just sitting through the lecture the whole time. Kind of like a hands -on approach to it."

Many of the students in the traditional group complained that, although they knew how important statistics is, they feel that the tools they obtained from this class were inadequate for them to be able to solve any real world problems. When asked whether she considers statistics to be part of mathematics, this is how a student named Susanne responded: *"From the way it was taught, I do consider it to be part of mathematics. And again that's because we just dealt with the basics, here's how to do this, here's how to convert things to z-scores, here's how to do it, so we just did the hard technical stuff......I think statistics....that's part of it, but the other part of it would be the interpretation of the facts because just*

having information is not gonna do you any good, so having 104 results on a test isn't gonna tell you much, you have to interpret those." She went on to say:

"Well, and I'm not sure, you know, I want to be able to spot in a journal article, if I read a journal article and they give all of the statistics to what they're studying and accomplished, I'm not sure if I could really say, wait a minute that was a poor way of doing that, or that's gonna be a bad way, and that's one thing I'm concerned about."

In the non-technology-based courses, due to the time necessary for training students in computational methods, instruction was technical rather than empirical. Examples were carefully chosen to make manipulation of formulas easier. Most of the problems encountered in the traditional classes were contrived textbook problems whose purpose was to illustrate the various statistical techniques: *"A lot of things we learned in the class were the basic technical things but we never got like here's a case, here's all the data to it, now how do you figure through, no practical application of statistics"*[Susanne]. Students never got the opportunity to work with datasets that had more than just a few values: *"I don't remember ever having discussed how you choose a sample size. I mean the sample sizes we always worked with were under twenty. The data was provided by the book."* [Sue]

In this age, almost any real world statistical activity will be conducted with the aid of some supportive computer-based technology. Familiarity with computers and appreciation of the role they play in statistical endeavors should, therefore, be one of the important goals of statistics instruction. However, when asked what tool they would use to get a random sample, only four out of the fifteen students in the traditional group suggested using technology. Most of the students in this group seemed completely unaware of the fact that one can use the computer for random number generation. The response of the following student, who suggests scrambling up all 50,000 names, is a typical one: *"I'm gonna get pieces of paper and pen and just write their name and pick my sample."* [Steve]

PACE Course Group

Unlike students in the traditional courses, the use of technology gave students in the PACE course much more experience with data collection, manipulation and representation. Instead of spending most of their time learning formulae and techniques, students were given the chance to conduct real investigations and gain experience of the wide applicability and usefulness of statistical methods. Jason, a PACE student, reported that technology has helped him a lot improve his understanding of statistical concepts: *"I already had statistics before and I did very poorly in it. And when we went over to the computer lab, I understood a lot more by seeing what was going on, rather than just writing it down and looking at the board."* Tyler, another student, said he liked the fact that computers were used for enhancement, for demonstrating real world applications of statistics:

"I think if you just did the lecture, you'd be having people say, " How do you use this in the real world?" And even when you do say something they'll be like, "Yeah, sure, how am I ever going to ..." Because I find that a lot in my math classes. People ask how do you use it in the real world and they're like.....So, I found that, when you actually saw it yourself, using it, you could say, okay. Nobody ever had to ask how are we ever going to use this. I mean, you understand how."

Engagement with interesting activities through the use of technology seems to have led to an increased enjoyment and appreciation of the subject. Six out of the seven PACE students reported that despite their generally negative attitudes towards statistics before taking the class, they ended up enjoying the course much more than what they had thought. Tyler, before taking the course, had the impression that statistics was going to be nothing more than *"number-crunching", "playing with a bunch of statistics and figuring out averages."* But unlike his expectations, he ended up finding the course quite interesting. Computers had a lot to do with this:

"Yeah, it's not so much just like taking average. I mean, I really thought a lot of it was just averages and stuff like that, but there's more than just averages. You have your errors, your skewed to the rights and lefts and all that stuff. Computers, I really didn't think much of....I mean I knew computers could help you, but I didn't realize with the graphs and stuff like that. I didn't find it that...I mean it wasn't boring...I mean, I was expecting to fall asleep in class. It wasn't bad."

Chris also had the prior impression that statistics would be *"a bunch of equations"* but his thoughts changed a lot after taking the class. He found the course to be much more involved that what he had thought and feels he learned *"a great deal of all the different subject areas; it went into a lot of different*

things." Helen, before taking the class also thought statistics would be *"boring and easy"*, but she ended up finding out that it is *"not boring and you have to think."* Joan also reported having had very negative feelings and anxiety before taking the course. She was also feeling that statistics had nothing to do with what she was studying (meteorology) and she would end up *"doing all this hard work and it has no real benefit."* However, she said that now she does not find the course boring at all, and can see a lot of benefit for her personal research.

Don, a prospective secondary education mathematics teacher, also now has a much different view of statistics than before. Whereas before taking the class, when hearing the word statistics he would *"automatically think just an abstract concept....numbers to samples, you know"*, taking the class helped him realize *"what lies behind those numbers, how they get them."* He thinks that his experience with technology will help him a lot as a teacher because he knows that *"we're getting computers more and more in the classroom and since we did it on the computers, it's going to be easier to do it that way than it was to try and do it by formulas"*. Sylvia reported her surprise at *"the amount of computer hands-on stuff"* employed in the class. She considers computers to be extremely helpful for instruction because they make the *class "a little more interesting than if it was just numbers"* and manipulations of formulas. When asked whether she thinks that the teaching of statistics could be as effective without the use of computers, she responded: *"I don't think so because if you don't use the computers, you're not going to see the application of statistics."*

Students in the PACE course came to view technology as an indispensable tool for statistical problem solving. When, for example, asked what tool they would use to get a random sample, six out of the seven PACE students mentioned a calculator or a computer without further prompting. They seemed well aware of the fact that using computers or calculators makes the process of generating random data much more efficient and that *"trying to do it yourself, that would take a lot of time"* [Helen]. The following student's response shows awareness that technology can be used to generate a random sample, knowledge of at least one specific method doing it, and reliance on technology to perform the task:

"When they (students) come in from high school, it's probably in the computer, with their application. It's probably entered into the computer. And then you could just pick a 100 random or 500 random out of the list. Have a computer randomly pick them then you've got a sample. But, if you don't have that, then I don't know how." [Jason]

The fact that one can use technology to solve a particular problem does not necessarily imply that they have a thorough understanding of the underlying statistical concepts. What we observed was that not only the students from the traditional courses, but PACE students also often seemed to have a superficial understanding of statistical ideas and confusions that persisted despite the use of technology. One of the most important statistical ideas covered was that of the sampling distribution. The "recognition that the estimates of a population parameter will vary and that this variation will conform to a predictable pattern" (Lipson, 1997, 137), is a critical step towards developing the theory of statistical inference. Students in the PACE course engaged in several computer activities to help them develop this important idea. Unfortunately, their opportunity to use computer simulations as a tool for drawing repeated samples from a specified population and summarizing the results did not seem to be as effective in helping them develop the idea of sampling distribution and see its connection to confidence intervals, p-values, and hypothesis testing. Often students often failed to see the purpose behind the computer exercises they were doing:

"Yeah, all that. When we were doing it on the computer, I knew how to do it, but I felt like I didn't know why I was doing it. To me, it was just that we were using too much of the computer and I didn't understand what was going on because I think that we didn't have enough of it in the lecture." [Tyler]

Nearly every single student expressed frustration and limited understanding of the concepts covered at the last part of the course. Several said that they did not have any problem with the course until the point where concepts related to statistical inference were first encountered. Joan said she was doing really well until towards the end of the semester when the concepts got pretty complicated and she *"tried to memorize everything, not really seeing that it was based upon the stuff that we had done"*. Even after doing all of the computer labs, *"it wasn't quite registering"*, she *"didn't quite know how to put it all together."* Sylvia found the course to be *"more interesting in the beginning and fairly difficult near the end"*. She had an especially hard time with hypothesis testing and sampling distributions because *"it's more in depth"* and computer labs did not seem to help her much either. Although she knew how to do the

tasks on the computer, she could not see the rational behind the computer activities or appreciate how what they were doing was connected to what they had been doing the whole semester.

Discussion

The way technology is currently being used in the statistics classroom is to enhance the teaching of traditional material by presenting it in more exciting and, hopefully, more insightful ways. Students in the PACE course were certainly much better off compared to the other students we interviewed. It seems that the use of technology had a positive impact on the PACE students' motivation and helped them get a much better grasp of the practical aspect of statistics. However, arousing students' interest is a necessary but not sufficient condition for learning (Hawkins, 1997, 3), and statistical competence with the technology is not adequate in its own right. As Starkings (1997) stresses, *"statistics is a subject that is both theoretical and practical by nature and needs to be addressed in both of these aspects"* (Starkings, 1997, 250). Being statistically literate, requires not only the ability to process data using some piece of software, but also the capability to understand the assumptions behind the statistical analyses and the constraints imposed by the underlying theory of the analyses (Jeffers, 1995, 229; in Glencross et al., 1997, 307). The findings from the interviews suggest that providing students opportunities to experiment with technology or other activities was often not adequate for them to acquire a good understanding of the statistical concepts under investigation. Despite the use of technology, confusions about the nature and purpose of statistical processes persisted.

Our findings are by no means unique. Several other researchers have questioned the effectiveness of computer simulations in helping students develop the important ideas of statistics (Lipson, 1997; Hawkins, 1997). Green (1990), after conducting a study to determine the effects of using Microcosm Software on students' understanding of probability distributions, concluded that it is *"doubtful whether the pupils get from computer simulations what the teachers or software writers assume"* (62, in Hawkins, 1997, 10). Rossman (1997) warns us: *"Although I firmly believe that computer simulations are very powerful and enlightening tools for understanding the long-term behavior of sample statistics under repeated sampling, I question whether many introductory students really see and understand what instructors want them to when they look at the simulation results."* (Rossman, 1997, 231)

The persistence of students' difficulties despite the use of interesting activities and the incorporation of technology suggests that there might be a need to reconsider curricula. The structure of the PACE course was the structure of virtually every other introductory statistics course - the course started with descriptive and exploratory data analysis and then moved into statistical inference. Biehler (1994) warns us that the danger of a curriculum with such a structured progression of ideas is that students' knowledge becomes compartmentalized and gives them the impression that *"EDA [Exploratory Data Analysis], probability and inference statistics seem to be concerned with very different kinds of application with no overlap"* (Biehler, 1994, 16). The linear and consecutive structure of the course makes it come in sharp contrast with the complex nature of stochastical knowledge.

The assumptions posed in the statistics classroom often come in conflict with the students' everyday experience and project a static view of reality that does not take into account the fact that the world is continuously changing and consequently distributions do change too, that *" the conditions do not determine the sample completely, and variation is an important and unavoidable feature in all finite sample sizes"* (Pfannkuch and Brown, 1996, 15). The amazing increase in the processing power of computers offers us the opportunity to move beyond traditional approaches to statistical inference, where *"the distributions are reduced to the mean values and the question 'are the mean values different' is posed - assuming that distributions are equal in all other respects (normally distributed with known variance)"* (Pfannkuch and Brown, 1996, 14). There is a need for taking advantage of improved learning technologies that allow students to build their own computational models of probabilistic phenomena of interest to them and explore the effect that the change of assumptions and the influence of lurking variables can have on the models. Such technologies will hopefully help students understand how events can be both unpredictable and constrained at the same time, how regularities and stabilities emerge out of complexity.

Conclusion

The purpose of this study was to investigate how technology is changing the learning of introductory statistics at the college level. The conclusions drawn concerning the impact of technology should be treated carefully as the number of students interviewed was a small voluntary sample who might have benefited from technology differently from the rest of the students in these courses. Also, the effect of technology cannot be judged in isolation from curricular materials and instructor characteristics. What made the experience of students in the PACE classroom distinctive was not the use of technology alone but the overall nature of the course with its emphasis on problem solving and working with real life problems. However, this study does provide some insights into the effects of technology on student learning of statistics. We saw that engagement with technology had a positive impact on the PACE students' motivation, on their enjoyment and appreciation of statistics, and gave them increased exposure and familiarity with the practical aspect of the subject. At the same time, we observed that not only the traditional, but also the PACE students' knowledge of statistical ideas seemed to often be superficial and not well interconnected. The prevalent tendency, in both the PACE and the traditional group, towards an overly deterministic thinking and confusion about the nature and purpose of inferential statistics led to some conjectures about what the real obstacles to students' better comprehension of statistical concepts might be. We hypothesized that the linear and consecutive way in which the different statistical ideas are presented causes students' knowledge to become compartmentalized. Finally, we suggested that statistics education should take advantage of powerful new technologies in order to move away from traditional approaches that project a static view of reality, towards new, dynamic approaches that make more sense to students and allow access to the theoretical level.

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The Evolution of Web-Based Mathematics Laboratories at West Virginia University

Laura Pyzdrowski
West Virginia University
United States
lpyzdrow@math.wvu.edu

James Miller
West Virginia University
United States
miller@math.wvu.edu

Lori Georger
West Virginia University
United States
georger@math.wvu.edu

Abstract: Interactive computer laboratories are used in College Algebra and Pre-Calculus at West Virginia University. Local high school faculty began collaboration to adapt the laboratories for their use. Two projects are explored. One project is the development of a college credit mathematics course to be offered in the high school. The other project is a research study performed at WVU. The research questions pertain to: searching for significant changes in students' attitudes toward mathematics, searching for significant changes in students' critical thinking skills scores on the Watson Glasser Critical Thinking Skills Appraisal, searching for gains in students' achievement scores, and searching for a significant increase in the student retention rate. The objectives for the work done in the high school include opening the line of communication between the mathematics departments and easing the transition for students between high school and college. The interactive computer laboratories are now the foundation of a projected web-based course.

Introduction

United States mathematics teachers face a challenge to help students become first in the world in science and mathematics achievement. (US Department of Education, 1991) This has become a greater challenge given the poor performance of the United States high school students on the Third International Mathematics and Science Study (TIMSS). In his *Call to Action for American Education in the 21st Century: Ensuring Educational Excellence in 1998 and Beyond*, President Clinton hopes "to open the doors of college to all who work hard and make the grade, and make the 13th and 14th years of education as universal as high school." If students, especially those in transition from high school to higher education, can be kept in the mathematics pipeline, they may be more likely to continue into programs of study that will allow them to pursue the highly technical jobs of the future. In fact Ray (1995) believes that the academic preparation provided to students should reflect the realities of existing and future work places. This means that students should not only learn to think, but they should learn to use technology and learn to work together. In the *NCTM Member Handbook* (1998) it is documented that learning mathematics is maximized when teachers focus on mathematical thinking and reasoning. The Organization also supports the use of calculators and computers by students to investigate mathematics and to increase their understanding of mathematics. The American Association of Two-Year Colleges, AMATYC, believes that problem solving should be introduced to students in the context of real, understandable situations (1995). It promotes mathematics as a laboratory discipline, one that uses hands-on investigations. Its publication also supports the use of technology as an essential component of an up-to-date mathematics curriculum. In *Technology and Algebra Curriculum Reform: Current Issues,*

Potential Directions, and Research Questions (1995) it is suggested that more consideration should be given to changes in the curriculum and how computers and calculators should facilitate those changes.

An effort is being made to meet the challenge to help students learn mathematics. The first step in the design of the interactive computer laboratories was to examine the curriculum of the "before calculus" courses at the University. It was found that there are many topics in the curriculum, and these topics are covered quickly and superficially. The Drop, Failure, Withdrawal (DFW) rate for these courses fluctuates between 40% to 60%. Students develop a deep dislike for mathematics. The teaching methods are designed to herd large numbers of students through the courses. This teaching approach encourages broadcasting, and students are passive in their learning environment. The use of multiple choice homework and examination questions is used, and students seem to no longer develop work habits and skills necessary to be successful in the courses or mathematics and its applications.

The Study

A modification of both curriculum and teaching methods is needed in the "before calculus" courses. College Algebra and Pre-calculus were chosen to begin the reformation mainly because of the expertiese and interests of the faculty involved. It is a goal to have students become active participants in the courses. Students are encouraged to practice the basic techniques of manipulation in connection with applications and to explore and discover patterns and mathematical concepts. It is hoped that students will become more successful in the courses, and that they will become better able to apply mathematics to real world problems. Interactive computer laboratories are used to encourage students to be actively involved in doing mathematics; and thereby, enabling them to construct their own knowledge. Because a goal is to increase the retention rate in the courses, it is important the University faculty understand the State Instructional Goals and Objectives for mathematics. In essence, the idea of "building a bridge" between high school level mathematics and University level mathematics became the phrase often used to define this facet of the project. Contact was made with faculty at the local high school. The communication line was opened, and the exploration of similarities and differences began. The high school faculty helped adapt the laboratories so that they could be used in the high school classroom. University faculty visited the high school classes while the students used the laboratories to explore mathematics.

The collaboration among faculty sparked an interest in the administrators in both the public schools and the University. Also, as a result of West Virginia Senate Bill # 547, the West Virginia University System Board of Trustees adopted a set of initiatives in which they asked University System institutions to engage in a number of activities to improve efficiency and effectiveness and to become more involved in statewide service. One of these initiatives called on institutions to work with a number of counties to help improve student college-going rates, student SAT/ACT scores, the number of high school students taking college courses while in high school, and the number of non-traditional students taking college courses. In response to this initiative, West Virginia University and its five identified counties (Hampshire, Harrison, Marion, Monongalia, and Wood) decided that it would be valuable to make an effort to improve mathematics instruction in high schools such that high school graduates are better prepared to enter college-level mathematics courses. In the Spring of 1998, public school administrators from the five counties in cooperation with administrators from West Virginia University, WVU, and West Virginia University at Parkersburg, WVU- P, developed a committee to investigate the particular needs of mathematics students in Harrison, Hampshire, Marion, Monongalia and Wood counties. The Blue Ribbon Mathematics Partnership Committee was formed to organize and implement projects targeted to improve mathematics education in the State of West Virginia. The committee is comprised of mathematics - science coordinators and high school teachers who were appointed to the committee by their respective superintendents. The chairs of the mathematics departments chose university mathematics faculty members. Representatives on the committee also include a faculty member and an administrator from the College of Human Resources and Education from West Virginia University. Because there was common in the curriculum and instruction issues for the pre-calculus courses at all institutions, a project of the committee is to develop a University pre-calculus course to be offered in the high schools. The computer-based laboratories will be a foundation of the project.

Another facet of the project includes research performed within the Mathematics Department at WVU. The interactive computer laboratories were incorporated into weekly assignments for a summer section of College Algebra. The interactive computer laboratories are comprised of computerized mathematical worksheets, computer pages, on which the student is able to explore a mathematical concept. The student is

able to change the input components for various functions on the worksheets. The student can then explore how the analytical changes to a function relate to the changes in the graph and/or table of the function. During the computer laboratories, students are guided through assignments and projects by written laboratory directions and questions. For all three sections of College Algebra in the summer, students' attitudes were tracked through weekly journal entries. All students participating in the study took pre and post achievement tests and pre and post critical thinking skills tests. Each of the 77 students chose one of the three sections; Section A, Section B, or Section C. Sections A and B were the control groups or traditional sections and Section C was the experimental group. The students who selected Section C were aware that the section was one half hour longer and that the section required the use of computers. Of the 27 students in Section A, 11 completed all tests. Of the 31 students enrolled in Section B, 11 completed all tests. Of the 19 students enrolled in Section C, 9 completed all tests. Only those students who completed all tests were used in this study.

The summer investigation is guided by the following questions: Do students gain in critical thinking skills while taking a standards-based college algebra course? Do students gain in critical thinking skills while taking a traditional college algebra course? Do changes in critical thinking scores relate to changes in mathematics achievement scores?

The experimental section of college algebra differed significantly from the traditional sections taught at the University. The experimental section was one half an hour longer than the traditional sections. Computers in laboratories were used on a weekly basis. The students completed activities that accompanied the laboratory, worked in groups in the laboratory and shared a laboratory grade. Each student was asked to pick a partner to work with in the laboratory. The students in the experimental section of the college algebra course learned the same topics as those in the traditional sections. The same book was used in all sections. The experimental section made use of written communication through weekly journal entries and of cooperative learning combined with computer use in a laboratory setting. Assessment took into account individual performance on tests, individual responses in journal entries, and group performance on computer laboratory activities.

All students took three tests as well as a pretest and posttest on mathematics achievement. The students were asked to complete five journal entries and a questionnaire during the session. In the journal entries the students responded to specific questions about the structure and content of the course. The search for an instrument to measure critical thinking skills was begun with four basic needs: The instrument is non-mathematical in nature. This is necessary so that the skills tested are not those of the mathematics classroom but those of the workplace. The test does not require a high readability level of the students. This is necessary so the reading skills of the students do not interfere with the conclusions based on critical thinking skills. The instrument is easy to administer and score. It is important that a proctor be able to administer the test in one class period and that the scoring is non-subjective. The instrument is reliable and valid. The Watson-Glaser Critical Thinking Appraisal was found to meet the above criteria. The mathematics achievement test is a comprehensive multiple-choice departmental test on college algebra skills. A maximum of 100 points may be obtained on this test. For the purposes of this study, the university coordinator of college algebra developed two versions of a comprehensive final test. One was used as a pretest and one as a posttest. Only the posttest score affected the grade of an individual student.

In the fall semester, the developed interactive computer laboratories were weekly requirements for all pre-calculus students at WVU. The instructors also incorporated the use of particular pages of computer laboratories into the lectures of the course. This helped synthesize the laboratories and the lectures. It was hoped that the students would not see the laboratory component as an add-on to the course, but as a support component of the learning process. All students enrolled in pre-calculus were asked to participate in a research study. Most of the data collected is still under analysis; however, grade and withdrawal distributions are available.

Findings

The first research question -- Do students gain in critical thinking skills while taking a standards-based college algebra course? --Was answered by computing a t-test. The t-test was use to analyze the mean difference in pre and post critical thinking skills test scores of the experimental group. The t-test compared a zero gain in critical thinking skills test scores against a significant positive gain in critical thinking skills test scores. The mean and standard deviation of the difference in pre and post critical thinking scores of the experimental group are reported in Table 1. The t- test showed no evidence of a significant positive gain in

critical thinking skills, t = -2.92, df = 8, p-value = 0.99. The mean difference in pre and posttest scores of the experimental group is x= -5.56. Using a confidence level of 95%, a confidence interval was computed for the population mean difference between pre and posttest scores of the experimental group, (-12.70 , 1.59). The data yielded a negative mean. Zero is included in this interval; hence there is a possibility of no gain or no significant positive gain.

Table : t-Test for Zero Gain verses Positive Gain in Critical Thinking Skills for the Experimental Group (ect)

Group	N	Mean	Standard Deviation	t	p-value
ect	9	-5.56	5.70	-2.92	0.99

The second research question--Do students gain in critical thinking skills while taking a traditional college algebra course? --Was answered by computing a t- test. The t-test was used to analyze the mean difference in pre and post critical thinking skills test scores of the control group. The t-test compared a zero gain in critical thinking against a significant positive gain in critical thinking skills. The mean and standard deviation for the difference in pre and post critical thinking skills of the control group is reported in Table 2. The t- test showed no evidence of a significant positive gain in critical thinking skills, t = -2.21, df = 22, p-value = 0.98. The mean difference between pre and post critical thinking skills of the control group was x = -4.73. Using a confidence level of 95%, a confidence interval was computed for the population mean of the control group, (-8.46, -0.42). The data yields a negative mean. Therefore, there was no significant positive gain.

Table 2:t- t-Test for Zero Gain verses Positive Gain in Critical Thinking Skills of the Control Group (cct)

Group	N	Mean	Standard Deviation	t	p-value
cct	23	-4.73	10.30	-2.21	0.98

The third research question--Do changes in critical thinking scores relate to changes in mathematics achievement scores? --Can not be answered with the data collected in this study. The data yielded a negative mean difference in pre and post critical thinking skills test scores in both the experimental and control group. Therefore, no relationship will be established between critical thinking scores and changes in mathematics achievement scores.

The achievement scores did increase significantly in both the experimental and control group. The mean difference between pre and post achievement scores in the experimental group is x = 7.22. The mean difference between pre and post achievement scores in the control group is x = 8.09. A t-test was use to analyze the contrast between the mean difference in pre and post achievement scores of the experimental group against the mean difference between pre and post achievement scores of the traditional group. The means and standard deviations of the difference in pre and post achievement scores of the experimental group and of the control group are reported in Table 3. The t- test showed no evidence of a significant difference between the mean difference of pre and post achievement test scores of the experimental group and the pre and post achievement test scores of the control group, t= 0.47, df= 30, p-value =0.32.

Table 3:t-Test for Comparison of Mean Difference in Pre and Post Achievement Scores for Experimental Group (eat) and Control Group (cat)

Group	N	Mean	Standard Deviation	t	p-value
eat	9	7.22	5.19	0.47	0.32
cat	23	8.09	5.70		

A t-test was used to analyze the contrast between the mean difference in pre and post critical thinking skills test scores of the experimental group against the mean difference between pre and post critical thinking test scores of the traditional group. The means and standard deviations of the difference in pre and post critical thinking skills test scores for the experimental and for the control group are reported in Table 4. The t- test

showed that there was no evidence of a significant difference between the mean difference of pre and post critical thinking test scores of the experimental group and the pre and post critical thinking test scores of the control group, t =0.02, df = 30, p-value =0.41.

Table 4: t-Test for Comparison of Mean Difference in Pre and Post Achievement Scores for Experimental Group (eat) and Control Group (cat)

Group	N	Mean	Standard Deviation	t	p-value
ect	9	-5.56	5.70	0.02	0.41
cat	23	-4.73	10.30		

The journal entries provided insite to the experimental students' attitudes as the summer course progressed. It is interesting that all students felt that working with a laboratory partner positively affected their learning, doing and understanding mathematics. Most reported that they did homework and studied for tests with their partner. Students reported spending anywhere from 20 minutes to five hours per day on homework. Most students felt that the computer laboratoreis positively influenced their doing and understantding of mathematics. However, several talked about feeling frustrated in the laboratories. But, these students often said that they felt the feeling of frustration was good for them. The main reason given for likeing the laboratories was that it helped in the understantding of the concept of graphing. Two students said the laboriatories clarified their understanding of domain and range. Three students had early journal entries claiming to dislike the labs, and in their last journal entry, they wrote that the lab sessions most influence their understanding. Three other students had early journal entries disliking the labs, and at the conclusion of the course, they did not think the labs helped them learn or do mathematics. Most of the students mentioned that the small class size and the teacher significantly influenced their success.

The following table compares grades and withdrawal rates for pre-calculus at WVU from the fall 1996 to those in the fall 1997.

Table 5: WVU Distribution Levels for Pre-Calculus Grades Comparing Fall 1996 and fall 1997

Grades	A	B	C	D	F	Withdraw	Total
Fall 1996	31	50	72	52	53	24	282
Fall 1997	41	83	73	28	15	12	255

Conclusions

The analysis of the data showed that there was no gain or no significant positive gain in the critical thinking scores in the experimental college algebra class. The analysis also showed that there was no significant positive gain in critical thinking scores of the traditional classes. The critical thinking test scores decreased in both the standards-based algebra class and the traditional classes. It is illogical for critical thinking skills to actually decrease throughout any course. This information suggests that some outside factor played a significant role in this study. It is possible that the students participating in this study did not take the critical thinking skills test seriously. Due to human subjects' guidelines, all students were informed that the score would have no effect on their final grade.

The achievement scores in the standard-based algebra class and the traditional classes all increased; however, the analysis of the data showed no evidence that mean increase in one group was significantly different than the mean increase in the other.The critical thinking scores in both the standards based algebra class and the traditional classes all decreased; however, the analysis of the data showed no evidence that the mean decrease in one group differed significantly from the mean decrease in the other.

It is possible that a six week session may not be long enough for students who are enrolled in college algebra to feel comfortable with the material. This is important if the student is to develop critical thinking skills. It is therefore recommended that the study be performed during a regular 15-week semester. Although an effort was made to integrate laboratory activities with class discussions, it may be beneficial to use the computer in class on a daily basis. It may also be beneficial to use the computer on some test questions and on homework assignments to tie in the use of the computer to all areas of the course.

The qualitative analysis indicates that students, for the most part, benefitted from working with a partner in a laboratory setting. Student's attitudes as well as their performance can affect the retention rate in the course. Although the follow up study data is still being analyzed, the data comparing changes in grade distributions and withdrawal seems to indicate that the added computer laboratories, along with curriculum changes in the course, helped students succeed in learning the content of pre-calculus.

Thus far, about 1000 University and high school students have used the computer laboratories in their present form. During lectures, the instructor uses the computer material, where possible, to guide the students in discovering the rules and mathematical laws which are being applied. This provides students with a continuity of materials and methods used in the laboratories and lectures. During the computer laboratories, students are guided through assignments and projects by written laboratory directions and questions. For some topics, the computer laboratories and homework assignments introduce concepts before they are covered in the lectures. Many students entering WVU take mathematics courses which are preparatory for calculus. Because of backgrounds and motivations, many of these students are not prepared to complete the work without extra assistance. This revised method of teaching "before calculus" topics should provide needed assistance to those students who are at risk of dropping from a program requiring mathematics. With properly designed interactive laboratories and with assistance and coaching from an instructor, students will have a base for "experiential learning." This type of exploration is more meaningful to students by encouraging them to use "what if" experimentation.

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Development of Mathematical Training Systems: Application of MPIE Based Architecture.

German Nemirovski, Eberhard Heuel, Gunter Schlageter
University of Hagen, P.O. Box 940, D-58084 Hagen, Germany
Tel: +49 (2331) 9 87 311, Fax: +49 (2331) 9 87 314,
german.nemirovski@fernuni-hagen.de, eberhard.heuel@fernuni-hagen.de, gunter.schlageter@fernuni-hagen.de

The semantic complexity of mathematical tasks makes the development of mathematical training systems and their use in World Wide Web particularly difficult. The authors of this paper are looking for a theoretical basis of an effective development technology for this software category. The MPIE model is chosen as the core of this technology. It is a formal model, that describes the behaviour of interactive training systems. The example of an interactive mathematical task implemented in a training system "Linear Algebra" illustrates the advantages of the MPIE based architecture for the development and use of Mathematical Training Systems. In general, these advantages concern the increase of the development efficiency and form a good prerequisite for web based authoring and training.

1. Introduction

Mathematical training efforts can benefit from courseware and training software which supply interactive tasks and support the user's actions by additional tutoring and coaching features. The most important requirements for mathematical training software concern the level of interactivity implemented for individual task solution, the flexible modelling of solution procedures and the individualisation of support and feedback.

In this view we can leave mathematical software like *Mathematica* [Wolfram 1996] and *MathCad* [Hörhager & Partoll 1995] out of consideration, because they operate as problem solvers and do not serve learning or training purposes. There is, however, a vast range of learning and training software designed for schoolchildren, picking up mathematical topics and problems, but mostly set on rather low levels of knowledge and skills. Obviously instructional designers in the domain of mathematics give up in the face of more complex mathematical problems hard to transfer into computerized interactive training approaches with non-trivial procedures for task solution.

The level of complexity concerns the developer as well as the user of training software considering criteria such as the extension of solution strings, the number of possible variants, the number of parameters which describe the relative problem, the level of problem dimension, etc. The implementation of high level problems within mathematical training software requires precise and complete analysis of determinants relevant to the training process as well as a substantial theoretical basis.

Along these lines we will describe the modelling of high level mathematical training systems for local and Web based learning environments and illustrate this by an exemplary training software "Linear Algebra". This software was designed for university and college students and results from a project focussed on the application of the so-called *Modified PIE Model.* It will be shown that this model helps to improve the conceptual validity of training software development as well as the efficiency of the development process and the "operational range" for users and authors, particularly within the World Wide Web.

2. MPIE model and Properties of Mathematical Training Systems

The MPIE model was defined by [Nemirovski & Schlageter 1997] as a means of optimising the development of computer and web based training systems. MPIE is a modification of the PIE model [Dix 1986] which helps to describe the behaviour of interactive systems. The MPIE is a three layer architecture, where each layer corresponds to a certain class of requirements defined for learning systems in general.

There are three fundamental classes of system requirements for learning systems corresponding to three semantic levels usually used for the description of the functionality of learning systems (see [Nemirovski et. Al. 1998]).

The first class concerns the domain of learning contents and gives answer to the question „What should the user learn?". The second class of requirements defines the methodical characteristics of teaching and training, answering the question: „How should the user learn?" . The third class of requirements is rather close to the implementation basis of learning and training systems. This corresponds to the traditional interpretation of interaction provided by the system interface.

Nemirovski et al. (1998) consider a learning system as a set of *local learning approaches*, dealing with a certain topic or problem. The user is able to learn a topic or to train task solving carrying out the corresponding local learning approaches. The different classes of requirements defined for a learning system in general have to be specified for each of these local learning approaches. Similarly, a basic local learning approach for MTS can be defined as a *training task.*

However, the requirements set for a training task within a mathematical training system neither determine the architecture of the task nor its development procedure. Both usually are concerned with objects and their properties. Although object properties are based on abstract system requirements, they are more concrete and material. The objects and object properties are precisely what the MPIE model deals with. The following analysis of training task properties in the existing examples of MTS will show how training tasks can easily be described using the MPIE model.

Interactive mathematical tasks include basically the following components:

- *A permitted algorithm for task solution.* For tasks that suppose formula operations, the algorithm that solves the task can be denoted as a certain sequence of formulas.
- *An analysis of user's answers*. During the process of problem solving the user expects a prompt, precise and individualized reaction and feedback to his/her input from the system.
- *An interactive environment for task solution.* This environment makes it possible to solve the task by means of interaction between the user and the system.

These three components of computer based mathematical tasks correspond perfectly to the three layers MPIE model. The domain layer which describes the learning contents, is specified in case of MTS by the algorithms, the ‚methods' of solving a mathematical task. The analysis of user's answers is the prerequisite for any form of assessment. So the analysis component of an interactive mathematical task belongs to the methodical layer. The specification of the interactive environment belongs to interface layer (fig. 1).

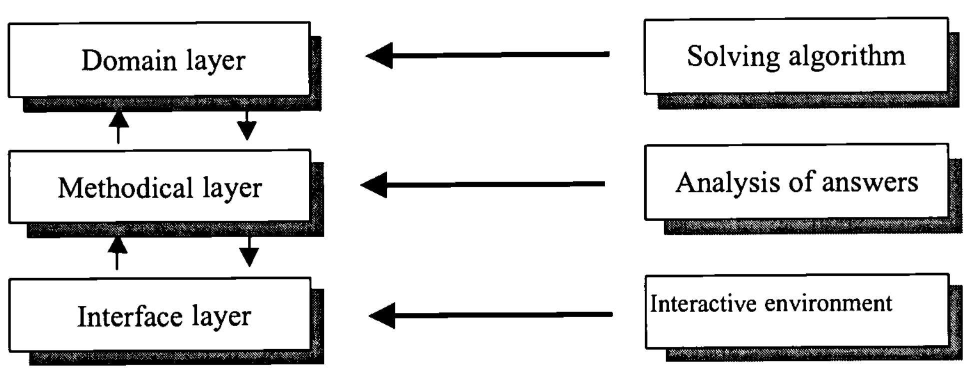

Figure 1: *Mapping of mathematical task properties onto MPIE model*

3. Example of an interactive mathematical task

The mathematical training system *Linear Algebra* developed at the University of Hagen (Germany) for basic studies in linear algebra ([Piehler & Reidmacher 1996]) is a good example for demonstrating the features of MPIE based architecture.

The training system includes mathematical tasks regarding the following topics: n-dimensional vectors, matrices, quadratic forms, linear programming. The related tasks are based on operations with matrices, vectors and determinants, such as adding and multiplying matrices, the processing of Gauss, calculus of determinants,

etc. Any task can be processed through a formula editor divided into a certain number of input sequences, edited by the user. Fig. 2 shows the editing field of an exemplary task of the program.

$$\left(\begin{array}{ccc|c} 1 & 2 & 3 & 2 \\ 5 & 8 & 13 & 0 \\ 21 & 34 & 55 & \lambda \end{array}\right) \rightarrow \left(\begin{array}{ccc|c} 1 & 2 & 3 & 2 \\ 0 & -2 & -2 & -10 \\ 0 & -8 & -8 & \lambda - 42 \end{array}\right)$$

$$\rightarrow \left(\begin{array}{ccc|c} 1 & 0 & 1 & -8 \\ 0 & 1 & 1 & 5 \\ 0 & 0 & 0 & \lambda - 2 \end{array}\right)$$

$$\text{für } \lambda \neq 2: \quad L = \emptyset$$

$$\text{für } \lambda = 2: \quad L = \{ x \in R^3 \mid x_1 = -8 - x_3 ,\ x_2 = 5 - x_3 ,\ x_3 \in R \}$$

Figure 2: *Example of using the formula editor for task solution*

Only in case of correct input of each formula sequence the user is allowed to proceed with the solution process. In case of an error, however, he/she gets individualized feedback. At the same time the precise position of the incorrect input is marked clearly.

The user's input is converted by the formula editor into a string form of special format. This is more convenient for the syntactical analysis than a data structure formatted in a complex way as it is used for presentation of the mathematical formula (fig. 3). At the same time the system generates a number of strings, defined in the same format, corresponding to alternative solution sequences of the algorithm. They have to be matched with the user's input. The procedure of string matching is located within the methodical layer of the MPIE architecture (fig. 3). (A similar procedure of input assessment, the *Tracing model*, was described by [Anderson, 1993]).

If the strings are identical, the user's input will be evaluated as correct. In this case the identification number of the correspondent part of the algorithm is sent to the domain layer where it will modify the current state of the algorithm of the task solution. Within the domain layer the algorithm is described by a mathematical graph (fig.3). Each node of this graph describes a certain step of solution. Links between nodes describe the mathematical operations applied to expressions presented by the nodes the links start from. The command which was sent to the domain layer shifts a special pointer, which points out the current step of solution, to a new position.

Modifications of the domain layer are mapped to the methodical layer. The result of this mapping is an update of the so-called goal tree within the methodical layer, a sub-graph of the algorithm graph located within the domain layer. The goal tree defines that part of the algorithm which will be used as a pattern for matching the following input of the user (node 8). Any modification of the domain layer as well as of the methodical layer has to be perceivable for the user. They are mapped onto the interface layer.

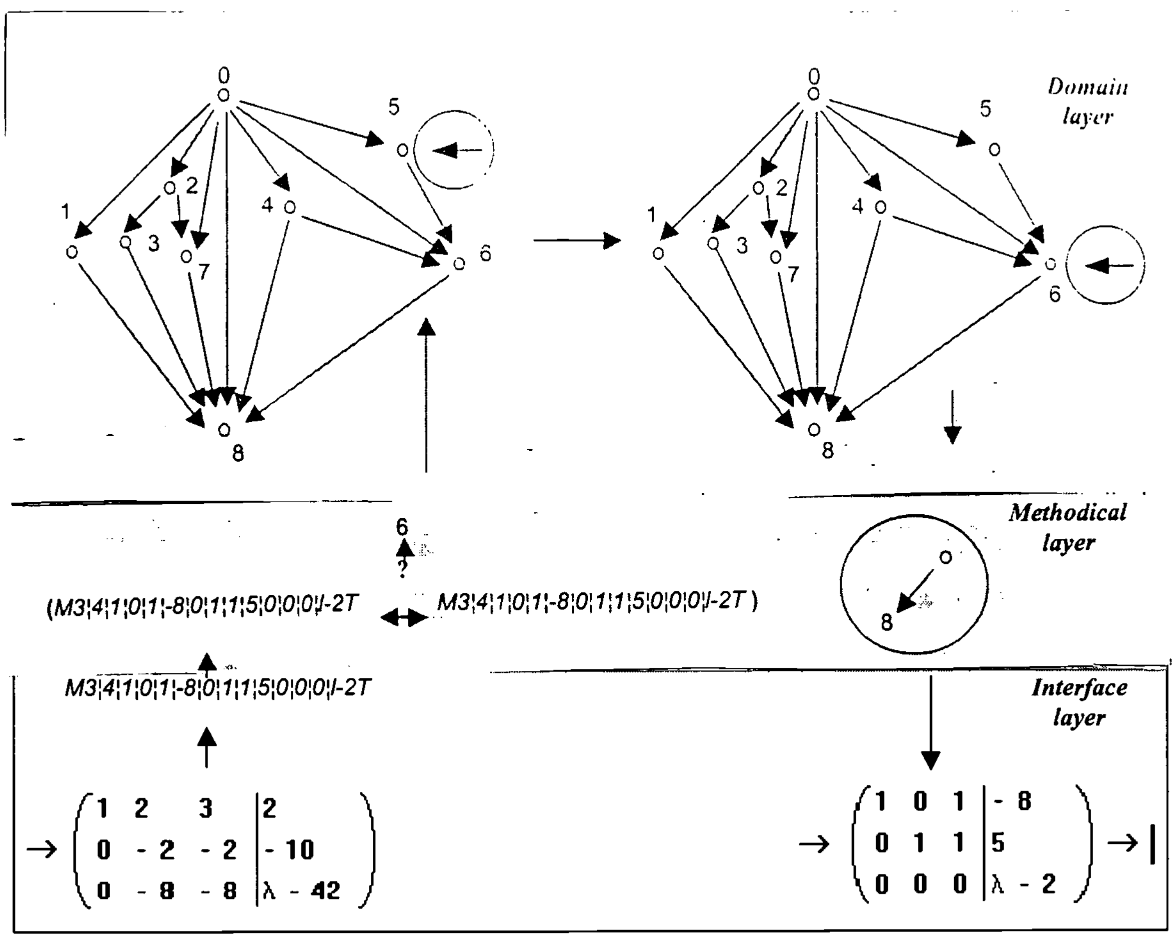

Figure 3: *Example of an MPIE based mathematical task*

Due to the space limitations of this paper we cannot describe the processing of fault diagnosis as detailed as in case of correct input. But it is worth to say that in case of incorrect input there will not be any event invoked within the domain layer and the state of the task solution will remain unaltered. At the same time the events of the methodical layer are limited to define the position of errors made by the user.

4. MPIE based architecture and the development of Mathematical Training Systems

In summary, the MPIE based architecture and its clear and formal definition of different layers guarantees an optimal mapping of the content (or task domain) to the user interface and its interactive features. MTS benefit from the best possible presentation of tasks semantics, from an optimized interpretation of user's actions, and from a diminution of resources required for interpretation and performance.

The three layers structure of this architecture sets up three independent development areas. This well structured approach fosters the efficiency of teachware development. In case of MTS the definition of algorithms for task solutions located within the domain layer is considered as the job for domain experts , i.e. mathematicians. They operate with the terms and objects of mathematical expertise. The interactive task environment (the interface layer) is developed by computer scientists and interface designers, who do not need to consider the specific semantics of the mathematical content. The intermediate layer of the MPIE architecture is the workspace of instructional designers. They have to be aware of basic knowledge from both of the neighbouring layers, but the main scope of their work are didactic and methodical aspects and features.

In this three layers architecture the complexity of development is reduced (and its efficiency enhanced) by splitting the development jobs. To give an example: in the mathematical training system "Linear Algebra" a

complex semantic analysis of the user's input in the process of solving a mathematical task is reduced to four considerably simple sub-problems. These are: parsing of the algorithm graph, string matching, string parsing (to detect the position of errors) and mapping the position of error through a formatted string to the objects of the user interface.

Consequently the troubleshooting and error fixing during the development and testing of training programs is easier and less complex. A lot of errors can be localized and fixed within one single layer so that the resources required for error fixing will be kept low.

Furthermore the separate development of different layers guarantees an effective reusing of the system modules, e.g. of objects of the interface layer. Even for the implementation of considerably different mathematical tasks a common interface layer can be used.

5. Optimizing web based Training and Authoring

Subdividing the architecture of mathematical training systems in different layers in particular fosters its use within the World Wide Web and the web based authoring of learning and training programs.

As the interface layer generally consists of data common for a large class of tasks, it does not vary from task to task. Any specific information related to a single task is located within the domain and the methodical layers which define each task completely. Thus, tackling the development of a new interactive task only concerns the definition of a new domain and methodical layer. This layers together form a *task specification.* MPIE based architecture enables authors to use different tools and strategies for task development provided that the resulting task specification uses the format required for the corresponding class of tasks.

The use of the MPIE based architecture for mathematical training systems dramatically reduces the resources required for data transfer from the author to the server as well as from the server to the user/learner. Only data of the domain and methodical layer are transferred continuously from the author 's side to a WWW server and from the WWW server to the users. The interface layer has to be transferred only once. Being downloaded and installed as a plug-in component extending the local web browser, the interface layer performs any mathematical task of a definite class. The interface layer is the most data intensive part of an entire MPIE based task. Thus the reduction of the resources needed for a transfer of a number of tasks via internet is significant.

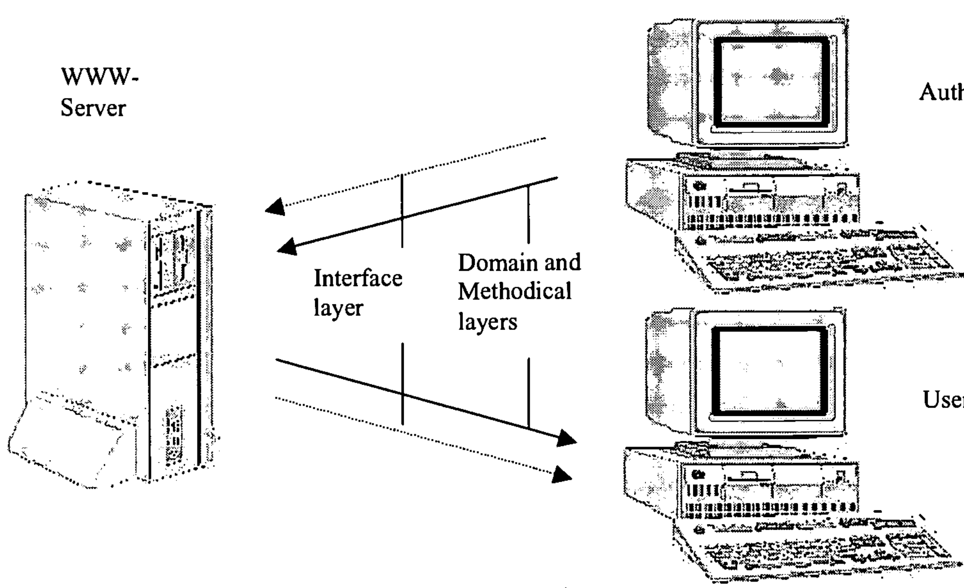

Figure 4: *MPIE based architecture and web based learning and authoring*

6. Conclusions

The applied MPIE architecture for MTS described in this paper considers the interactivity of task solution as a most important property of mathematical tasks. On the one hand this approach leads to the splitting of user interaction from the semantic core of the given task. On the other hand it enables an optimal classification of system requirements and their efficient application.

The use of MPIE architecture guarantees a high-level presentation of complex mathematical contents, a well structured interactive solution process as well as an exhaustive interpretation of the user's actions. This architecture reduces the resources required for the development of learning and training programs and consequently improves efficiency of the development process. It facilitates the interpretation of considerably complex interactive tasks, and for the first time gives access to a new generation of MTS, designed for target groups of advanced learners, university and college students.

Due to its layered architecture the MPIE approach is particularly suited for web based authoring and learning, especially as it substantially reduces data transfer in the net.

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How to Use Some Multimedia Technologies in a New Course of Mathematics: the Case of Architecture of the Academy of Architecture of Mendrisio

Nicoletta Sala
Academy of Architecture of Mendrisio
University of italian Switzerland
Largo Bernasconi
CH 6850 Mendrisio - Switzerland
nsala @ arch.unisi.ch

Abstract: The increasing need of education in contemporary society and the reduction of overall costs and study flexibility, together with the availability of powerful telecommunications and computer systems have fostered investigation and implementation of different types of technology-supported teaching and learning system.
This paper describes an activity developed for a first-year undergraduate course at the Academy of Architecture of Mendrisio, University of italian Switzerland (Accademia di Architettura di Mendrisio, Università della Svizzera Italiana).
The regular professor Sergio Albeverio has realized an innovative course of Mathematics using also the multimedia technologies.

Introduction

At the Academy of Architecture of Mendrisio (a new university of italian Switzerland) there is a course of mathematics where the students learn some different and interesting aspects of this subject.
The course intends to provide an introduction to basic facets of mathematical thought (logic, algebra, geometry, topology, analysis and stochastics).
Also, it aims to introduce a host of applications.
We try to show that this thought is an integral part of our culture and that, frequently, it is developed in close contact with artistic research and creations.
Both the systematic side ("mathematical language") and the creative one (the discovery and study of new forms and structures...) are stressed.

The course description

The themes of the course include: the concept of symmetry and broken symmetry; numbers and algebra: natural, real, complex numbers. The relationships between structures and algebraic constructions; the infinity in mathematics: potential (infinite process) and real infinity. The infinite numbers and infinitesimals. The concept of limit and the fundamentals of analysis; the concept of proximity-deformations, transformations, and elementary topology; logical structures, how they relate to the theory of foundations ("Cantor's Paradise" or what is left of it). Chance: tools to analyze it. The basic concepts of probability theory and stochastic processes.
Fractal forms: geometry, measures, architecture. Dynamic systems and their attractors, strange attractors as fractal sets. Complex systems: measuring complexity, algorithmic complexity, entropy, dissipative systems, biological and ecological systems. Mathematics as an instrument for understanding nature, interpreting it, and for creating and developing new forms and concepts. Mathematics and epistemology, philosophy and aesthetics.

The use of the multimedia technologies in this course

This course of Mathematics is presented as 26 lectures, given weekly throughout the academic year.

In this course we have used some multimedia technologies (e.g. CD-ROM, computer-aided design (CAD) tools, scientific documentaries, educational hypertext and hypermedia) in alternative to the traditional educational tools (overhead projector or blackboard).

The term multimedia has been around for several decades (Brown, Lewis, & Harclerod, 1973). Until recently, the term has meant the use for several media devices, sometimes in a coordinated fashion. The computer plays a central role in this environment and it coordinates the use of various symbol systems (Kozma, 1991).

For this reason, in the lecture hall we have a personal computer, connected with a LCD projection device, with the following features:

- CPU Pentium II ^{R}, 233 Mhz;
- 2 Gb hard disk;
- 32 Mb RAM
- graphics card SVGA;
- sound blasters cards.

In the detail we have used an **educational computer aided design** (Cartesio^{R}) to explain the platonic solids and to illustrate the isometry, the perspective and the axonometry (see Fig.1) . This s/w tool is propaedeutic to learn other architectural CAD.

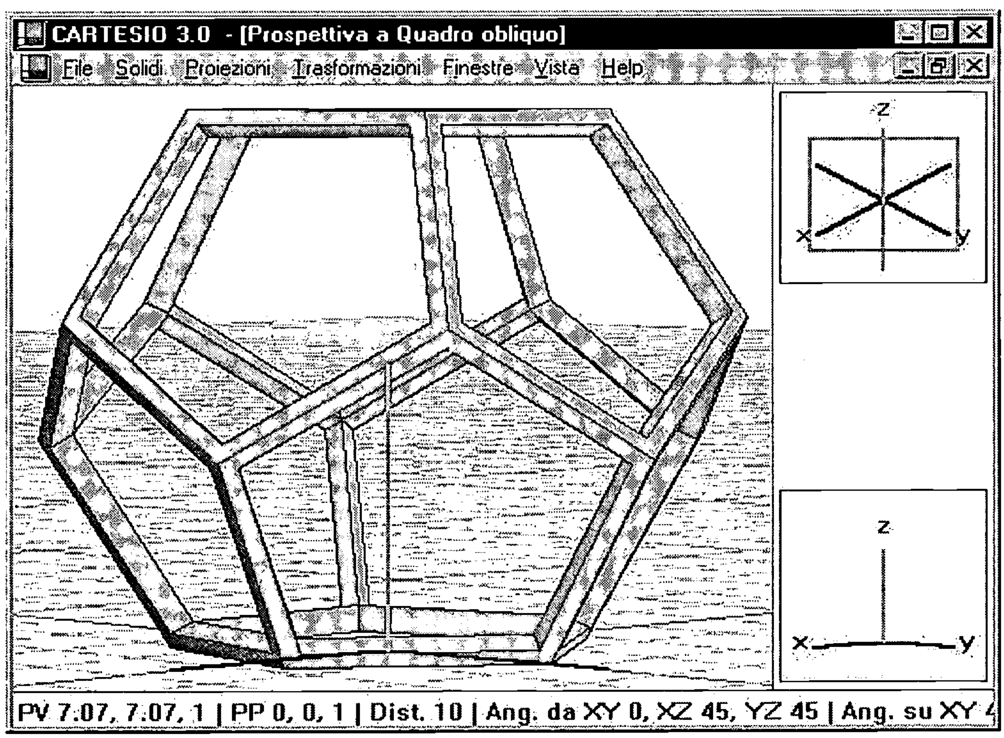

Fig. 1: Square perspective carried out using the s/w tool Cartesio.

We have thought to use also some **scientific documentaries** to expose:

- the platonic solids;
- the soap bubbles;
- the chaos and the fractals theory;
- the interconnections between mathematics and arts.

It is a significant attribute of video that the auditory and the visual symbol systems are presented simultaneously (Kozma, 1991). A number of studies have compared a video program with its decomposed audio and visual presentations to determine the role of these two sources of information, individually and

together (Baggett & Ehrenfeucht, 1982, 1983; Beagles-Roos & Gat, 1983; Nugent, 1982; Pezdek, Lehrer, & Simon, 1984; Pezdek & Stevens, 1984).
In most of these studies, the combined use of visual and auditory symbol systems resulted in more recall than visual only and audio - only presentations (Kozma, 1991).
We have observed which, using these educational movies, the students can construct a mental representation of the semantic meaning of a story more easely instead of the traditional teaching methods.

In the part of the academic year where we explain the fractal theory and their foundations, we have used some **software tools** to generate and to analyse the fractal objects and the brownian motion.
To explain some fractal forms we have created some algorithms, in Pascal[R] language, to generate some iterative function systems (the fern, the Mandelbrot set, the Julia set, the fractal trees) choosing the number of the iterations.
To expound the brownian motion we have searched in Internet some applications on topics of the physics. We have found, at the Internet address: http:// physicsweb.org/ TIPTOP/VLAB/ , a Virtual Laboratory, which is an archive of java-applets. It contains an animation of the brownian motion. It shows little particles batting about a more massive one and what it would look like if you could see only the massive one through a microscope. This applet demonstrates which a big particle can be considered as a dust particle while the smaller particles can be considered as molecules of a gas (this topic is difficult to explain using only the blackboard or the overhead projector).

We have also created a **hypertext** to present the fractal objects and their applications in architecture, in arts and in nature. It has been carried out using the Hypertext Mark Up Language (HTML) and some Java-script procedures for the animations.
This hypertext includes:
- **the Mandelbrot set**;
- **the Julia set**;
- **fractal forms in nature** (the pineapple, the fern (see Fig.2), the Von Koch snowflake, the dendritic structures, the fractal forms inside the human body);
- **the fractal worlds** (created using the computer graphics);
- **fractal architecture** (with some examples of fractal architecture);
- **fractal arts** (a little digital gallery);
- **some interesting Internet sites** (with some links to other Internet sites).

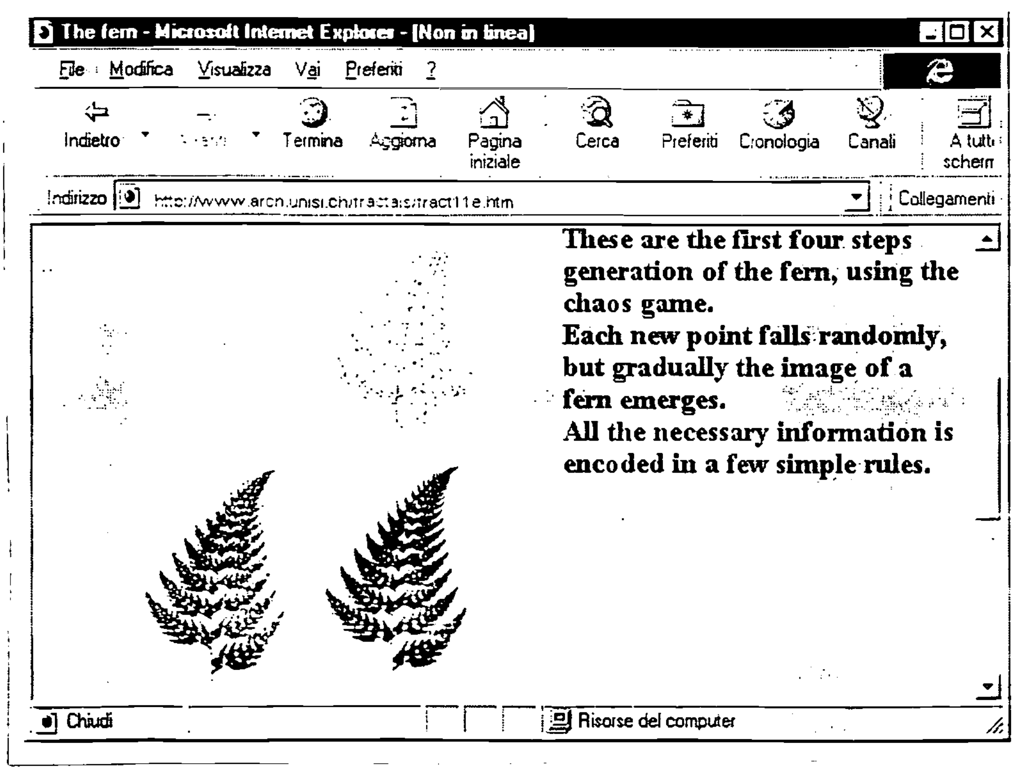

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Figure 2: A page of the hypertext dedicated to the fern.

During this hypertext development, we put a particular care to make "friendly" the user interface (Pisani et al., 1995).

We have decided to guide the students through a path, based on a structured didactic methodology, to reach the proposed educational goal (Bloom's taxonomy) and the final result is balanced for the educational path (Sala, 1997).

We have chosen:

- the icons, with shape and image recall the linking function (e.g. a little home recalls the function which permits to go at the main page of the hypertext);
- the visual interface, which involves the choice of colors, background, bottom shape and so forth.

Hyperlinks among pages have been studied to give continuity to learning trail (Sala, 1997; Sala, 1998).

In this hypertext the graphic interface has been thought for an easy navigation; in fact, the navigation as a search for information still constitutes the bottleneck of most hypertext systems; this is why it is possible to identify the existence of a similarity between navigation in the real world and navigation in a virtual world (Calvi, 1997).

The hypertext is written in two languages: Italian (the official language of the university) and English. It can be read at the Internet address: http:// www. arch. unisi.ch/ fractals/fract1e.htm.

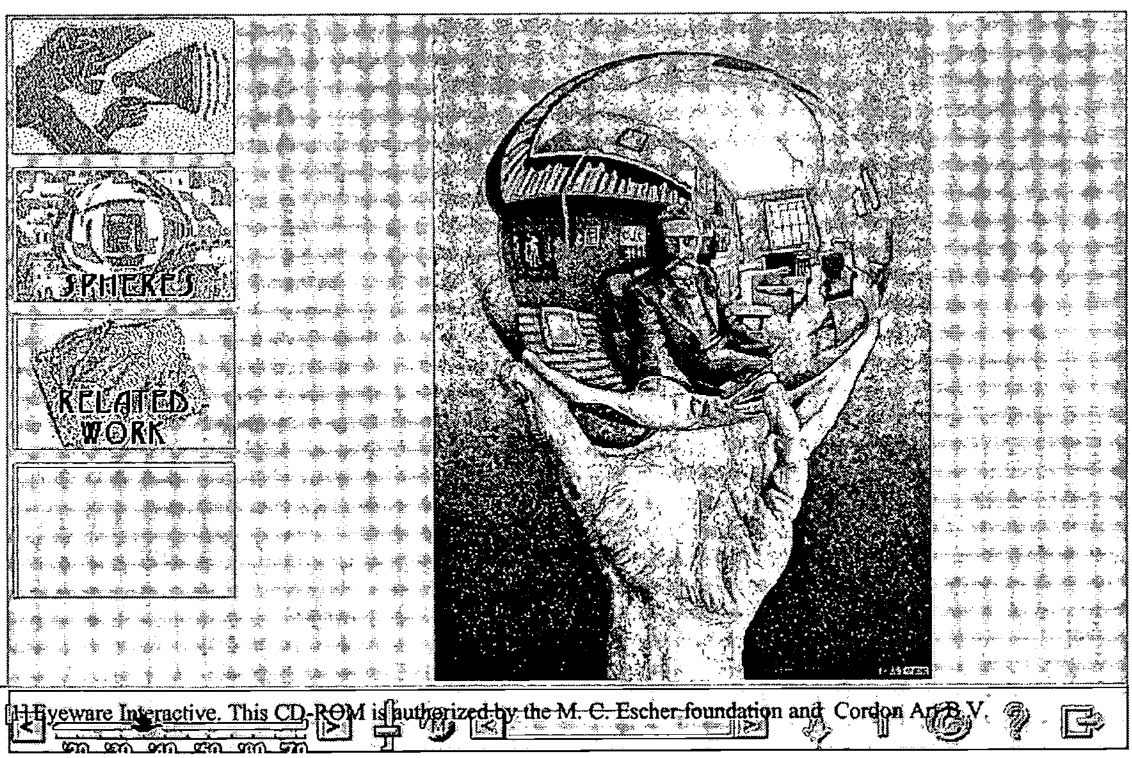
In the last part of the academic year we analyse the relationships between mathematics and arts.

We put particular care to present the artist Maurits Cornelis Escher (1898 – 1972) and his works. Escher's preoccupation with simmetry is well known (MacGillavry, 1986). His periodic plane-filling patterns, his Circle limits, his impossible images have been analyzed by several authors.

In this phase we have noted which is difficult to illustrate the interconnections between arts and mathematics using the tradional educational tools.

For this reason we have proposed to the students a hypermedia and a hypertext.

The hypermedia is the **CD-ROM Escher Interactive**^{R} [1] (for Windows^{R}) which contains an audio/ visual life of M. C. Escher and videos of the artist at work (see Fig. 3).



[1] Eyeware Interactive. This CD-ROM is authorized by the M. C. Escher foundation and Cordon Art B.V.

Fig. 3: Escher's interactive: a page dedicated to the gallery.

We have explained the sections dedicated to:
- the impossible shapes;
- the tessellations;
- the morphings;
- convex and concave (this is a game which describes a space that could be convex or concave depending upon the perspective of the objects placed within it);
- the spheres (which describe the distortion produced when a spherical lens is placed over a two dimensional picture space).

For the final lecture of the academic year we have created an other hypertext (using HTML). It is a little gallery of the pictures of Dalì, Escher, van Gogh and Durer. It includes some links at the other Internet sites dedicated to the arts, too.

Conclusions

Controversies about the impact of multimedia on learning proliferate throughout the literature. In spite of these controversies, increasing numbers of educators are considering ways to integrate technology into courseware, and they are especially corcerned about how to practically approach the inclusion of multimedia (Yaverbaum, Kulkarni & Wood, 1997).

Experts are ambivalent about the ways multimedia impacts a learner. One theory claims that multimedia improves motivation and thereby improves understanding (Levin, 1989). Another theory is that the varying impacts of different media influence the way we represent and process information (Kozma, 1991). Contrarily Clark (1983, 1991) views media merely as a vehicle which by itself does not influence student achievement (Yaverbaum, Kulkarni & Wood, 1997).

The multimedia technologies in our academic course have allowed to study in depth the platonic solids, their symmetries and perspective, to observe the tessellations; to study the fractal forms using a media, the computer, which permits the animations in real time and which quickly elaborates the fractal algorithms. The computer can make more interesting and interactive the lessons instead of the traditional educational methods.

We are creating now some educational hypermedias on the relationships between arts, mathematics and architecture (e.g. the golden section, the Fibonacci's sequence, the platonic solids, the proportions) and we are searching for other interactive CD-ROMS to introduce in our lectures.

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Innovative Mathematical Learning Environments

Using Multimedia to Solve Real World Problems

Dr. Larry Johnson
Professor, Department of Mathematics and Computer Science
The Metropolitan State College of Denver

Peggy O'Neill-Jones
Associate Professor/Chair, Department of Technical Communications
The Metropolitan State College of Denver

Abstract: This paper is a report on the design and development of a 4th grade multimedia math assessment tool. The project, called *Wyzt's* (Why Is It?) *Playground*, began with the idea that, although there are more and more multimedia learning tools on the market, few have directed learning objectives, and even fewer give the teacher feedback on student skills and progress toward standards. *Wyzt's Playground* is a high-quality multimedia project that emulates and simulates the real-life scenario of building a playground. The playground project supports the instruction of mathematics and measures proficiency in five NCTM (National Council for Teachers of Mathematics) standards.

Introduction

The economic health of our nation depends on the ongoing availability of a literate and technologically competent workforce. The responsibility for preparing that workforce places an unprecedented challenge on our entire educational system. We must educate a workforce that can integrate knowledge and think creatively to solve complex problems in their jobs and lives. Standards-based curriculum applies to all students at all levels and does not mean simply rewording objectives or increasing the number of assignments. Standards-based curriculum strives to integrate knowledge and skills into a meaningful whole. More than just learning facts, the students must think clearly and communicate their ideas and their solutions.

Wyzt's Playground -- A Multimedia Strategy

Much work has gone on in the last decade to revise and reform school curriculum, particularly in the area of mathematics. The National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics and their Assessment Standards for School Mathematics provide national guidelines for content priority and emphasis, as well as assessment in fourth-grade mathematics curriculum. NCTM has published three areas of assessment: 1) Curriculum and Evaluation Standards for School Mathematics, 2) Professional Standards for Teaching Mathematics, 3) Assessment Standards for School Mathematics. *The Wyzt's Playground* multimedia project is based on these NCTM standards.

Wyzt's Playground is a high-quality multimedia project that emulates and simulates the real-life scenario of building a playground. Wyzt stands for "Why Is It?". Wyzt is a cartoon character from outer space who shows kids that math is not only useful, it can be fun. The students build a

playground that is within budget and space restraints and choose equipment that will let the most kids play. The playground project supports the instruction of mathematics and measures proficiency in the following NCTM standards: spatial sense, patterns, computation, statistics, and communication. Integral assessment components are designed into the multimedia project that enables teachers to quickly evaluate the students and their mathematical progress.

The mathematics involved in *Wyzt's Playground* are significant and have extensions in school mathematics beyond the fourth grade. The mathematical concept underlying *Wyzt's Playground* is a linear programming problem with constraint inequalities about space, time and money. The optimization function maximizes the number of kids who can play on the playground. Moreover, the answers must be integers. Thus, the mathematical problem, and the related assessment, can extend beyond fourth grade through high school algebra.

The Mathematical Model

The model is formulated in the following way:

> maximize $z = ax + by + c$
> where a, b, c are positive integers chosen for the number of kids using the equipment, choices represented by x, y and a required basketball court, and
>
> $dx + ey \leq f$ (Space)
> $gx + hy \leq i$ (Cost)
>
> where d,e,f,g,h,i are all appropriate numbers selected on the basis of reasonableness of the solution, and x and y are the numbers of each type of equipment as above.
>
> The solution then, is an integer choice of z representing the highest number of children on the playground constructed with pieces of x pieces of one equipment and y pieces of another, each of which will occupy space and cost money. As mentioned earlier, a third piece of equipment (a basketball court) was required for all playgrounds.

To illustrate the model and the solution, let us consider one of many playgrounds we could build. Suppose that we choose swings and slides as the type of equipment we will use along with the basketball court. An amount of $10,000 is available for the playground. We also know that swings cost $1000 each and can hold 8 kids, slides cost $500 and can hold 4 kids, and the basketball court cost $2500 and can hold 10 kids (at a time). Furthermore, the space available for the playground is 4900 square feet. The basketball court uses 1500 square feet of space, swings occupy 300 square feet of space and slides occupy 150 square feet of space. Our problem is now:

> maximize $z = 8x + 4y + 10$
> such that
> $300x + 150y + 1500 \leq 4900$ (Space)
> $1000x + 500y + 2500 \leq 10000$ (Cost)
> where x, y and z must all be positive integers.

The solutions to some of our playground problems are not unique. For instance, one of several solutions to the example is $x = 1$, $y = 13$ and $z = 70$. Another is $x = 7$, $y = 1$ and $z = 70$.

The 4th grade assessment has several choices of equipment and several levels of sophistication of questions, allowing each child to work at his or her own level. The above description of the mathematical model is the highest level in the assessment currently, but the problem itself is amenable to algebraic and geometric answers for middle school children. All such problems are solvable by linear programming if non-integer solutions are acceptable. See Chapter Nine of "Linear Algebra with Applications" by Gareth Williams for an example. A second reference is Book 5 of "Mathematics for Decision Making" by E.W. Martin, Jr.

The Multimedia Production Process

Project TEAMS was a collaborative venture between the Metropolitan State College of Denver, Englewood Public Schools and Adams County 50 School District.

Project TEAMS goals:

- Train teachers in both computer technology and in multimedia authoring and program development, and
- Evaluate student progress following the evaluation guidelines established by the National Council of Teachers of Mathematics,
- Provide Access via the Internet and on CD-ROM to the multimedia project for educators, students and parents.
- Produce state-of-the-art Multimedia programs, and
- Support instruction of fourth-grade mathematics.

In addition to the pedagogical, math, communication and technical teams made up of faculty and students from The Metropolitan State College of Denver, the *Wyzt's Playground* production team included four elementary school instructors, Kirsten Herring and Cathy Brown from School District Adams 50, Denver, Colorado and Megan Tobler and Kathy Vargo from the Englewood School District , Englewood, Colorado, and School District Adams 50's Director of Learning Services Dr. Ken Turner.

Much work has gone on in the last decade to revise and reform school curriculum, particularly in the area of mathematics. The National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics and draft Assessment Standards for School Mathematics provide national guidelines for content priority and emphasis as well as assessment in fourth-grade mathematics curriculum. *Wyzt's Playground* is based on these NCTM standards.

The production team worked within the framework of using multimedia to create an environment that would engage the students in active learning. But equally important and developed in tandem, was the development of the playground math problem and its relationship to NCTM standards. In Sherry Turkles' book "Life on the Screen" she discusses the concept that we turn games into reality and that games are likely to reflect our real-world assumptions. (Trukles, 1995, p.72)

Wyzt's Playground emulates and simulates the real-life scenario of building a playground to support instruction of mathematics and to measure proficiency in five of the NCTM standards, either individually or in combination. It serves as a prototype to measure proficiency in the additional standards, or to use as a model for like development in other disciplines like art, science, communication and others. Integral assessment components are designed into the multimedia project that enable teachers to quickly evaluate their students mathematical progress.

In "Being Digital" (Negroponte, 1995) Nicholas Negroponte's asserts that CD ROM titles are explored by different people in different ways. When going through the Wyzt-lead tutorial the students can answer the questions visually by placing pieces of equipment on the playground to see how many fit, or mathematically, using addition, multiplication or subtraction. The multimedia interface allows for diverse learning styles and repetition of the concept on an individual basis. *Wyzt's Playground* integrates fluid movement from one medium to the next and saying the same thing in different ways. (Negroponte, 1995, p.72)

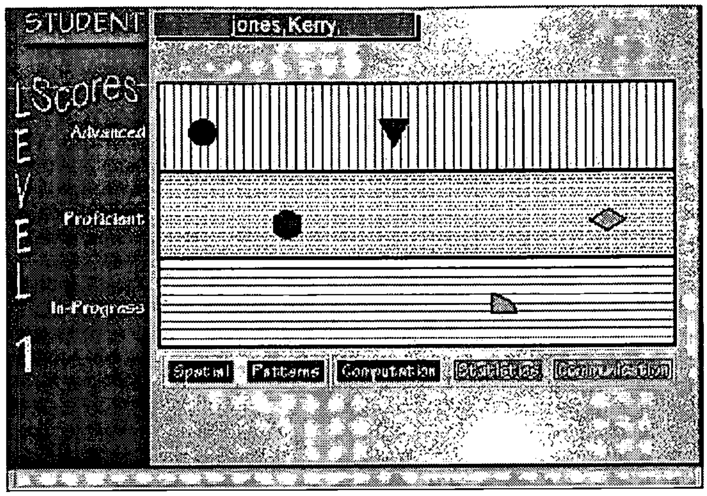
The production values of *Wyzt's Playground* use sophisticated 3-D graphics and animation, broadcast-quality video and audio, and a highly interactive navigation scheme. The Wyzt's Playground is designed to be accessible by schools and the general public alike via the Internet and also on CD-ROM for use on local hard drives.

The "Results" Book

A key component of *Wytz's Playground* is the *Results Book.* As mentioned earlier, a major goal of the multimedia production team was to go beyond the "cool CD ROM game" to a multimedia title that would assist in teaching the concepts (the Tutorial), evaluate student work (Level I,II,II assessments) and report the results to the teacher using NCTM standards (the Results Book).

The teacher has the option of having the student go through the **Tutorial**, which reinforces the instruction of the concepts necessary to build a playground: budget, space, survey and writing a rationale. If the students get a wrong answer in the tutorial it takes them to a "Show Me" screen. They can choose to have Wyzt show them how to get the answer, or go back to the tutorial and try again on their own. How many time the student uses the "Show Me" is recorded and reported in the Results Book.

In the **Level I** assessment the students do an on-screen survey and choose the playground equipment based on the survey results. In the **Level II** assessment the students are shown which equipment they used in Level I and then are asked to choose equipment that will let more kids play. In **Level III** the students are asked to choose equipment that will let the most kids play. In all three assessments the students must stay within budget ($10,000) and stay within space constraints (4900 sq. ft.). All answers are scored using an NCTM standards-based rubric and recorded in the Results Book.



Conclusion

The project is a work in progress. It took nearly two years to design and produce the CD ROM title. The project has been developed in both the PC and Mac formats. Wyzt's Playground is in use in the Englewood Public Schools District and in the School District Adams 50 system. To date the findings has been antidotal, the students love to "play" Wyzt and the teachers find that the students do apply what they learn from Wyzt to similar teacher-lead activities.

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Please visit the *Wytz's Playground* homepage at http://clem.mscd.edu/~techcom/wyzt

Presenters:

Dr. Larry Johnson
Professor, Department of Mathematics and Computer Science
The Metropolitan State College of Denver
johnsonl@mscd.edu

Peggy O'Neill-Jones
Associate Professor/Chair, Department of Technical Communications
The Metropolitan State College of Denver
oneilljp@mscd.edu

On Changing the Focus of a Linear Algebra Course with a TI-92

Antonio R. Quesada, Department of Mathematics and Computer Science.
The University of Akron, Akron Ohio 44325-4402
Aquesada@uakron.edu

Abstract: The use of the TI-92, via the scaffolding method, helped to transform a traditional first semester of college linear algebra to a matrix-oriented course that emphasized conceptual understanding, relevant applications, and numerical issues, and included additional topics. There was an increase of students' overall performance in course grades. A survey on students' perceptions seems to indicate that they find the calculator very useful to solve problems, to investigate, to cover the material more in depth, and to facilitate the study of different applications. They seem to believe that the calculator helped them to better understand the course content and to feel more confident doing linear algebra.

Introduction

This paper reports a two-semester experience on changing a traditional introductory Linear Algebra course that began in the spring of 1998. As described in the existing course syllabus, the main topics of the course, to be investigated from both a theoretical and computational standpoint, are: systems of linear equations; algebra of matrices and determinants; vector spaces and linear transformations; eigenvalues and diagonalization; inner product spaces; quadratic and canonical forms. The last two topics, together with some suggested additional topics, are rarely covered. Students are expected to write and understand elementary mathematical proofs.

The original course was perceived by some of the instructors as too theoretical and lacking enough applications, numerical ideas, and use of technology to give the students a realistic idea of the current role of linear algebra in many applied fields. The textbook used did not help to improve this perception.

The main goals on reforming the existing course were to change the current course to a matrix-oriented one, and to include, if possible, application relevant to the disciplines of the attending students. These goals agreed with the recommendations of the Linear Algebra Curriculum Study Group (LACSG, 1993). Secondary goals were to introduce some numerical issues and to reduce arithmetic calculations by integrating the use of the TI-92 symbolic calculator. In addition, the students were encouraged to think geometrically and to improve their mathematical writing.

The principles that guided the experience were:

1. Proceed from the concrete to the abstract, that is, the use of examples to support students' "intuition" preceded the introduction of new concepts.
2. Use a hands-on, inquiry based approach.
3. Use technology continuously to:
   - I) facilitate exploration of many relevant applications,
   - II) to discover through experimentation important theoretical results,
   - III) to bridge over cumbersome calculations thus gaining access to relevant algorithms excluded from the existing syllabus, and
   - IV) to reduce the time spent and the number of numerical mistakes made by the students while learning to implement different algorithms.

Implementation

In addition to the course topics included in the syllabus, the use of the TI-92 allowed for the introduction of several new concepts, applications, and numerical ideas. Thus, besides diagonalization, the LU-factorization and the QR-factorization of matrices were included. Partial pivoting, ill-defined systems

and iterative solutions were added to the study of linear systems. A modern view of matrix algebra was followed by introducing the product $A\vec{x} = [\vec{a}_1 \quad \cdots \quad a_n]\vec{x} = \sum \vec{a}_i x_i$ as a linear combination of the columns of A, rather than as a column of inner products. Consequently, in addition to the classical array of rows times columns, the product AB was obtained as a row of columns $[A\vec{b}_1 A\vec{b}_2 \ldots A\vec{b}_n]$ each of which is a linear combination of the columns of A with coefficients from a column of B. The interplay between the vector equation $\sum \vec{a}_i x_i = \vec{b}$, the matrix equation $A\vec{x} = \vec{b}$, and the linear system whose augmented matrix is $[\vec{a}_1 \ldots \vec{a}_n \vec{b}]$ was emphasized throughout the semester. Thus the matrix $[\vec{a}_1 \ldots \vec{a}_n \vec{b}]$, for instance, can be used for deciding if a vector $\vec{b}$ belongs to the span of a given set of vectors $\{\vec{a}_1, \ldots, \vec{a}_n\}$, or if a vector $\vec{b}$ is in the range of a linear transformation whose matrix relative to the standard bases is $A = [\vec{a}_1 \cdots \vec{a}_n]$. Technology helped to easily discover the contrasting properties of matrix operations with those of the familiar real numbers and to introduce partitioned matrices. In addition to the QR factorization, orthogonality was extended with the least squares solution of overdetermined linear systems and the subsequent applications to data fitting. Students were then able to compare the results obtained via the least squares solution with those yielded by the built-in regression features in the calculator, confirming the they were identical. A more extensive treatment of linear transformations between any two vector spaces was possible. This included finding new bases, via equivalent matrices, to simplify the matrix of the transformation. Several applications such as traffic models, electrical circuits, the Leontiev input-output model, Markov's chains, networks, iterative algorithms, difference equations, cryptography etc. were studied. These were aimed to illustrate the pervasive use of Linear Algebra in many applied disciplines and its role as an essential tool for scientists in industries. Whenever possible numerical remarks were made to underlie time constraints and the stability or lack of it of different algorithms.

It is worth noticing that during the first semester the existing textbook was used albeit supplemented with the missing concepts and applications mentioned before. However, a survey of the students' perceptions after the first semester indicated the need for a textbook more in tune with the LASCG recommendations. A review of the literature yielded a handful of excellent alternatives. The top three choices were Lay (1998), Leon (1998), and Tucker (1998), the first of which was chosen. Students comments at the end of the fall semester indicated that they found the book easy to read and with very good examples. The author includes excellent applications and worthwhile "numerical notes" in most sections.

Students at this university are required three semesters of calculus as prerequisite for linear algebra. The majority of the students taking this course are engineering majors, although there are also students from mathematics, secondary education, physics, and occasionally, some representatives from other disciplines. Two or three sections of Linear Algebra are offered each semester. For the experimental section ads were posted to inform students that the calculator TI-92 would be required in the course and the rational for its use. Thus, it is likely that a large percentage of the students registered were technologically inclined, although some of them have had no previous experience with graphing calculators and had minimal computer skills. No handout on the basics of the TI-92 was provided. The last day of the first week of classes the instructor gave a quick introduction to the use of matrices in the calculator. Students learned to enter and edit a matrix and where to find the matrix menu. They loaded a program to perform elementary row operations and immediately used it to solve a system of equations. From that point on the students were encouraged to use the calculator to perform along with the instructor (whose calculator work was displayed by way of a panel and an overhead projector) the calculations needed to solve different problems. Moreover, sometimes the instructor proposed a problem for the students to work in teams of two or three members. The instructor then called a team member to present their solution using the panel.

In the existing course most results are proven and great attention is placed on mastering the necessary skills with pencil and paper. In the approach reported in this paper definitions and statements of theorems were carefully presented and assessed. However, by reducing the number of proofs and limiting the paper and pencil calculations to very simple examples, the focus was shifted in favor of a stronger emphasis on problem solving, applications, and conceptual understanding.

This calculator saves in the *Homescreen* a work session of up to 30 commands that can be reviewed at a later time. A work session can also be saved as a text file, called a *script*, that can be later recalled, commented, and executed, becoming a template that can be used to solve similar problems.

```
(aa)
Prgm
Local n,m,var1,var11,var12,var21,var22,var31,var32,var33, lsel: ClrIO
Disp "This program performs ero to obtain the ref of a given matrix"
dim(aa) → n: n[1] → m: n[2] → n: aa → u: clrlo
Pause u
PopUp {"rowSwap","mRow","mRowAdd","undo","end"},var1:var1 → lsel
While var1 ≠ 5
 If var1=1 Then
  Dialog
   Title "row swap":  DropDown "row",seq(string(I),I,1,m),var11
   DropDown "swap with row",seq(string(I),I,1,m),var12
 EndDlog
Lbl lbl1
rowSwap(u,var11,var12) → u
Pause u
ElseIf var1=2 Then
 Dialog
  Title "scalar x row": Request "scalar",var21: DropDown  "row",seq(string(I),I,1,m),var22
 EndDlog
  expr(var21) → var21
  Lbl lbl2
  mRow(var21,u,var22) → u
 Pause u
ElseIf var1=3 Then
 Dialog
  Title "linear combination αx + y ":  Request "scalar",var31
  DropDown "times row x",seq(string(I),I,1,m),var32:
  DropDown "add to row y",seq(string(I),I,1,m),var33
 EndDlog
  expr(var31) → var31
 Lbl lbl3
  mRowAdd(var31,u,var32,var33) → u
 Pause u
ElseIf var1=4 Then
 If lsel=1 Then
  Goto lbl1
 Else
 If lsel=2 Then
    1/var21 → var21: Goto lbl2
 Else
 If lsel=3 Then
  -var31 → var31: Goto lbl3
 EndIf: EndIf: EndIf: EndIf
var1 → lsel
PopUp {"rowSwap","mRow","mRowAdd","undo","end"},var1: clrlo
EndWhile
Disp u
EndPrgm
```

Figure 1: Program to row reduce a matrix step by step selecting the necessary elementary row operations.

The use of *scripts* in the TI-92 not only facilitated the inclusion of new topics, but it also helped students focus on key algorithmic steps without arithmetic errors and with a minimum investment of time. The program included in Fig. 1 proved to be very helpful, particularly at the beginning of the semester.

Asking the students to show a couple of intermediate steps in the row reduction process forced them to use the program. Once they gained some experience with *ero* they were guided to bypass them via the *ref* and *rref* built-in operators. This approach, patterned after the scaffolding method (Kutzler, 1996), seems to be successful. That is, first the students acquired the necessary skills on a given algorithm (as evidenced by their performance in their homework, quizzes and/or tests) by performing calculations with pencil and paper in elementary examples and via the *Homescreen* in general. Then they were allowed to bypass the algorithm via a program, a function, or in some cases to develop a *script*. Fig. 2 contains an example of a *script* used to obtain the QR-factorization of a matrix whose column vectors are given.

```
: Find the QR-factorization of a matrix A=[v1,v2,v3]
C:ClrHome
C:[1,1,1] →v1: [0,1,1] →v2: [0,0,1] →v3
 :Use G-S to get an orthogonal basis
C:v1 →g1: v2-aaictcm\orthogp(v2,g1) →g2
C:v3-(aaictcm\orthogp(v3,g1)+aaictcm\orthogp(v3,g2)) →g3
 :Get the corresponding orthonormal basis
C:unitV(g1) →t1: unitV(g2) →t2: unitV(g3) →t3
 :Form the matrix A=[v1,v2,v3]
C:aaictcm\vtom()
 :Form the matrix Q=[t1,t2,t3]
C:aaictcm\vtom()
 :Find matrix R
C:aaictcm\qraq(a,q)
 :check
 :q*r=a
```

Figure 2: Example of a script to obtain the QR-factorization of a matrix

The course assessment consisted of ten quizzes, three partial exams, a comprehensive final, and some projects where students, grouped in teams, studied and solved problems in several applications. Students were made aware that the exams and quizzes could include questions from the projects. Theoretical questions in the form of short answers, fill in the blank and/or true-or-false (with additional penalty for wrong answers) were included in every test and quiz to focus students' conceptual understanding. The scope of the questions and length of the exams far exceeded those of previous years, since they took into consideration the use of the calculator. During the fall semester teams of students were encouraged to prepare a particular application of linear algebra of relevance to their field of interest. For an additional test grade, they made 10-25 minute presentations in an out-of-class session to be held the last week of classes. The final grade was determined by deleting the two lowest quiz grades and by replacing the lowest test score with the average of that test and the final exam.

The use of technology generally increases the number of possible approaches that the student may use to answer a question. It is of utmost importance then, that the test questions include not only what the students must calculate but also specific approaches. Moreover, most students, especially those using technology, need to be constantly reminded that they should express symbolically or in plain English what they are doing and show the key intermediate results. It is a good idea to include in the instructions of each test a statement to that effect, reminding the students that an answer will not be given credit unless properly explained. The existence of illicit programs and scripts may pose some problems. To that effect, it is important to make the students aware of what they are allowed to use in a test, since they could be asked to reset their calculator (and upload what is needed from the instructor) at the beginning of any test. The use of a *"graph link"* for the students to download any program or *script* (prior to the test) proved to be helpful in controlling available stored information during test time. Random check-ups during the test may help to enforce the policy. During the fall semester a computer with the graph link was made available for the students to be able to download their calculators' content at any time; the instructor also made available a calculator for them to download any program at the test site.

Findings

Students' interest, as evidenced by in-class participation and general responsiveness, seems to have increased with the change of course format. Two indicators were used to get some indication of the students overall performance and their perceptions about the integration of the TI-92 in the course. First, the final course grades of the last four Linear Algebra classes (control group) taught by the same instructor using a traditional approach were compared with the combined corresponding grades of the spring and fall semester (experimental group). As can be seen in Tab. 1 there seems to be a definitely positive shift of grades in the experimental group.

	A		B		C		D		F		Total	Weighted Averages
Control groups	24	21%	28	25%	44	39%	11	10%	5	4%	112	2.49
Spring & Fall 98	14	39%	8	22%	11	31%	1	3%	2	6%	36	2.86

Table 1: Grade distribution of experimental and control groups final grades.

The last week of classes students were asked to answer, as candidly as possible, the survey included in Tab. 2 using as reference their experience in the semester of Linear Algebra. Their answers seem to indicate that they find the calculator very useful to solve problems, to explore and investigate, to cover the material more in depth, and to facilitate the study of different relevant applications. They seem to believe that the calculator helped them develop a better intuition about the material, to better understand the course content, and to feel more confident doing linear algebra. They express willingness to choose future math courses where the calculator is used, and to recommend to their friends courses that integrate the use of the calculator. The students do not think that the use of the calculator may have lessened their ability to perform well in future math courses. When asked to rate the use of the calculator using letter grades, the majority rated the overall use of the calculator as A or B. These answers despite of the fact that most of the students say they have spent more time doing mathematics than in the past, and that their performance in this class is not better than in previous math courses.

	1&2	3	4&5
1. The G.C. helped me to better understand the course material	71%	18%	12%
2. The G.C. was useful in solving problems	100%	0%	0%
3. The G.C. allowed me to do more exploration/experimentation	94%	6%	0%
4. The G.C. has helped me to develop a better intuition about the material	71%	21%	9%
5. I will recommend my friends that they take courses were the G.C. is used	73%	21%	6%
6. I could have learned more if I had not used the G.C	9%	26%	65%
7. If given the choice I will take my required math courses in sections were the G.C. is used	71%	26%	3%
8. The G.C. allowed me to cover the material more in depth	74%	21%	6%
9. The G.C. facilitated the study of different relevant applications	94%	6%	0%
10. This semester I have spent more time doing mathematics than in the past	65%	18%	18%
11. I feel more confident doing linear algebra when I use the G.C.	81%	16%	3%
12. The use of the G.C. may have lessened my ability to perform well in future math courses	9%	29%	62%
13. I have performed better in this class than in my previous math courses	38%	24%	38%
14. What is your overall rating of:	A B C D		
a) the use of the G.C. in this course	45% 42% 12% 0%		
b) your performance in previous math courses	31% 47% 22% 0%		

Table 2: Survey of students' perceptions on the effects of using the TI-92 (G.C.) in Linear Algebra
Scale: 1. Strongly Agree 2. Agree 3. No opinion 4. Disagree 5. Strongly Disagree

The students taking the course were juniors and seniors, yet it is worth noticing that these perceptions are similar to those found in Precalculus students (Quesada & Maxwell, 1994) and Calculus students (Quesada, 1994).

Conclusion

It is unclear what causes the improvement in grades when the calculator is used. Several factors may have contributed. Is it that many more problems can be solved in a course than with paper and pencil, or the more interactive presentation of topics, or perhaps the immediate feedback and the ability to check the answers that the calculator provides, or the students' constructing of knowledge? Additional studies should address the individual contribution of these factors.

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Omega 1.5: a Math Teacher Productivity Tool

Xóchitl Rosal
Anáhuac University Research Center – CICE
Mexico
xra@correoweb.com

Claudia Limón
Anáhuac University Research Center – CICE
Mexico
climon@www.cice.mx

Elena Hernández
Anáhuac University Research Center – CICE
Mexico
ehernand@www.cice.mx

Hernan Quijano
Anáhuac University Research Center – CICE
Mexico
hqt@correoweb.com

Abstract: In our country we observe that many high school and college students do not have the necessary problem solving skills to succeed in their studies and later, at work. CICE is a research center of the Anáhuac University dedicated to counsel 46 schools in the use of new technologies. To help teachers develop problem solving skills and strategies in 1st to 7th grade students, we developed the program "Omega 1.5: a math teacher productivity tool" which includes software, a training course and a problem database. We are also implementing Internet discussion groups for tutoring, sharing didactic material (problems) and allowing feedback among teachers. To this day, 5 schools with 20 teachers and 400 students have been using it with good acceptance and results. During 1999, it will be implemented in 41 more schools in Mexico, Chile, Colombia and Venezuela with approximately 470 teachers and 13000 students.

From Where Does the Need to Develop Omega 1.5 Arise?

For the last ten years, CICE – a research center of the Anáhuac University - has worked closely with school teachers, developing solutions to improve learning through technology. In the mathematics area we note there is a great aversion against mathematics by many students, in part due to their experiences in this respect have been dull and very frustrating. It is also evident that higher level students do not have the ability to solve problems. As these skills cannot be developed in a short time, students must be exposed to problem solving situations during primary school. In most of our schools, teachers not only do not introduce students to an efficient problem solving methodology, they do no make them solve interesting, challenging problems. We developed "Omega 1.5: a math teacher productivity tool" to help teachers develop problem solving skills and strategies in 1st to 7th grade students, to reinforce and enhance specific mathematical ideas and concepts and to encourage students to take an active role in their learning. We decided to implement a productivity tool because teachers are constantly asking for new exercises. Our research center is unable to satisfy these requirements, because in order to do so we would not have time to develop new products. We also considered that it is difficult for a teacher to evaluate large groups and it is almost impossible to generate different home-works and evaluations for a large group. On the other hand, we believe that it is essential to encourage

students self esteem, to promote the construction of mathematical ideas, to favor team-work, to foster cooperative learning, to develop the habit to search for more efficient ways to solve a problem and the habit to persevere in the search of a solution.

Basically, the Omega 1.5 software consists of two modules: one that enables the teacher to design problems and solving strategies (solving procedures) and another where students choose a solving procedure, solve the problem and receive feedback.

What Is the Basis of the Design of Omega 1.5?

The design of Omega 1.5 is based on the concepts of "case" and "solving procedure". A "case" is the description of a significant situation which includes numerical variables (data) related by an algorithm. Each variable may become an unknown one thus generating a problem. In this way, from a single case as many problems may be generated as there are variables. For example, in one case we can talk about recovering a rectangular wooden zone by planting a certain number of trees per square unit. The algorithm would be as follows:

$$a = b \times c \times d$$

Number of trees needed = length x width x trees/square unit

Now, a teacher can create a problem where the unknown is the number of trees, another where the unknown is the length, and so on. Having defined a specific problem, the teacher establishes the solving procedure, that is, the sequence of steps the student must follow to reach a solution. Naturally there can be several procedures, ones more efficient than others. For example, one can find the total price of three theater tickets by adding or by multiplying. A second grade teacher can present these options to his students about the time he had introduce them to the concept of multiplication. If most of them choose to solve the problem by adding, he can conclude that they have not mastered the concept of multiplication yet.

On solving each problem, the student will discover the relationship that the variable in question (i.e. the unknown) has with the rest. This not only introduces algebra, but also establishes the basis for the analysis of functions. Going back to the trees example, teachers and students can then discuss "what if" situations: if the length and width remain constant and the number of trees/square unit grows, what happens with the number of tress needed?

Why Is It a Productivity Tool?

Omega 1.5 is a productivity tool because it encourages and makes use of the teachers' creativity: on altering the context or the numerical range of a case generates a different one. For example, with the algorithm presented before, $a = b \times c \times d$, we can also create the following cases:

Volume of a pool = length x width x depth

Possible combinations for breakfast = # different fruits x # different cereals x # different yogurt flavors

Area of a circle = Pi x radius x radius

A teacher can consult, use or modify those cases included in the program or others generated by other teachers. From one case, many problems can be produced. For each problem the program generates a different set of data for each student: the teacher only establishes the ranges and type of number (natural numbers or decimals). The program is self-evaluating and can generate evaluations and homework's with different sets of data and the correspondent list of answers. As the teacher actually writes down all text, he is able to use the appropriate language for every region where used.

The Omega 1.5 program includes an arithmetical and geometrical database with cases, problems and solving procedures. We believe that it is very important that students look for information in illustrations, therefore the program includes clipart (teachers can include numerical information in the clipart images) and geometrical illustrations.

Structure of the Omega 1.5 Software.

As we mentioned before, the Omega 1.5 software consists of two modules. The first one allows the teacher not only to design cases, problems and solving procedures, but also to print homework, evaluations and other problems to be solved in the computer center. Teachers can prepare this work on paper and then capture it in the software. Later on, in the second module, students work on the problems assigned to them by the teacher. This enables teachers to assign specific problems according to the special needs of each student.

Teachers Module

Given that from a specific case a number of problems may be derived and that the software is responsible for the evaluation, the teacher's work is more efficient. Therefore he can concentrate his energies in designing interesting and significant cases, befitting his students and which present targets for them. Teachers determine the numerical ranges within which the software will generate the data in a random way, respecting the type of numbers that the teacher wishes to handle, be they natural or decimal. In the last case, the teacher will decide the number of decimals he wishes to employ. The teacher can include data in the illustrations or introduce data in a text form (for example: ... Mary will buy three tickets, instead of .... Mary will buy 3 tickets). He can present his students different solving procedures. For example, if in one of the steps of a solving procedure the student has to calculate the price of three theatre tickets, a teacher can present the steps for two procedures as follows:

Solving procedure 1
Calculate the price of the three tickets:
Price of three tickets = 3 x price of one ticket

Solving procedure 2
Calculate the price of the three tickets:
Price of three tickets = price of one ticket + price of one ticket + price of one ticket

On designing the incorrect procedure, the teacher can employ the most common errors as red herrings to see if students have the ability to identify them, and consequently overcome them. For example, if the teacher notes that his students often mistake the conversion factor from meters to centimeters, he can present two solving procedures as follows:

Procedure 1
Convert the length of the table to centimeters:
Length in centimeters = length in meters x 100

Procedure 2
Convert the length of the table to centimeters:
Length in centimeters = length in meters x 10

Then he can see whether his students identify the error or not and decide if he has to work more on this subject with them. Teachers write the solution procedures in the language that he uses with their students. They can request the software to print out as many evaluations, homework's and answer sheets as required.

As we did not have enough time to develop a parser system (that is, a feature that allows us to introduce any formula we want like in a spreadsheet), we decided to include a certain number of algorithms which would fit most of the problems primary school teachers works with. We found that these ten algorithms meet most of their needs:

a = b + c	a = (b + c) x d + (e + f) x g x h
a = b + c + d + e	a = (b x c) + d
a = b x c	a = (b x c) + (d x e)
a = b x c x d	a = (b x c x d) + (e x f)
a = (b + c) x d	a = (b x c x d) + e

We took into account that many of our teachers only have a basic algebra knowledge. That is why even if some algorithms can be derived from others, we decided to present them separately to make them easier to use. In a later version of the software, we will implement the parser system.

Student Module

The student is presented with a statement of the problem along with the graphical information should the teacher supply it. From 1 to 3 solving procedures will be presented of which one is incorrect in order that the student identifies the error. He then selects a procedure to solve the problem. Each step of a procedure is divided on what to do and how to do it. The last part is expressed on a pseudo-code similar to the student's colloquial language thereby introducing him to algebraical language. For example, if in one of the steps of a solving procedure the student has to calculate the price of three theatre tickets, a teacher presents it as follows:

Calculate the price of the three tickets:
Price of three tickets = 3 x price of one ticket

The student then estimates a result, solves the problem, types an answer and receives feedback according to the type of error. A student can explore, try to resolve by trial and error, make mistakes etc. without embarrassment from the rest of the group. Only the teacher will know the number of attempts before solving the problem correctly. A student can decide if he wishes to see what the best solving procedure is. If the student solves the problem the "long" way and subsequently we show him the "short" way i.e. the more efficient, he won't feel frustrated since he was able to solve it in the first place. In this way, he is free to choose the procedure he best understands thereby making him responsible for his own learning. Working with all the variables involved in a case, the student analyses the way to calculate each variable, keeping the rest as constants (algebraical solving). He also explores the functional relationship which variables have between them, that is, analyses how a variable varies in a function in relation to the rest.

Pilot

Once that the first version of the software was completed, we proceeded with a pilot. The stages were as follows:

- Training.
- Feedback to teachers.
- Application.
- Analysis and design feedback.

First Stage: Training

Preparing Teachers and Students in the Use of Omega 1.5 :

Objective: On completion of this stage, the teacher will be capable of designing the necessary activities in order to prepare his students in the use of the Omega 1.5 software. As both teachers and students are not used to solve real problems, first they had to work on data analysis, solving procedures, estimating results. They also need to be introduced to a problem solving methodology.

Use of the Omega 1.5 Software (Modification and Application of Cases):

Objective: On the completion of this stage, teachers will be capable of modifying CICE cases adapting them to their own needs (in terms of context, type of number, number ranges, ...) and use them in the computer classroom using the suggested methodology.

Creation of Cases:

Objective: On completion of this stage, the teacher will be able to create his own cases.

It should be mentioned that the structure of the course was that of a workshop, at the end of which the teachers produced cases with one or various problems, which were then sent to CICE for feedback and revision by the assessor of the project.

Second Stage: Feedback to Teachers

The feedback which was carried out in the participating schools consisted in the revision of cases and problems prepared by teachers and captured in the software with assistance by the personal of CICE. We were glad to see that teachers did not find difficult to fit the cases they created in the algorithms provided by the software. We found that most of the teachers kept on creating typical problems, not interesting, challenging ones. That is why we decided to include the third stage of the training program (Creation of cases).

Third Stage: Application

Once teachers received feedback, the software was held during the hours assigned to the computer class room in order not to interfere with the normal activities either of the groups or the school. The pertinent observations were made in respect of each group and school. We observed that when the students were faced to typical problems which they did not find interesting, they did not engage in discussing the solving procedures. They tried to solve the problem by trial and error. When the solution was obvious, they found it very fast and as the teacher generally had not prepared additional problems, the students began to be restless. On the contrary, when the problem was challenging, the students were eager to find a solution.

Fourth Stage: Analysis and Design Feedback

The observations carried out during application allowed us to enhance the design of both the training course and software. We now know that the greatest problem on the teachers side is to create significant cases, looking for contexts that capture the students interest, that make connections to reality. Many students let us know that they did not want to write anything on paper so we implemented a notepad with a calculator (which the teacher can activate or not).

What's Next?

In respect of the software, subsequent updating is planned which will add new characteristics to the software thereby making it more powerful.

One of our main goals is to create a community of math teachers who are willing to share their work and experiences: we intend to create an Internet database with all our cases and those of other teachers (previously revised by our assessors). Right now, this community is formed by the 5 schools in which the pilot was carried out. Later this year, we will expand it to the other 41 schools affiliated to our institution - in Mexico, Chile, Colombia and Venezuela -, but we would like to expand it to other countries. We find M/SET99 the best opportunity to invite teachers to join us.

Acknowledgements

We are deeply grateful to everyone in CICE and to Isabel Ogalde and Jorge López who provided invaluable feedback, ideas and positive criticism to help us develop this program. We also want to thank Ralph Cooksey and Ana Stefanovich for their help preparing this paper.

Exercising and Discussing Mathematical Proofs in the Domain of School Mathematics Calculus

Peter Schmidt
Institut für Informatik, Universität Bonn, Germany
email: peter@uran.informatik.uni-bonn.de

Abstract: A conception is outlined which offers a student exercise opportunities of mathematical proofs. The conception is based upon the three pillars: Work on single proofs, discussions of domain knowledge, and techniques of adapting the system actions to a user's foreknowledge. The conception includes the computer based monitoring of user proofs which are entered in a not very restricted natural language at the screen. Techniques of the fields of formula manipulation and of theorem proving are applied. The work is a part of the project to design and develop a stand-by system for secondary school mathematics. The goal of the stand-by system is to support students during their whole school education when they work at mathematics on their own.

Introduction

When novices and not only novices try to prove a mathematical theorem difficulties may arise. The difficulties may stem from different causes: The person may not be familiar with the general proof techniques or with the proof techniques of the actual domain. The person may lack enough insight into the details and into the inner connections of the domain knowledge. Last, but not least, the theorem may be hard to prove, because a very special idea is necessary which is not known to the person, or because the knowledge of another domain must be applied, or because the proof needs a very deep mathematical understanding or is very complex.

The reasons listed above give hints on how to design a conception and a software system which may help students to improve in constructing mathematical proofs. The conception is based upon three pillars each of which needs a special apparatus to be realized as a software system. The pillars are: (1) Work on single proofs, (2) discussions of knowledge in subdomains and across domains, and (3) techniques of adapting the system's actions to the user's foreknowledge.

As a domain to study proof exercises the domain of calculus is chosen. Reasons for that lie in the importance of calculus for the edifice of mathematics and for practical applications, in the fact that calculus is a part of school mathematics as well as of university mathematics so that the methods may apply to both worlds, and in the fact that methods of mechanical theorem proving exist to automatically prove theorems in that domain.

Some aspects of the conception and its realization as a software system are mentioned in the following sections. The work is a part of the project to develop a stand-by system for secondary school mathematics (Schmidt, 1994, 1997; Berewinkel et al., 1998). The goal of the stand-by system is to support students during their whole secondary school education when they work at mathematics on their own.

Mathematical Theorems and Proofs in the Domain of School Mathematics Calculus

The subjects of calculus include limits of sequences and functions, derivations of functions, determination of properties of functions, integrals, the study of special classes of functions, and many practical applications of theoretical results.

Proof methods used in calculus are multifarious and include direct proofs using the analytical definitions of concepts like limit, continuous or differentiable (epsilon-delta notation), inductive proofs, indirect proofs or proofs by counter examples, or direct proofs utilizing chains of inferences of already proven theorems.

Many proofs have a simple, clear, and straightforward structure. When understanding the basic ideas and techniques students may easily prove theorems of which they never saw the proof by taking over and using the known patterns. Many limit theorems, theorems proven by induction, and theorems utilizing an indirect proof or a counterexample belong to that category. A further characteristic of many proofs is that they employ formula manipulation as a central technique to establish the proof.

The characteristics of those proofs and results in mechanical theorem proving (Bledsoe et al, 1972; Buchberger et al., 1998) make it possible to realize exercise programs which allow users to enter proofs as into an exercise book and allow a system to monitor those proofs. Since mathematical proofs as they are found in math books usually utilize a restricted natural language with many typical recurring phrases it is not a severe restriction when certain phrases within a proof are expected. Such phrases may be offered by the system so that no complex techniques of natural language understanding are necessary to monitor a user proof.

Conceptions of Exercising Mathematical Proofs

The conception of exercising proofs comprises three pillars: Work on single proofs, discussions of knowledge in subdomains and across subdomains, and techniques of adapting the system's actions to the user's foreknowledge. They are roughly outlined in the following subsections.

Working on Single Proofs

Working on single proofs includes generating complete proofs which may be entered in a natural way with only a few prescriptions and modifying given proofs. Modifications may refer to completing a proof by adding lacking proof parts or foundations or to rewriting a proof of a general theorem to fit to a special case.

The computer based monitoring of a user's proof takes as a core formula manipulation methods, techniques of theorem proving, and simple pattern matching methods to understand natural language input.

(Fig. 1) shows an example of a theorem and a possible user proof

Entering a user's proof. How a user may enter a proof is demonstrated by the below-mentioned example of (Fig. 1). A *logical* line of a proof consists of a line number in brackets , e.g. [4], a statement, and a foundation of

Theorem:
Let
[p1] f: R->R, g: R->R, a in R,
[p2] f continuous at the point a,
[p3] f continuous at the point a.
Then
[s1] the function f+g is continuous at the point a.

Proof:
[1] *Proof method:* Direct by definition
[2] *To prove:*
ALL eps > 0 SOME delta > 0 ALL x with |x-a| < delta |(f(x)+g(x)) - (f(a) + g(a))|< eps {[s1]}
[3] *Choose:* eps > 0
[4] SOME delta1 > 0 ALL x with |x-a| < delta1 |f(x) - f(a)| < eps/2 {[p2]}
[5] SOME delta2 > 0 ALL x with |x-a| < delta2 |g(x) - g(a)| < eps/2 {[p3]}
[6] *Choose:* delta = min(delta1,delta2).
[7] ALL x in R |(f(x)+g(x)) - (f(a) + g(a))| = |(f(x) - f(a)) + (g(x) - g(a))| {rewriting}
<= |(f(x) - f(a)| + |g(x) - g(a)| {triangle inequality}
[8] ALL x with |x-a| < delta |(f(x)+g(x)) - (f(a)+g(a))| <= |(f(x)-f(a)| + |g(x)-g(a)| {[7]}
< eps/2 + eps/2 {[4], [5]}
= eps
[9] *qed*

Figure 1: Example of a theorem and a possible user or system proof

a statement in curved brackets, e.g. {[p2]}. Valid statements within the proof may be e.g. logical expressions

resulting from analytical definitions like [2] or statements in a restricted natural language, e.g line [3]. A foundation may include the name of a theorem, a line number which denotes a logical line of the current proof, or the marking of a precondition or a statement of the theorem.

The system offers several *keywords* (*italic* within the proof), patterns, and building blocks. The words ALL and SOME are the universal and existential quantifiers. With that we follow the notation in (Bledsoe et al., 72).

- The keyword *Proof method:* may be followed by the name of a proof method from a list of proof methods, e.g. by 'direct by definition' as with the theorem above, 'direct by a chain of theorems', 'indirect', counterexample', or 'induction'.
- The keyword *To prove*: may be followed by the analytical formulation of the statement of the theorem.
- The keyword *Choose:* may be followed by a variable name and a restriction to the variable like *eps > 0* or an assignment like *delta = min (delta1,delta2)* in the example.
- The keyword *qed* finishes the proof of a theorem.

The external system proof. One resource to monitor a user proof is a complete and correct mathematical proof, here called *system proof.* The proof of (Fig. 1) may be such a system proof. To word a system proof the developer utilizes the same language as a user when he enters a proof. Additional information may be inserted into the system proof. One type of information which may be inserted is structural knowledge of the proof. The proof of (Fig. 1) e.g. consists of a construction process including the following phases: (a) Notification of the construction process (line [2]), (b) completion of the construction process (lines [3] – [6]), and (c) establishing the success of the construction process (lines [7]-[8]). That information can be included by using the keyword *PHASE* which is followed by a corresponding phase name. Further keywords are *SUBPHASE to characterize a part of a phase (e.g. line [4])* and *LEMMA to characterize the use of a lemma (e.g. line [7]).* Besides such structural or classification information, knowledge about possible user errors in a proof may be inserted. See an example in a paragraph below.

The additional information may be used when the system gives hints to a user in the case of a help request or a detected error in the user proof. Other applications lie within the discussion of proof techniques or when a user reads and tries to understand a system proof. When the scheme of the proof is communicated to the user he will perceive the proof on a higher level than on the level of logical expressions and he may transfer the scheme of the proof more easily to similar proofs.

Monitoring a user's proof. Monitoring a proof with regard to its correctness and completeness means checking, whether the entered statements are valid, whether the foundations of the statements are complete and correct, whether the statements are needed to prove the theorem, wether there is no gap in the chain of inferences, and finally whether the statements of the theorem are proven.

The monitoring of the proofs relies on formula manipulation methods, techniques of theorem proving, simple pattern matching methods to understand natural language input, and the external system proof. Regarding the theorem proving techniques it is similar to the methods of Bledsoe, Boyer, and Henneman to automatically prove limit theorems (Bledsoe et al., 1972).

The monitoring of the user proof which is listed in (Fig. 1) is now roughly outlined. Both the user proof and the system proof are transformed into an internal representation by the same methods. Since the proof of (Fig. 1) is correct and complete, it may also be used as a system proof.

The first step is to transform the logical expressions into a quantifier free form (see Chang, Lee, 1973). The following substeps are performed: (a) The ALL and SOME quantified variables are collected into a table. The variable succeeding the keyword *choose* is treated as an ALL quantified variable, if the condition attached to the variable represents an interval, e.g. line [3] of (Fig. 1). If the condition represents an assignment, e.g. line [6] of the proof, the variable corresponds to an existentially quantified variable. (b) The ranges of the ALL and SOME quantified variables are determined: The range ends when another quantifier with the same variable name appears or with the last appearance of the variable name. (c) The quantified variable names are replaced by unique names. The existentially qualified variables are replaced by Skolem functions (see Chang, Lee, 1973). (d) The quantifiers are removed and the equations and inequalities are assigned a corresponding interval. After that first step the logical expressions of the example proof take the below-mentioned internal form. Note: The variable eps of line [3] is renamed into eps0; delta1 und delta2 are replaced by the Skolem functions d1(eps0) and d2(eps0) which depend on eps0; delta of line [6] is renamed into delta0 and defined as min(d1(eps0),d2(eps0)); the various variables x are not renamed here in the text because of readability.

[2a] |(f(x)+g(x)) –(f(a)+g(a))|< eps and x in (a-delta , a+delta),

[4a] |f(x) - f(a)| < eps0/2 and x in (a-d1(eps0) , a+d1(eps0)) ,
[5a] |g(x) - g(a)| < eps0/2 and x in (a-d2(eps0) , a+d2(eps0)) ,
[7a] |(f(x)+g(x)) –(f(a)+g(a)) |= |(f(x)-f(a))+(g(x)) –g(a)) |<= |f(x)-f(a)|+|g(x) - g(a)|
[8a] |(f(x)+g(x)) –(f(a)+g(a)) |<= |f(x)-f(a)|+|g(x)-g(a)| < eps0/2 +eps0/2 and x in (a-delta0 , a+delta0) ,

The next step consists of matching the lines of the user proof with the lines of the system proof. The technique of unification is used and variable bindings result (see Chang, Lee, 1973). The lines of the user proof which appear in the system proof will be marked by the monitoring program in the system proof.

Several cases may occur:
(A) The user proof corresponds to the system proof. All the statements and foundations of the user proof appear in the system proof and all the lines of the system proof are marked when the user finished the proof. In that case the user proof is correct and complete and the user gets the message ‚correct proof'.
(B) A line of the user proof is not complete, because the foundation is lacking. In that case the user is asked to complete the line.
(C) A line of the user proof cannot be found in the system proof. Then the program tries to prove the corresponding statement by utilizing the preceding user statements of the proof and the foundations of the current statement. When the user statement is found to be correct the statement is marked as redundant in the user proof. That case may often appear when formula manipulation operations are involved and a user enters transformations of a small step size. When the user statement is found to be incorrect, the program lists the error and asks the user to correct the error. When the user statement cannot be verified or falsified, the user is informed about the state of the proof. Additional ERROR lines in the system proof may help to diagnose user errors (see an example below). Error situations or situations in which the monitoring program cannot decide the correctness may be interesting for the developer and may make him analyze the situation and possibly expand the monitoring program.
(D) When a user asks for help, the program checks the state of the proof by having a look at the lines of the system proof which are already marked. The first unmarked line of the system proof or the line following the current user line may be the candidates to continue the proof. Help is supported by the additional lines in the system proof.
(E) When a user finished a proof and all the statement were correct, the system checks whether all the lines of the system proof are marked. If not, the user proof is not complete. The system reaction is similar to the case when a user asks for help.

Example of an error. Assume the proof of (Fig. 1) is the system proof. And assume that the user entered the statements [1] and [2] like in the system proof and then instead of the statements [3], [4], and [5] the below-mentioned statements [4'] and [5']:
[4'] ALL eps SOME delta1>0 ALL x with |x-a|<delta1 |f(x)-f(a)|< eps/2 {[p2]}
[5'] ALL eps SOME delta2>0 ALL x with |x-a|<delta2 |f(x)-f(a)|< eps/2 {[p3]}
The statement [4'] corresponds to the statements [3] and [4]. The statement [5'] is correct, because it states that the function g is continuous at the point a, but both statements together are not sufficient to prove the statement [s1] of the theorem.

While monitoring that user proof the program will find out that the statement [4'] is a part of the system proof, but that statement [5'] is not a part of the system proof. This can be seen by having a look at the internal representations. After renaming the twice used variable names eps by eps1 and eps2 one gets the internal representations: with de1 and de2 being the corresponding Skolem functions
[4'a] |f(x) - f(a)| < eps1/2 and x in (a-de1(eps1) , a+de1(eps1)) ,
[5'a] |g(x) - g(a)| < eps2/2 and x in (a-de2(eps2) , a+de2(eps2)) ,
The internal system proof contains the statements
[4a] |f(x) - f(a)| < eps0/2 and x in (a-d1(eps0) , a+d1(eps0)) ,
[5a] |g(x) - g(a)| < eps0/2 and x in (a-d2(eps0) , a+d2(eps0)) ,
which contain the same eps0.

The unification of [4'a] and [4a] yields the substitution [eps1/eps0], i.e. eps1 replaces eps0. The statements [5'a] and [5a] are not unifiable any more, since a second substitution [eps2/eps0] of eps0 is not possible. The program will mark the statement [5'] and its internal representation [5'a] as correct and redundant and statement [5] of the system proof is not marked as being part of the user proof.

Assume the user proceeds entering the statements [6], [7], and [8]. The second inequality of statement [8] will take the internal form

[8'a] $|f(x)-f(a)| + |g(x)-g(a)| < eps2/2 + eps2/2$ with x in $|x-a| < \min(de1(eps1),de2(eps2))$,
because the range of ALL eps (which is renamed to eps2) in statement [5'] is the rest of the proof. The program cannot find that statement in its system proof. It tries to prove the statement using the known facts. Of course it cannot find a proof, because there is no statement that the inequality $|f(x)-f(a)| < eps2/2$ is valid in any interval.

When the users finishes the proof by *qed* the monitoring program may give the following feedback: It can output the user statements in the internal form and it can output the remark that the statement [8a'] cannot be proven and that the stament [s1] of the theorem is not yet proven. The external system proof may be extended by an ERROR line which characterizes a situation and gives a comment on that situation. Such a line may be used to provide a more detailed hint in a faulty situation. The characterization of the situation may be that line [5] of the system proof is lacking and line [5'] of the user proof is redundant. A connection between the two lines is given by the same foundation, namely {[p3]}. An ERROR line in the system proof may take the form:

ERROR „lacking {[5]} & no genuine use of {[p3]} & redundant use of {[p3]} "

„The choice of the same eps in the lines ... is necessary for both inequalities"

Discussing Proof Knowledge in Subdomains and Across Domains

Mathematical proofs utilize the definitions of concepts, already proven theorems, and the ideas in a subdomain and in a domain, and the connections across domains. Insight and a detailed knowledge of the theoretical edifice determine the elegance and persuasive power of a proof.

To support the construction of proofs the system offers discussion sessions so that a user may occupy himself with a mathematical subject on the basis of pre-stored questions. A discussion session aims at the deepening, the integration, and the consolidation of already introduced material. The word *discussion* is to express that the subject of the discussion is didactically analyzed as to the contents.

Examples of subjects of a discussion in the field of calculus are e.g. i) properties of continuous functions and their proofs, ii) examples and counterexamples of continuous and differentiable functions, iii) discussing a proof method like direct, indirect, or inductive proofs.

Our current approach to a tool which supports the specification of a discussion session of any mathematical subject within the stand-by system may be outlined as follows:

A *collection of questions* is established for a clearly defined subject. The collection formulates the essential aspects of the subject in the form of questions. The questions may be grouped and sequenced according to several criteria. The wording of the questions is free.

The *user's answers* may consist of any mathematical expressions or of simple phrases using natural language.

The *system's reactions* include: correct answer, explanation, help sequence, hints in the case of recognized errors, hint to text material, hint to exercise material

The user has several *options to control* the course of the session: i) A user may look at the questions and choose any question of the collection or he may choose a question fulfilling a set of criteria. ii) A user may choose any of the system's reactions to a given question or answer or he may rely on the system's actions.

Adaptation to a Student's Foreknowledge

The proofs which a student is able to generate depend on his current state of knowledge. Additionally, the formulation of a proof depends on the chosen approach of introducing concepts and the order of the material. Calculus offers teachers several different options to introduce the material. Therefore the offer of exercises and discussions must be accompanied by means to clarify the foreknowledge and the learning history of the user.

Suitable methods of questioning a student's history may rely on decision trees and a semantic net. Corresponding tools are already a part of the stand-by system so that only knowledge bases have to be developed.

Outlook

A conception was outlined which offers a student exercise opportunities of mathematical proofs. The considerations of the monitoring of proofs will be extended to comprise more limit theorems and other

theorems which employ other proof techniques. The proof exercising possibilities will be integrated into the already existing prototype of a stand-by system for secondary school mathematics (Berewinkel et al., 1998; Schmidt et al., 1999). Several already existing tools of the system may be utilized for the above mentioned purposes: The shell to solve mathematical word problems on the basis of a dialogue with a student may be used to clarify a student's foreknowledge. A semantic net tool may be utilized to store and to process knowledge about theorems and proofs in the domain of calculus. The exercise shell for mathematical word problems will be modified to present theorems and monitor a student's proof. A formula manipulation subsystem which was developed for the stand-by system will be extended to deal with inequalities and interval types. Parts of the proof exercise system can be demonstrated at the conference (see Schmidt et al, 1999).

The basic idea of the stand-by system is to develop a many-sided and coherent software system which integrates the whole school mathematics and which may individually support students in their specific working situations. It is obvious that the construction of a coherent stand-by system will be an expensive and lengthy project. Two arguments promise a successful and enduring development: (i) The conception of the system directs to the actual needs of the students in a very flexible way. Therefore we expect that the system will turn out to be useful. (ii) It seems realistic that the system may be developed step by step. The above-mentioned prototype will provide a workable nucleus which may be incrementally expanded into several directions. When reliable tools and efficient subsystems will be available, it will be relatively easy to produce additional knowledge bases and materials and to integrate further parts of school mathematics.

The system's interaction with the user is originally in German, but the programs are constructed in such a way that the use of additional languages is possible. For that it is mainly necessary to translate the knowledge bases into the corresponding language. The programming language of the system is Java.

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Interactive Learning of Geometry by Using Technology: Examples and Steps to its Implementation in the Classroom

Monika Schwarze
State Institute for School and Further Education
Soest, Germany
schwarze@swhamm.de

Abstract: Dynamic geometry tools may support and enrich a more constructive learning process with many activities by the students. Using or integrating paedagogically conceived WWW-resources or webbased learning environments with Java-tools are further steps to "new ways of learning" with more student activities, collaborative working and interactive tools for exploring and discovering math. These tools are more theoretically known by many German teachers. One has to face first lots of problems and purposes that it makes it difficult to integrate new technologies as a matter of course in the classroom. The following examples will show some efforts to spread the idea of using technology in geometry classes for the teacher's need e.g. how to get firm with new technologies with the help of in-service teacher training or by paedagogically designed websites on the internet. On the other hand I would like to show some HTML- or Java-based material drafted for the use in the classroom for individual and self-responsible exploration.

1. *learn:line*, the Educational Server: Spreading the Idea of Individual Learning (of Geometry Supported by Technology and Interactive Tools)

A Platform for Information, Communication and Cooperation

Learning in a our information society means to face many different specialized, inter-disciplinary or social problems. So school has to take care of more than teaching factual knowledge and special information of each school subject. Teaching aims at livelong learning as a perspective of being prepared in this changing world. Students have to be encouraged and taught to continue developing their knowlegde network. By including the new possibilties of new media- especially telecommunication- we hope to improve the quality of working and learning in school and further education. We would like to support a more responsible, constructive and communicative learning in open learning situations where the learning individual could better contribute information from his own experiences and actual interests in common work. We would like to initiate learning with exploration, communication and cooperation.

The educational server *learn:line* (http://www.learn-line.nrw.de)is a platform on the internet for information, communication and cooperation. We want to support possibilities, to get in contact with other people, to exchange experiences, to work together in projects and to learn from each other. The latest academic research of learning processes leads us to create learning situations that are not only linear structured but open, explorative, situations, in which learners have to play an active role. This will change the teacher's role, too- from an "instructor" to a "learner enabler", someone who advises and accompanies the individual learning process.

New media may play an important role. One may not forget that media competence is an assumption for acting in a socially responsible way. The extension of media competence is one of the most important aims. By working and using new and traditional media students will learn to use them in a creative nd appropriate way, knowing their chances and limits.

Work Areas –Characteristics of the NRW-Educational Server

Work areas relating to particular topics are characteristic of the NRW-Educational Server. They represent a kind of learning arrangement or provide an infra-structure for encouraging learning. Each work area that concentrates on a particular topic exists as an independent information and communication offer in its own right; it provides the relevant material while still encouraging the user to some feedback. Each work area is divided into the following sections: a *media centre*, a *foyer* and a *noticeboard*.

In the *media centre* the user will find information, selected materials and suggestions. Links to other sites will contribute to work on the topic and to build up a „didactic community". In the *foyer* interested parties can get the chance to present their own work related to the topic, results and experiences from a particular project.

The *noticeboard* is made available in every work area for questions, answers, suggestions and discussion.

The *work room* is a virtual place, that student can easily access with a browser where they can work together on documents, exchange ideas or files of their work.

Computational Geometry - a Work Area Especially for The Teacher's Need

From the learn:line homepage by choosing *subjects -> math* interested parties can gain access to the work aerea „computational geometry". They will find opportunities to use the internet to accompany in-service teacher training concerning computational geometry for k12-teachers. An "online tutorial" demonstrates the special "educational power" – focussed on teachers who only have little knowledge and and experience in dynamic geometry with programs like Cabri, Sketchpad, or the German Euklid (most of the German teachers did not learn about it in pre-service teacher training). They can see the possiblities and chances when using these tools in the classroom with the help of examples and a lot of constructed figures. In addition to this teachers may find short descriptions about these good new media, evaluated "exemplary" for a more constructive way of learning. Reports comparing similiar products and pointing out main differences are as well available as ideas for its use in classroom, possibilities to exchange Cabri- or Sketchpad-Files and pointers to other websites that use or discuss these math tools.

The *foyer* of this work area shows reports of classroom situations, results and classroom materials that had been sent by other teachers and could be discussed and improved.

http://www.learn-line.nrw.de/Faecher/Mathematik/Geometrie/medfoy/medioe.htm

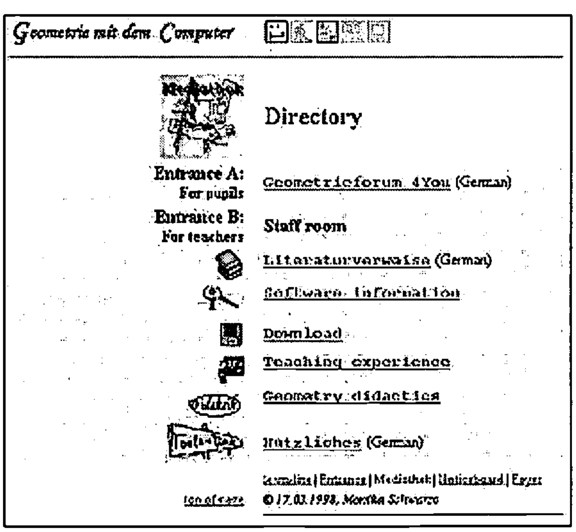

figure 1: media centre of the work area

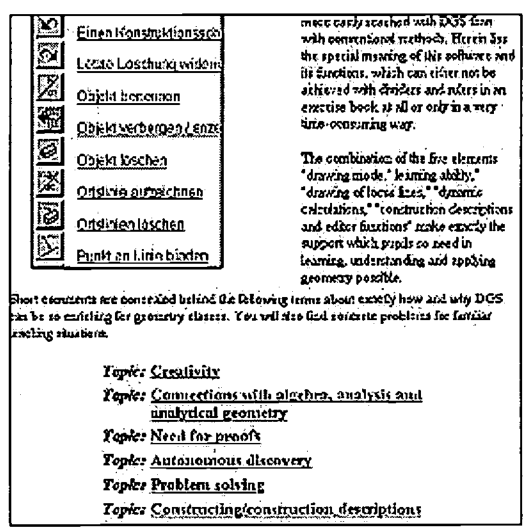

figure 2: page of the "online tutorial"

2. Materials, Exercises, Special Interactive Geometry Projects - Especially for the Classroom

New Ways of Learning and Teaching

There are many problems associated with the nature of teaching math, especially geometry:

- visualization of geometric properties in the range of its validity,
- teaching, how to proof theorems,
- showing the connection between geometric theorems,
- lack of simple real life problems that lead to a geometrical problem.

Today the academic research reminds us of the learning process being first of all an individual, autonomous, exploratory and self-responsible process, which will then be highly efficient if it takes place in a rich environment.

A change from the focus on the teacher and the teaching process to the learner and the learning process will demand a change of the teacher's role.They will have to change from being an instructor to a 'learner enabler', somebody who accompanies and supports the individual learning process. The learners will have to change from being a mere recipient to an active creator of their learning process. They have to be encouraged and enabled to take control of their own learning process, which means defining the aim, selecting the content and evaluating what they have learned.

In this classroom situation both teachers and learners need appropriate materials and tools to support the learning process mentioned above.

Here dynamic, interactive programs amd hypertexts, too, play an important role since the first generation of dynamic tools has been created. Since the internet and java-capable browsers have become more popular and can be used in school because of better hardware in the computer-labs teachers have more possibilities for getting information, for communication, interactivity, cooperation, for exchanging materials ready for use, etc.

Example: Ka's Geometriepage und Mathe-Galerie

My private website is meant to be additional to the work area of the educational server learn:line. There I' d like to support teachers in experimenting with interactive dynamic geometry tools. Like the famous *math forum in Swarthmore* I would like to offer well-working classroom materials, lesson plans and ideas, that have often been discussed and modified in teacher training. German teachers start to use the corresponding discussion area more tentatively than their collegues, for example in the United States- perhaps because of the lack of connection with the WWW at home and the costs for telecommunication that are still rather high in Germany.

In a special part of my website, called projects, I'm going to present classroom situations, where dynamic tools will gain ground for discovering and pursuing individual ways of learning and broaden the network of cognitive concepts. Here is one of my projects:

Supposing that learning takes place in an individual way and knowing that different students will choose different explanations and examples to understand essential geometric theorems and their proofs, I drafted a learning unit based on a worksheet about the Pythagorean theorem and its different proofs. I collected different proofs with a wide range of interactivity, knowing that students prefer different accesses to these proofs and related theorems. Some of the downloaded resources only visualize the theorem or are hypertexts that make understand the idea of the proof before it is written down in a more formal language. Some of the chosen websites contain java applets allowing the students to manipulate and experimentate interactively with dynamic constructions.

In addition to this, students could use the PC-versions of Cabri, Sketchpad or Euklid to prepare some explanations for the other students.

I used this learning unit in a ninth grade geometry class to stimulate the students to come up with their own way of building up their knowledge network; this meant that pupils have to decide for themselves what information is important, how much and what sort of help they require. After a period of individual work the students who worked in groups of two or three had to present their investigations and their results to all students of the class. It seems to be evident that discussion in a group of two or three could intensify the real understanding of a given context. In addition to this better students had to analyse informations at a higher level.
http://www.ham.nw.schule.de/projekte/swmathe/Uonline/

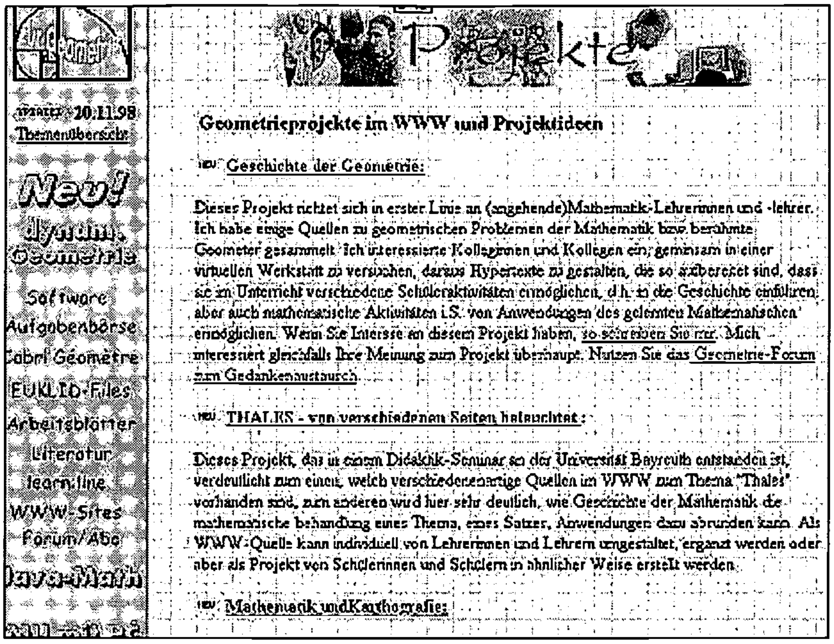

figure 3: geometry projects of Ka's Geometriepage und Mathe-Galerie

3. Integrating Webbased Materials and Java-Resources in Geometry Courses

Using (Creating) Interactive Dynamic Geometry (Java-) Resources

Besides the PC-version of dynamic geometry tools like Cabri, Sketchpad or Euklid Java-based constructions sometimes can complete demonstrations and geometric constructions for exploration in the classroom.

Some of the special advantages of these Java-applets are:

- complex constructions are just ready for use and can be combined with worksheets, that are appropriate for the special classroom situations
- most java applications for geometry constructions only "allow" manipulations that are provided by the constructor himself (an advantage for special problems where students otherwise can "destroy" the construction)
- the applicatons run at any platform and do not require a special program
- the teacher can build up a library ready to use and integrate in his own concepts or in the intranet.

Here is an example in which way a geometry applet may be integrated and modified for a special need: The applet comes from "Manupula Math", a Japanese website that offers more than 100 tiny well-working applets. It runs as well in the intranet as in the internet.

`http://kunden.swhamm.de/Geometriepage/mseties.htm`

Some other could be found:
Cabri Java
`http://www-cabri.imag.fr/projets/cabrijava.html`

JavaScetchpad:
`http://www.keypress.com/sketchpad/java gsp/`

Cut-the-knot
`http://www.cut-the-knot.com/`

IcosaWeb
`http://www.guetali.fr/home/berdel/maths/cours/geom.htm`

4. Learning Environments and How it May Work

In General

Good learning-environments based on hypermedia are advantageous for learning and understanding mathematics.The understanding of math requires the knowledge of details, conclusions and relations between single objects. If subjects are offered in a linked-up, but not linear structure it will be easier to build up a network of mathematical, geometric knowledge in the learner's mind.

That's why good learning environment should offer some important "details", e.g.:

- guided tours
- survey of the learning subject,table of contents, glossary
- meta level map (where am I?)
- some (recommended) provided paths
- different modes of representation and levels of activity
- hypertextual structures with internal and external relations
- some helpful biographical facts of famous mathematicians, real-life application,...
- exercises and contextual help
- possibilities to integrate other documents and visualizations- either static or dynamic, interactive tools and demonstrations

A glance at the market of new offline-media shows that only a few products match up to almost all criteria so that they could be called "examplary" in they way mentioned at the beginning. Learning environments in the WWW have even more advantages:

- HTML-based hypertexts are open,
- can easily be modified and beeing published in the internet,
- they can be improved, developed, discussed
- can include practical advice for teachers, etc.

"Exemplary" learning-environments for geometry (written in German) do not exist at the moment. But we will find some hopeful steps to using technology for individual, meaningful, exploring, that means, constructive learning:

Computational Geometry with the Java-based GEONET

At the math department of the University of Bayreuth (Germany) the Java-based dynamic geometry tool **GEONET** has been developed. Based on this tool there are some little hypertexts that offer diffent ways through the subject, for example "the order of the quadilaterals" and some (applied) exercises, too. Students of math education have dealt with further subjects (Thales, Pythagorean theorem).

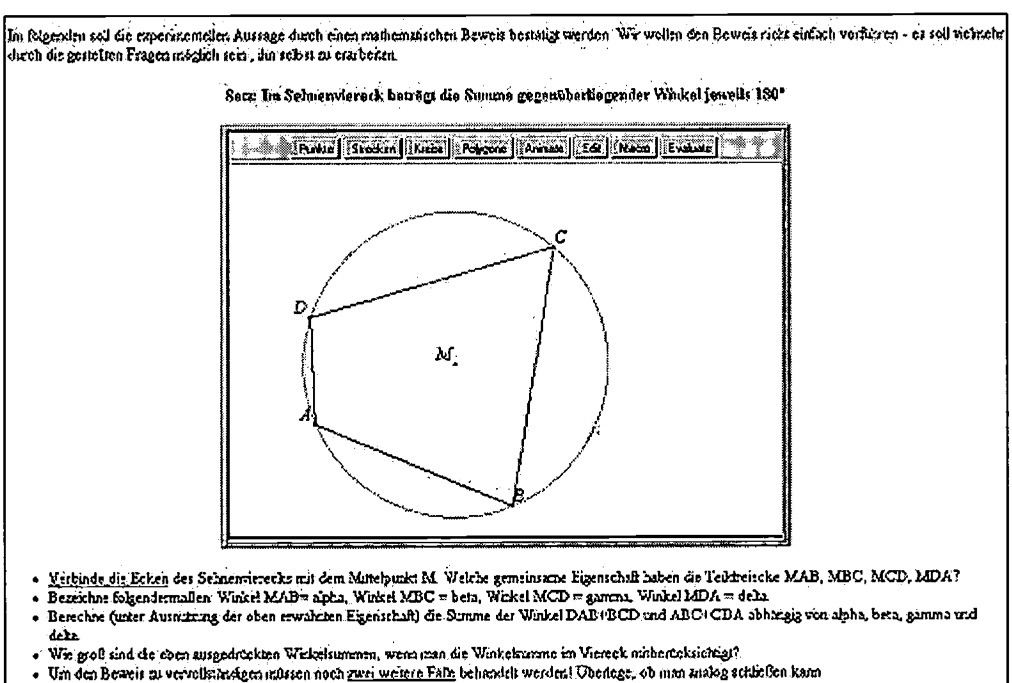

Figure 4: learning environment including the java-based dynamic geometry program GEONET

The Pilot Scheme "self -learning environments for college math"

At the beginning of this month a big pilote scheme has started in Germany. North Rhine Westfalia takes place with math education. Its aim is to analyze and draft examples how arrangements and situations of learning mathematics in the college must be organized so that students may temporarily work in groups without a teacher (maybe with the help of a „teacher on demand“ by using the internet). 15 teachers of 5 schools work on this projects, supported by publishers of multimedia or schoolbooks. One year later 25 other selected schools and teachers will test and evaluate the drafted material.

We are sure that these periodes where students have to organize their tasks by themselves and work at their own have to be supported by software like geometry tools, CAS and other interactive programs and ressources of the internet. We would like to invite everyone to take part of this project with advice, materials, good ideas or suitable software. You could find out more details on our website (`http://www.learn-line.nrw.de/Faecher/Mathematik/MV/`)and may contact our project-coordinator by email (`guido.von-saint-george@mail.lsw.nrw.de`).

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The Use of Computer Technology in a First-year Finite Mathematics Course

Morteza Shafii-Mousavi
Mathematics and Computer Science
Indiana University South Bend
United States
mshafii@iusb.edu

Paul Kochanowski
Business and Economics
Indiana University South Bend
United States
pkochano@iusb.edu

Abstract: This paper describes the use of computer technology in an interdisciplinary course entitled Mathematics in Action: Social and Industrial Problems that we developed and team-taught at Indiana University South Bend for freshmen students of Business, Economics, Education, Liberal Arts and Sciences, Nursing, and the School of Public and Environmental Affairs. The course is part of an NSF sponsored grant Mathematics and Science Throughout the Curriculum awarded to the Indiana University system. In this course, students learn mathematics by modeling and solving actual real-world problems for business, industry, social, and governmental agencies.

Introduction

The primary intent of the course, Mathematics in Action (Shafii-Mousavi & Kchanowski, 1998), is to encourage an appreciation of mathematics as students see an immediate use for it in completing actual real-world projects. The course emphasizes learning mathematics through completion of actual industrial group projects. Sources of projects are local organizations such as banks, school corporations, industries, government agencies, and social organizations. Projects are selected to emphasize finite mathematics tools, incorporate the use of computer technology, and are assigned to students who work in teams, with three or four students on each team. To optimize the interaction of students with diverse academic interests, each team consists of students from several disciplines, such as business, nursing, science, public and environmental affairs, and education. Given a particular project, student teams start by formulating research issues, problems, and questions. They then focus on data needs and on acquiring the mathematical, statistical, and computer skills necessary to solve these problems. In the classroom, students learn core mathematical techniques and concepts, which satisfy replaced courses of diverse disciplines, and customized mathematical topics necessary to finish industrial projects. In the computer laboratory, students learn computer application software, which are used to apply mathematical models in solving large scale real-world projects. Finally, each team writes a comprehensive report and makes a presentation in class and at its resource organization. The learning activities that take place in working on the projects cut across all disciplines and benefit education majors as much as they do science and business majors.

The nature of the projects in the course often involves sizeable data bases or mathematical solution requiring large numbers of computations. Data bases used in class projects for banks, industrial firms, and social organizations often contain literally thousands of observations on multiple measures. A data base for a local credit union, for example, included twelve months of loan information by customer, delinquency status, and product type, each month having approximately twenty thousand observations. Analyses of such data sets cannot be done by hand or calculator but require the use of powerful computers and sophisticated applications software, such as EXCEL, SPSS, and the like. Other projects can only be completed using large scale mathematical models. One class project, for

instance, investigated a truck delivery system for a local school corporation using the traveling salesperson model. The delivery system had five routes with each route consisting of 83 variables and 85 equations. Obviously, a model of this size cannot be solved graphically or through simple analytical methods. Students thus were required to rely upon Schrage's Lindo Lingo software, a user friendly computer package that solves linear and quadratic programming problems (Winston, 1994). In short, a project based learning approach such as we use necessitates introducing students to computer technology.

Interdisciplinary Design of the Course

In order to pull together students of different disciplines, Mathematics in Action replaces a diverse set of courses. We designed this course as a replacement for a number of traditional freshman level mathematics courses that satisfy diverse disciplines of the university students who normally would take M118 Finite Mathematics (business and economics majors), M110 Excursions in Mathematics (a course satisfying liberal arts and sciences language of quantity, nursing program, general education, along with other divisions' requirements), and T102 (required for preservice K-8 teachers).

Mathematics in Action has attracted a diverse group of students from business, economic, and liberal arts and sciences, public and environmental affairs, and education. To recruit students, we personally meet with student counselors, try to excite them about the innovative nature of the course, and encourage them to advise students to enroll in it. In addition, we advertise the course as an innovative, exciting, real-world approach to learning mathematical tools. We have generated flyers which have been posted in proper places in the campus. We distribute the flyer in the mathematics classes that prospective students come from. Also, our previous students have written articles about the course in the student newspaper and have talked to their friends about this course.

We have designed this course such that it covers a common denominator of the core topics covered in the courses it replaces. Prerequisites for this class are very minimal. We require mathematical background at the level of precalculus or college algebra. Students are generally freshmen or sophomores who have not taken any college level computer courses. Most students can use a mouse, have some acquaintance with simple word processing programs such as Microsoft Works but have not been exposed to more sophisticated software such as EXCEL or SPSS.

Course Development and Technology Tools

The course development process started in May of 1996 and involved the following steps: preparation of the mathematical concept modules; identification of the resource industries; contacting and necessary arrangements with the area resource industries and organizations; preparation of mathematical models for solving industrial projects; recruitment of students for the course; reservation of the computer lab; preparation of the necessary technological equipment such as software and computers that would be used in the course; identifying a student assistant (a senior mathematics education major student).

Our initial development of the course did not place a great deal of emphasis on the use of computer technology. Our early thinking was to build on the proficiency students had acquired in using the graphics calculator. As we shall discuss below, the realities of doing real world projects required a mid-course correction in our thinking about the level of technology that would be necessary to achieve our goals.

Teaching the Course and Incorporation of Technology

Mathematics in Action course is project driven and it should be taught from a modeling point of view. Also, practical applications of the mathematical techniques should be highlighted in the teaching of the course. For these reasons, the course should be taught by two faculties of mathematics and an applied discipline. We have been very successful in team teaching the course as one of us is a mathematician and the other faculty knows the world of business and views the subject matter of the course from a practical view point. He knows the organizations,

dealing with them, and what are expected from students. The authors share their teaching experience in Mathematics in Action in an article (Kochanowski & Shafii-Mousavi, 1998).

We team-taught the course for the first time in the spring semester of 1997 and again in 1998. In a fifteen-week semester class activities involved: teaching of mathematical materials in class (weeks 1-14); instruction of spreadsheets in computer lab (weeks 1-6); formation of student teams, assigning projects, and making arrangements with the organizations (week 3); introducing students to organizations they worked with (weeks 4-5); working with students, organizing their working relationship, and teaching project specific skills outside the classroom (weeks 6-10); midterm examinations (weeks 3, 6, 9, and 12); student team presentations (week 15); final examination (week 15); evaluation of the students' work, projects, and writing letters and submission of project reports to the participating organizations.

Prior to the first time we taught the course we had not adequately assessed the sizes of the data sets or the mathematical complexity of some of the projects students would undertake. As the course evolved that first time, we realized that primitive computational devises such as hand held calculators would not suffice. One of the student projects that semester involved monthly loan delinquency data for approximately 14,000 loans. Students were to take these loan data and calculate conditional probabilities indicating the probability of delinquency conditioned on loan type and or depositor characteristics. Over a twelve month period there were more than 150,000 observations that had to be grouped, sorted, and analyzed for meaningful patterns. One alternative we discarded was to randomly sample a small number of the delinquent accounts and use these in place of the population data. This seemed inappropriate given that the population of data were available and that some information was bound to be lost through sampling. Instead of sampling, we decided to develop students skills in the use of EXCEL. This was done by designing handouts that showed students how to use EXCEL spreadsheets, graphics, and pivot table capabilities. Large data base problems were not the only problem requiring technology that we encountered that first semester. One of our team projects involved solving a traveling salesperson problem for a school corporation truck routing system. This problem requires a large number of calculation and is beyond anything that can be done graphically or by hand calculator. Here again we had the choice of simplifying the problem to make it more computationally manageable or using computer technology and specialized software to solve it. Simplifying the problem meant that it would lose much of its value to the school corporation. Thus, we opted to have students solve the problem using the Lindo-Lingo software. Our instruction on binary programming that semester involved only one team. The second time we taught the course, we introduced an EXCEL module on linear and integer programming that was taught to the entire class.

Student Collaboration

Given the scope of the course, it is not possible to teach and learn elements of the course in the classroom, in the traditional way. Students should get involved in the teaching and learning of the material to each other. We place students in teams of three or four. Student teams collaborate in the learning of the mathematical concepts, acquiring computer technology skills, and solving industrial projects. Student teams meet several times a week, starting the fourth week of the semester. Teams meet in the classroom prior to class, in the computer lab, at their assigned project organizations, in the library, and in the mathematics department seminar room. Team members also communicate via telephone and e-mail; distributed data collection, library research, and the teaching and learning of the necessary skills. Their collaborative work involves: working laboratory team projects; communication and collecting data at the resource organizations, library research, browsing the Internet for relevant data, designing and survey analysis; formulating mathematical models for projects; collecting additional necessary data and information from organizations; periodical group meetings with faculty; communication with their organizations for additional data, clarifications, etc; preparation of technical reports; presentation of projects in class and at the organization.

Many of these team activities require the use of technology. Two projects, for instance, made extensive use of the Internet to obtain required information. One project dealt with the keep-replace decision for a service vehicle. Part of the information needed was how age and condition influenced the trade-in value of a truck. A student team was unable to obtain such information from local dealerships but found a wealth of information on trade-in values on the Internet. The other project involved using conditional probabilities based on race, age, and gender to predict the geographical location in a city of potential diabetics. The student team working on the project for the local diabetes association found that that organization had no information on these incidence probabilities. Stymied at this point,

the team went on the Internet for help. Internet searches finally uncovered the required information in data collected by the Center for Disease Control. Without the use of technology, neither of these projects could have accomplished their goals.

Project Based Real Data Requires Technology

Since the real data should be used in the teaching of Mathematics in Action, the course must use actual real-world projects. The projects should drive part of the curriculum of the course. To obtain useable projects, we contacted more than 350 organizations including hospitals, school corporations, universities, government agencies, and firms within 50 miles distance to the campus. The companies were selected according to the size of their capital investment, of more than \$50 million, and the number of their employees, of more than 50 people. We have also included social and nonprofitable organizations in our region. Our partner organizations include: Ashley Ward, Inc, Elkhart, Indiana; South Bend Community School Corporation; American Diabetes Association, South Bend , Indiana; Teachers Credit Union; Penn Harris Madison School Corporation; South Bend Times, Inc.; North Village Mall.

Students must see that mathematics is really useful and works. For this reason, real data are essential. Through processing real data students learn more and appreciate the power of the skills. The use of real data and actual projects in this course creates the following outcomes: internships for students; real need for technology; dialog between students, instructors, campus, and the real-world; the excitement that math is really useful; unity between students and instructors; student confidence; team work ability; and an atmosphere for students to work harder. Students coordinate time, share results, distribute work, collect work together, and appreciate each other's concern. The project base learning environment creates a pleasant atmosphere for the instructors to work together, understand each other's discipline more, and exchange views about teaching.

Perhaps one of the most important aspects of real world projects is that they create a natural integration of mathematical and technological tools. Many business and statistics textbooks have problems with data bases that allow computer application. These are far less meaningful than real world projects since students have no role in designing the research project, asking the relevant questions, or figuring out how to obtain the requisite data. Real world projects act as focal point around which tools of analysis are constructed. Students learn the mathematics of linear programming and computer software that solves linear programming problems not because of some problem in their text but because the successful completion of their project requires these tools. Such an environment illustrates much better than artificial text examples the role computer technology plays in actual problem solving.

Core Mathematical Topics and Resources

The core mathematical topics taught in the Mathematics in Action consists of topics regularly covered in the courses that it replaces. These are materials generally covered in a finite mathematics course including: Data Description, Forecasting, Linear Regression Analysis, Systems, Systems of Linear Inequalities; Supply and Demand Problems; Algebra of Matrices; of Linear Equations, Input-Output Analysis, Linear Programming, Counting Methods, Elements of Probability, Random Variable, Quality Control and Conditional Probability. The primary text in the course has been the textbook used for the regular finite mathematics course that our course replaces (Barnett, Ziegler, Byleen, 1999).

We have produced ten mathematical modules and used them as lecture notes and students use them for exam preparation. The modules are MODULE 1: Data Description; MODULE 2: Basic Counting Principles; MODULE 3: Elements of Probability; MODULE 4: Conditional Probability and The Baysean Method; MODULE 5: Network Analysis; MODULE 6: Systems of Equations; MODULE 7: Linear Programming Modeling; MODULE 8: Project Planning and Control with PERT-type System; MODULE 9: Inventory Models; MODULE 10: Queuing Theory. These modules could serve for multiple courses such as: Management Information System, Operations Research, Finite Mathematics, Linear Algebra, Statistics, Econometrics, Mathematics for Elementary Teachers.

Customized mathematical topics are also taught in the course that are used in the solution of industrial projects.

These are Network Analysis (covered 1997), Queueing Theory (covered 1998), Inventory Theory (covered 1998), and PERT-type Systems (covered 1998). In each case, we prepared handouts containing specialized material and exercises pertinent to the needs of particular student team projects.

We select appropriate industrial and social projects and structure proper modeling techniques that would use most of the core mathematical skills. Also, the project based learning orientation of the class drives additional mathematical modules and tools that we teach inside and outside of the classroom. These are customized mathematical tools that vary semester by semester depending on the nature of the project in a semester. The course mathematical tools involve modules on linear algebra, linear programming, basic statistics, elements of probability, regression analysis, forecasting, and computer software such as spreadsheet and statistical packages.

Hard algebraic manipulative work is avoided in this course as the emphasis is on concept matters, applications, and modeling. Therefore, technological tools such as graphing calculators and computers are used for problem solving in the course. Software available in the market such as Microsoft's EXCEL, Mathematica, SPSS, or Minitab are also used. The computer software modules primarily consists of introductory exercises in EXCEL. These exercises start out with basic spreadsheet exercises such as data entry, cutting and pasting, and simple statistical calculations such as the mean, median, and mode. More complex spreadsheet operations are then introduced with students practicing their skills by analyzing discrimination by race and gender using an actual employment data base. The EXCEL modules then turn to teaching students basic graphing techniques. Two more EXCEL modules instruct students on the use of the EXCEL pivot table and solver functions. Specialized modules in EXCEL and in other software are designed as the need arises from the demands of particular projects.

Student Projects

Given a particular project, student teams start by formulating research issues, problems, and questions. They then focus on data needs and on acquiring the mathematical, statistical, and computer skills necessary to solve these problems. These are learning activities that cut across all disciplines and benefit education majors as much as they do science and business majors. Economics majors, for example, whose capstone experience requires undertaking a primary research project (i.e., reviewing literature, formulating models and hypotheses, collecting data, using statistical techniques, writing a paper based on all of these activities, etc.) will have a tremendous advantage in carrying out such a project after taking this course.

In the past two times of course offering, our students have completed the following projects for the partner organizations: for the American Diabetic Association Diabetes *Demographic Survey Analysis* (1997) and *Diabetics in Indiana* (1998); for the Ashley F. Ward, Inc. *Study of late Shipments* (1997); for the North Village Mall *Analysis of Parking Availability* (1998); for the Penn Harris Madison School Corporation Keep v. Replacement (199 and *Amount of Pool Works* (1998); for the South Bend Community School Corporation *Truck Delivery System* (1997) and Textbook Inventory Project (1998); for the South Bend Times, Inc. *Advertising Analysis* (1997 and *Inventory Control* (1998); for the Teachers Credit Union *Loan Risk Analysis* (1997) and *Loan Process Control* (1998). More information about the completed projects and the course activities are found on the course website (Shafii-Mousavi & Kochanowski, 1998).

The following illustrates the use of computer technology by a student team in completion of an organizational project. This team consisted of three students and completed the truck delivery system project for the South Bend Community School Corporation.

0) Faculty take preliminary steps: a semester before the course was offered, faculty request projects and initiate contact with SBCSC; prior to the beginning of the course, faculty explore, refine, and model SBCSC project.
1) Team meets with the corporation.
2) Staff relates history of the corporation.
3) Corporation representative explains the team problem: efficiency of the SBCSC truck delivery system.
4) Team narrows the focus of the project to the lunch routes.
5) Team breaks schedule into four individual routes: each route contains 8 to 12 schools.
6) Team and faculty model the problem and identify applicable technology: Traveling Salesperson Problem,

use of Binary Programming techniques, and Schrage's Lindo Lingo software.
7) Team discovers that the only information available is on the currently used routes.
8) Team makes assumptions: the order of schools on a route is not important; school is visited only once; leave locations within their original route; stay on the main roads.
9) Team collects additional data. Students measure routes using an area map involving: 72 measurements for each route; scale (1 inch = 1 mile); generate distance matrices; generate equations and inequalities; each route uses 83 variables, more than 80 equations, and several minutes computing time on a fast computer.
10) Team interprets the computer generated results.
11) Team formulates recommendations and checks post optimality of the results.
12) Team writes a technical report.
13) Team presents its findings to the class and later to the corporation.

Computer technology plays a critical role in steps 6 through 10 of this project. Even for a relatively small traveling salesperson problem such as that analyzed by the students, the model consists of more than 83 variables and 80 equations. Computer friendly software such as Lindo-Lingo not only allows students to solve such real world projects but to see the structure of the modeling effort. The equations, constraints, parameter values that Lindo-Lingo requires all become part of the technological exercise. Students see that the technology solves the model but they further see that they as users provide the technology with the modeling structure. Students further appreciate the marriage of mathematical tools and computer technology and the value such a marriage has in providing valuable real world solutions.

Concluding Observations

The project driven nature of the course refocuses the motivation of students to learn mathematics and enhances their appreciation for the importance of computer technology. Instead of learning mathematical and technological tools simply to satisfy some curriculum requirement, students in this course see the importance of mathematical and technological tools to solve real-world, applied projects. The emphasis on the diversity of students, faculty, and disciplines, all in one course, is also innovative. Instead of separate courses designed for disciplines such as business, science, and education students from these disciplines learn together in the same course. By working together with students from other disciplines, students gain an appreciation of each other's discipline as well as awareness of the breadth of mathematical analysis and computer technology across a wide range of intellectual pursuits. By working together with faculty from other disciplines, faculty teaching the course also gain insight into the use of mathematics and computer technology in their own disciplines that they could not hoped to have gained without such a collaborative effort. Our experiences prove to us that the integration of mathematics across the discipline coupled with computer technology provides a powerful teaching-learning experience even in an introductory course.

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A Whole Brain Teaching and Learning Approach to Introductory Calculus: Technology as a Lever

Tobia Steyn
Gold Fields Computer Centre for Education
University of Pretoria
South Africa
tsteyn@gold.up.ac.za

Alan Carr
Gold Fields Computer Centre for Education
University of Pretoria
South Africa
alan@gold.up.ac.za

Ann-Louise de Boer
Centre for Academic Development Programmes
University of Pretoria
South Africa
deboer@libarts.up.ac.za

Abstract: The advancement in and the availability of technology have necessitated a rethinking of tertiary mathematics education. This discussion focuses on action research experiences during 1993-1998 in a restructured tuition approach to a first course in calculus at the University of Pretoria. The concept of whole brain utilisation is used as a paradigm to describe the teaching and learning activities when graphing technology is used as a lever to promote the understanding of fundamental concepts that underpin the study of calculus. The importance of the coherency between teaching, learning, instructional media and instructional content is highlighted and the judicious use of technology in a well structured tuition approach is advocated.

Introduction

During 1993 an academic support programme was initiated in the Faculty of Science at the University of Pretoria. The aim of the programme was to identify and educate underprepared students, who had the potential to pursue a career in science and applied science, but who did not meet the entrance requirements for admission into the Faculty of Science. Most of these students had inadequate schooling in mathematics and as a result lacked a conceptual understanding of mathematics. Action research experiences with these students necessitated a rethinking of the tuition approach in order to improve their mathematical knowledge.

The restructured tuition approach includes interactive lectures, mathematical practical sessions and tutor sessions. The interactive lectures are student-centered in that students are encouraged to actively participate in organised discussions, which form the core of a lecture. Tutor sessions are structured according to principles that are conducive to optimising learning in small groups.

The focus of this paper is on the practical sessions conducted in a computer laboratory. In these practicals an MS-Windows based graphing utility is used. The use of this graphing utility is aimed at enhancing principles from precalculus which underpin a study in calculus: concepts related to the Cartesian coordinate system; two-dimensional functions; the concepts of limit, continuity and differentiation as well as the significance of the first and second derivative.

Experiences in the Gold Fields Computer Centre for Education, with more than 800 students who have used computer generated graphical representations of two-dimensional functions, indicated that the visual representation of functions through their graphs has a notable impact on students' knowledge and conceptualisation of two-dimensional functions. The way in which the teaching activities are structured, when

graphical representations are used, influences the acquisition of concepts by students. The structure of these learning and teaching activities required meaningful answers to the following questions:

- How can graphing technology be used to promote better understanding of mathematical concepts in a first course in calculus?
- What are the requirements for graphing technology to ensure meaningful visualisation of two-dimensional functions?
- How should instruction be done so as to foster learner cognition and conceptualisation when technology is used as a lever?

A Whole Brain Model for Graphical Manifestation of Mathematical Concepts

The pioneering work of Sperry and colleagues, on split-brain patients at the California Institute of Technology in the 1960's, paved the way for research about the human mind in the fields of neuroscience, psychology and anthropology. Ongoing research has reaffirmed that functionally the human mind can be divided into two hemispheres that control vastly different aspects of thought and action (Gazzaniga, 1998). It has been established that for most people logical, analytical, quantitative and fact based knowledge is located in the left brain hemisphere. The right hemisphere predominantly supports and coordinates intuition, emotion, spatial perception and kinaesthetic feelings. Herrmann (1995) combined this knowledge with current theories of how the human brain is physiologically organised to develop a four quadrant whole brain model. Steyn (1998) has adapted Herrmann's model as a whole brain model for graphical manifestation of mathematical concepts (see Figure 1). Figure 1 illustrates that graphical exploration (in mathematics) is experiential and non-verbal and is focused mainly on the utilisation of right brain functions and that graphical analysis is verbal and structured and is focused mainly on the utilisation of left brain functions.

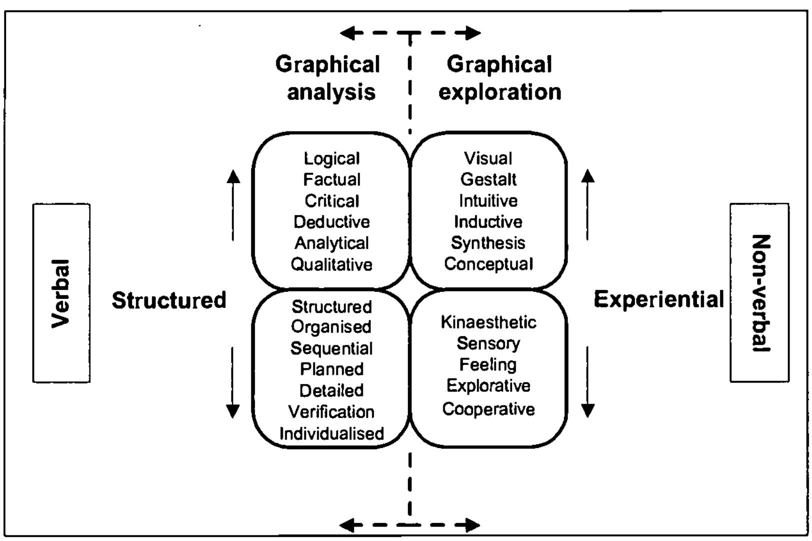

Figure 1: Graphical manifestation of mathematical concepts: a whole brain perspective.

The meaningful and judicious combination of graphical exploration and graphical analysis is regarded as a condition for the manifestation of mathematical concepts in a teaching and learning approach aimed at whole brain utilisation. It should be noted that the traditional instructional approach in (tertiary) mathematics education is aimed at the utilisation of left brain functions. In this regard Sperry remarks that "our educational system, as well as science in general, tends to neglect the non-verbal form of intellect. What it comes down to is that modern society discriminates against the right hemisphere" (as quoted by Herrmann, 1995, p.9). The availability of modern graphing technology has created the possibility to utilise left and right brain functions in the tuition of introductory calculus. This, however, necessitates a rethinking of the way in which learning is facilitated as well as determining the requirements for graphing technology to ensure meaningful learning activities.

Graphing Technology as a Lever for Exploring Mathematics

Graphing technology for teaching and learning mathematics include pen and paper, computer graphing software, graphing calculators and the graphing capabilities of other software, such as symbolic manipulation programs and spreadsheets. The use of graphing utilities in mathematics education can be categorised as exploratory and illustrative (Steyn, 1998). In the exploratory use of graphing technology, technology is regarded as an aid (tool) to support a learner in the thorough investigation and examination of mathematical concepts that are represented by a graphical image. The illustrative use of graphing technology can be described as a 'have-a-look-at-it' use. This is usually done by someone who is competent in mathematics and who may or may not be proficient in the use of graphing technology. In this discussion graphing technology is viewed as an exploratory tool for mathematical concept mastering. In the following paragraphs the requirements of graphing technology, when used as an exploratory tool, are discussed. It should be borne in mind that graphing technology should foster whole brain utilisation (see Figure 1).

Technical Features

The user interface of a graphing utility should be conducive to learning. The utilisation of left and right brain functions are promoted and optimised if text is in the right visual field and visual images (graphics) are in the left visual field (Herrmann, 1995). The layout of the user interface of the graphing utility in Figure 2A is structured according to these principles. The human brain has an inherent fast response to colour, shape and contrast (Jensen, 1996). Therefore, the use of colour in the user interface of a graphing utility should also be presented in such a way so as aid and not to impair learning.

The technical capabilities of an educational graphing tool must promote opportunities for authentic explorations and convincing observations. For example, entering functions should be easy; it should be possible to display more than one function simultaneously and functions should be distinguishable from each other. Real exploratory activities, such as physically following a curve with a mouse, should be possible. Changing the dimensions of the graph window[§] should be easy; toggling between consecutive graph windows should be possible and an easily accessible zoom feature should be available. Very useful features, for the meaningful exploration of related changes in x- and y-values, are moving horizontal and vertical lines as well as the ability to add fixed horizontal and vertical lines to the image displayed by the graphing utility.

Didactical and Pedagogical Features

When technology is incorporated into a (tertiary) tuition programme, the focus should not be on the technology. This means that the skill to use a graphing utility should be easily acquired and retained by the learners for whom the instruction is intended. Technology should add value to students' learning experiences and should facilitate rather than dictate learning.

In using graphing technology as a tool to explore mathematics, learners need to be able to get an intuitive feeling of the graph through the activity. The authors feel that the screen size of a computer and the relative ease in manipulating a mouse are conducive to authentic experiential activities, which include intuitive activities. "Intuition and concepts constitute the elements of all our knowledge. I believe that no reform in the education of mathematics can be successful which does not focus on how we can strengthen intuition" (Fuchssteiner, 1997, p.14).

When a graphing approach is used for the teaching and learning of two-dimensional functions in mathematics, the images, displayed by the graphing utility, should be accurate representations of the functions. Experiences with students in the Gold Fields Computer Centre (1993-1998), using graphing utilities, have shown that ambiguous graphical images give rise to mathematical misconceptions. Figure 2A illustrates the graph of a rational function drawn by the computer graphing tool, *Master Grapher for Windows* (Carr & Steyn, 1998), and Figure 2B illustrates the same function drawn by a graphing calculator. The image in Figure 2B is displayed by many graphing utilities. The authors feel that such an image cannot be used for authentic graphical exploration as students believe that the graph displayed is the representation of the function.

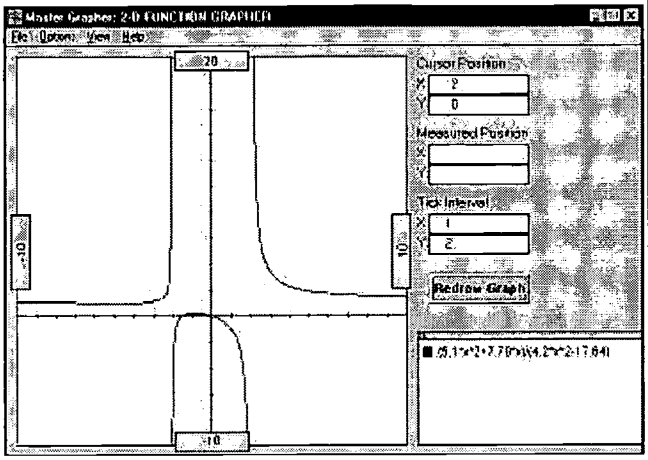

Figure 2A

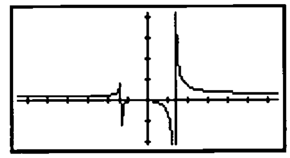

Figure 2B

Figure 2: The function $\boxed{f(x)=\dfrac{5.1x^2+7.79x}{4.2x^2-17.64}}$ is displayed unambiguously in Figure 2A. The image in Figure 2B evokes misconceptions and **cannot** be used for graphical exploration.

In the experience of the authors, graphing technology can be utilised as a powerful lever to promote the understanding of fundamental mathematical concepts. This is possible if technology is used judiciously and if tuition is structured prudently and appropriately in order to facilitate meaningful learning.

A Whole Brain Teaching and Learning Approach

The instructional model (Steyn, 1998) in Figure 3 presupposes an interdependence between teaching, learning, instructional media and instructional content when technology is used in tertiary mathematics education. In this model the tertiary student of the late 1990's is viewed as a developing learner, neither child nor adult in a technologically rich environment. The use of only traditional theories of learning to describe the cognitive activity of such a learner of mathematics is no longer sufficient. The concept of whole brain utilisation can be used as a paradigm for elucidating the teaching and learning of tertiary mathematics in the late 1990's. The facilitation of learning in this model is based on research and experiences related to student learning as well as on the concept of a whole brain approach to teaching. This approach is aimed at utilising whole brain functional activities of all tertiary learners engaged in graphical exploration in a first course in calculus.

Whole brain utilisation in a first course in calculus, where the graphical representations of functions are used in the tuition approach, is based on the combination of graphical exploration and graphical analysis. Figure 1 shows that graphical exploration is non-verbal and graphical analysis is verbal. The successful manifestation of mathematical conceptualisation lies in a combination of these two aspects. This, however, necessitates a well structured tuition approach. Students need to be taught how to explore graphs (right brain utilisation) and make meaningful interpretations (left brain utilisation). In order to structure learners' exploration activities, when a graphing utility is used, detailed guidelines for the exploration activity should be given. This implies that students have to read, comprehend and use this instructional information to do the exploration activities. In such activities, left brain utilisation is promoted through the structured format and verbal information. This is followed by right brain utilisation in the actual exploration activity which is then again followed by left brain utilisation in analysing, formulating and writing down the solutions to the problem. Ideally, for mastering fundamental mathematical concepts, graphical interpretation should be accompanied by algebraic verification (orally and/or in writing) and algebraic results should be illustrated graphically. This coherence also indicates the utilisation of left and right brain functional activities.

A further major contribution that a graphing utility can make in revealing mathematical concepts lies in the visualisation of functions through their graphs. Interpreted from a whole brain perspective this implies

utilisation of a predominantly right brain function. Graphical representations further enhance conceptualisation through *gestalt* (wholeness). This means that a mere glance at the graphical representation of a function conveys more information regarding the features of a function than is the case when an equation alone is considered.

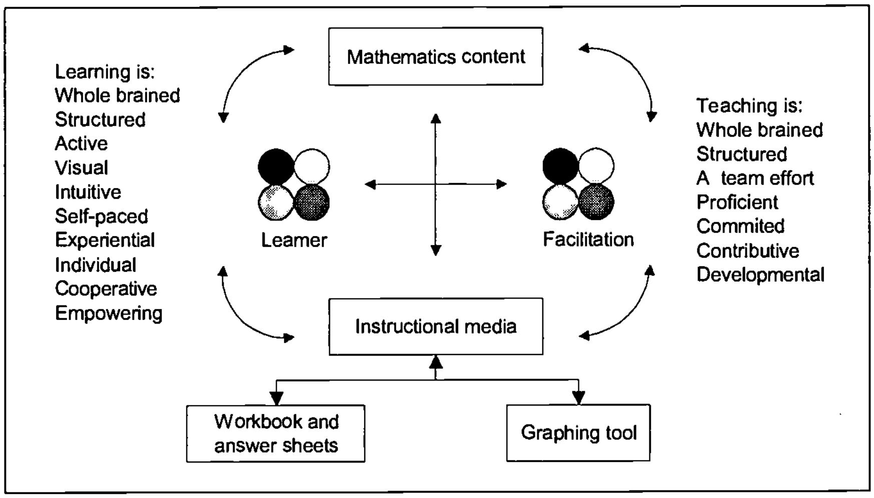

Figure 3: An instructional model for technology aided mathematics tuition - a whole brain approach.

As a learner becomes proficient in graphical exploration, left and right brain activities are seemingly utilised in congruence. Furthermore, there is continuous movement between the left and the right brain functions. However, it cannot be assumed that students automatically have the expertise to do graphical exploration in such a way that right and left brain functions are utilised. Competency in whole brain utilisation in teaching and learning (in mathematics) can only be achieved through training (teaching), motivation and practice. This can ideally be accomplished when instruction follows a well structured tuition approach.

The main components of the instructional model in Figure 3 can be combined with the whole brain model in Figure 1 to illustrate how whole brain utilisation in teaching and learning is accomplished in the mathematics practicals mentioned in this discussion.

- The instructional media comprise of a workbook and accompanying answer sheets as well as a computer graphing utility (Greybe *et al.*, 1998). The layout and use of the workbook and answer sheets focus mainly on utilisation of brain functions in the lower left quadrant. The computer graphing utility supports whole brain utilisation and satisfies the prerequisites for a graphing utility to be used as an exploratory tool.
- Learners doing mathematics practicals do not receive knowledge passively but are active participants in the instructional process. The learner activities in this instructional model can be described by the functional aspects in all four brain quadrants. Exploring graphs, visualising mathematics, acquiring a whole picture and conceptualisation are predominantly directed to utilise brain functions in the right hemisphere. The structured activities, critical analysis and logical verbal descriptions are mainly directed to utilise brain functions in the left hemisphere. Spontaneous and informal cooperative learning occurs when students feel the need to discuss the work with their peers. This means that the brain functions in the lower right hemisphere are also utilised.
- The mathematical content is explored in a way so as to utilise left and right brain functional activities. On the one hand this is done by way of the algebraic verification (left brain) of graphical representation (right brain) and on the other by the graphical enhancement (right brain) of algebraic results (left brain).
- Facilitation of the learning activities is planned to optimise whole brain utilisation. "The benefits of technology integration are best realised when learning is not just the process of transferring facts from one person to another, but when the teacher's goal is to empower students as thinkers and problem solvers" (Sandholtz *et al.*, 1997, p.176). Team teaching has, amongst others, evolved through the rethinking of tuition in this instructional model. Knowledgeable insights in interactive lecturing, tutoring and computer aided learning of the participating facilitators have contributed to the ongoing development of this mathematics course.

Summary

The information presented is part of ongoing research into the upliftment of students with problems in mathematics. The models for teaching and learning with graphing technology have been refined through continuous observation of the students. These students have, together, spent more than 20 000 hours working through the practicals. This has had a positive effect on their attitude towards mathematics, as can be seen from their responses to a questionnaire: 92.7% reported that their experiences with the computer graphing utility had made mathematical concepts clearer; 91.3% indicated that using the worksheets improved their ability to read and understand the language of mathematics; 93.0% indicated that the communications during the practical sessions helped them to improve their ability to formulate mathematical concepts and express themselves in the language of mathematics and 93.4% reported that completing the answer sheets improved their skill in writing down mathematics correctly.

If technology is used judiciously and incorporated in a tuition approach, structured according to whole brain principles, it is a powerful lever in promoting meaningful learning.

Note

§ In some graphing utilities and textbooks the phrase 'viewing rectangle' is used to indicate the 'window' in which the graph is displayed.

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Improving Teacher's Understanding of Mathematical Modeling and Facility with Graphing Calculators

James Telese
School of Education
University of Texas, Brownsville, U.S.A
jtelese@utb1.utb.edu

Mufid Abudiab
Department of Mathematics
Texas A&M University, Corpus Christi, U.S.A.
maa0176@falcon.tamucc.edu

Abstract: Project GATE(way): Graphing, Algebra, Technology, and Excellence was designed to improve middle and high school mathematics teachers' knowledge of mathematical modeling during a three week summer institute. The participants were teachers in various schools throughout the lower Rio Grande River Valley of south Texas. A pre-, and post evaluation was administered, as well as other forms of evaluation were used, such as projects and reflective journal writing. At the end of the institute, the data revealed that a majority of the participants made tremendous strides in their ability to analyze real-world data using mathematical models.

Theoretical Framework

Algebra is considered a "new civil right" (Moses, 1993). This implies that all students should have access to the benefits associated with mathematical understanding, which leads to quantitative literacy. The gatekeeper for quantitative literacy is algebra (Dossey, 1998). Far too often, Algebra I acts as a deterrent to higher mathematics (National Action Council of Minorities in Engineering, 1995).

The intended curriculum has a tremendous influence on teacher actions. There are three other factors that direct certain actions of mathematics teacher while teaching. They are teacher cognitions (Putnam, Heaton, Prawat, & Remillard, 1992) previous experiences of the teacher (Pearce & Loyd, 1987), which includes pedagogical and subject training, and characteristics of the teacher's environment (Haimes, 1996). A study conducted by Telese (1996) at a local high school found that the majority of Algebra I teachers rarely related the function concept to real life applications. This may indicate that the teachers lack a thorough knowledge of functions to fully integrate them into applicable situations.

The National Council of Teachers of Mathematics [NCTM] (1998) suggest that all students should have and opportunity to "understand various types of patterns and functional relationships, use symbolic forms to represent and analyze mathematical situations and structures, and to use mathematical models and analyze change in both real and abstract contexts" (p. 280). This suggests that teachers need to be proficient in the development of mathematical models to represent various real world phenomena. The purpose of this paper is to report on a project designed to improve public middle and high school mathematics teachers understanding of mathematical modeling and their students access to graphing devices.

Language and Problem Posing in Algebra Classrooms

One model for learning algebraic concepts involves language. Some difficulties arise when students are unable to think of mathematical objects as concrete models and then use linguistic ability to explain the model (Dossey, 1998). The constructivst learning technique of problem posing is beneficial for developing mathematical understanding. The constructivist technique offers students an opportunity to link concrete algebraic models with their linguistic models (Brown & Walter, 1993).

The act of problem posing allows students and teachers to use the emerging relevancy for increasing the level of understanding (Brooks & Brooks, 1993). In order for algebraic understanding to occur, students should use the language repeatedly over an extended time period. Students should use the language of mathematics for expressing something meaningful and relevant. For example, students can express quantitative relationships of their understanding of relationships outside of mathematics when language is used to model our world (Kaput, 1998). Helping students to use language for expressing mathematical ideas requires guidance from teachers who have developed a repertoire for mathematical constructions consisting of posing, constructing, exploring, solving and justifying mathematical problems and concepts in order to develop a similar capacity to reflect on, and pose, mathematics problems (Confrey, 1990).

The Role of Technology

Hispanic students have less access than their White counterparts to technological tools, such as graphing calculators and computers (Silver, Strutchens, & Zawojewski, 1997). It has been suggested that technology's role in algebra instruction should be expanded. This expanded role may include the use of numerical or symbolic computations and actions taken on graphical objects (Kaput, 1993). According to Schwartz (1992), the content of secondary school mathematics should be "made coherent and pedagogically workable" (p. 303). The subject of functions has been considered a unifying topic in algebra and other secondary school mathematics courses (e.g., Fey, 1990). Two powerful representation of functions are symbolic and graphical (Schwartz, 1992). One avenue to capitalize on these representations is through modeling, a process that emphasizes a description of the relationship between dependent quantities.

A deeper examination of the properties of families of functions is possible with available technology (NCTM, 1998). Through changes in the parameters of a function, students come to understand ways in which families of functions may be represented (NCTM, 1998). Families of functions such as linear, exponential, and rational are reasonable models to study because their properties have the potential to model real world situations. This is accomplished through teacher directed activities, such as analyzing meaning of various rates of change, zeroes, maximum and minimum values within contextual settings (Heid, 1996).

Jonassen, Peck, and Wilson, (1999) have identified four aspects to personally constructed knowledge, when technology is employed as the tool for assisting in meaning construction. Meaning construction requires the first aspect, active learning, where students explore and manipulate components of technology-based environment and observe the results of their activities. A second aspect is constructive learning, which involves students in articulating what they know and reflecting on their understanding in a larger societal role. Intentional learning is the third aspect, which allows students to set their own goals and regulate and manage their activities. Authentic learning, the fourth component, occurs when students examine and attempt to solve complex ill-structured, and real-world problems. Students socially negotiate the meanings that they have constructed. But if students are to have the opportunity to construct their meaning and make sense of their world, then teachers must begin to relinquish some of their management and intellectual authority (Jonassen, Peck, & Wilson, 1999). Consequently, teachers must accept a new model of learning if students are to learn with technology.

Project GATE(way) II

Project Description

Project GATE(way): Graphing, Algebra, Technology, and had an overall goal of strengthening both the teachers' subject-matter knowledge and teaching skills. The major content objective was for teachers to gain the capability to model data using various types of functions, such as linear, quadratic, and systems of equations, through problem solving. A major pedagogical objective was to improve teachers' ability to teach algebraic concepts through the use of graphing calculators. As a result, there was an intention to maintain an intensive high quality professional development program for teachers.

There were 16 participants who taught at either at the middle school (7) or high school (9) level. They came from a variety of school districts in the lower Rio Grande region of south Texas. For example, one teacher taught at a small rural school in farming community, and other teachers taught in much larger schools in an urban setting. They attended a three week summer institute, meeting three hours each day. The summer institute focused heavily on the mathematics content related to modeling. During this time, teachers were presented with activities and knowledge to improve their mathematical modeling background. Graphing technology was integrated with instruction to enhance conceptual understanding and to represent models of real world phenomena. The content discussed included critical decisions concerning the process of modeling with such families of functions as linear, power, exponential, and logarithmic Teachers also worked in both independent and cooperative settings.

Project Evaluation

Instrumentation

The main goal of the class was to provide the participants with an opportunity to see how the pieces of a real-world application in various fields fit together via mathematical modeling. Throughout instruction, multiple approaches, such as numerical, graphical, symbolic, and verbal, were used to solve a variety of problems. The students received a day-by-day workbook which they used throughout the course. Graphing calculators were utilized throughout the instruction.

A pre-evaluation was administered that examined their knowledge of calculator use and function concepts. The participants were placed in groups to foster interactive learning via writing, reading, speaking, and collaborative activities. In addition, a group leader was assigned; the leader was responsible for reviewing, in the group, the material covered.

A typical day began with an answer-question session, followed by a presentation of the new material, a worksheet covering the lesson, weekly project preparation time, and a period of reflections pertaining to the day's activities. The projects dealt with issues related to South Texas like water conservation, Hepatitis B, and immigration issues. A variety of activities were performed in class in order to actively involve students in meaningful mathematical problems to build upon their experience and to focus on diverse math themes.

At the conclusion of the institute, a post-evaluation was administered that was different in item content but cover similar concepts as the pre-test. In order to measure the students' level of success, the pre-evaluation, weekly performance outcomes, weekly projects, and the post-evaluation were used. Both the pre-evaluation and the post-evaluation reflected the following topics: analytical solution and graphical support, matching equation with graph, use of mathematical properties for finding viewing window, explanation of solution method, interpretation of graph, and mathematical modeling skills. Each student's performance was measured based on a specified scale: Excellent (10), Very Good (9), Good (8), Above Average (7), Average (6), Below Average (5), and Poor (4 or less).

Results

The data collected from the pre-, and post-evaluations showed that the participants increased their level of mathematical knowledge and facility with graphing calculators. The ratings for each individual were compared in order to judge any progress made in relation to the topics. An average change in ratings was calculated for the whole group. The largest gain, a 22% increase, was in the interpretation of graphs. This was an area of weakness at the beginning of the institute. The next largest gain was an 18% change related to the objective of explaining a solution method. The participants ability to provide a rationale and support their findings greatly improved. The smallest gain, a 12% change, was made in relation to the objective of providing an analytical solution and graphical support. This result demonstrates that the participants ability to offer an analysis of the model was weak in the beginning and change slightly by the end of the institute. They had improved their ability to match an equation with a graph that represents the equation as demonstrated by a 15% gain.

Their ability to use mathematical properties for finding appropriate viewing windows also improved as illustrated by a 17% gain. They also showed improvement in their ability to use mathematical modeling skills with a 16% gain.

This was an area of weakness as well at the beginning of the institute. Overall, it can be concluded that the instruction positively influenced the participants' knowledge of mathematical modeling and facility with graphing calculators.

Teacher Comments

As part of the evaluation process teachers were asked to reflect on the day's activities by responding to the statement stems: a) 'Today I learned...,' and b) 'I have a better understanding of. . .' The topic on one particular day was mathematical modeling. One teacher wrote, "A mathematical model is a process to gain insight and make predictions about an observable behavior." Yet another teacher described mathematical modeling as a process where data are reviewed or collected from observations and a model then is chosen that best represent the data, "Mathematical modeling is a process, to review and observe and use a model that fits."

Another teacher reflected on the families of functions as formulas. This response suggests that this teacher viewed mathematical modeling as a cook book process, but understood that the families of functions are useful for representing real world phenomena, "the formulas to use when making math models, linear, quadratic and exponential are common for models."

Comments that followed the stem, 'I have a better understanding of. . .,' described their knowledge gain related to how mathematical model can be used, for example one teacher stated,: "I have a better understanding of mathematical modeling, how to use it and where it is used." Modeling was presented within various contexts, one teacher reflected on the realization that modeling ideas may come from a variety of situations, "How mathematical modeling has been used in different fields like, management science, population genetics, data analysis, coding information, population ecology, immunology, clinical medicine, social choices and decision making."

In a similar vein, on teacher stated, "Mathematical modeling is a powerful tool; a better process for gaining insight into and predicting the behavior of complex and seemingly unpredictable observed phenomena." This teacher clearly has an understanding of the power of mathematical modeling.

In regard to using the graphing calculator, one teacher's comment describes how she grew in knowledge as a result of activities with the graphing device. In response to the stem, I have a better understanding of . . , "what a quadratic equation looks like in a graph. I have an idea what the term c does to the parabola. It translates the parabola up or down. I also understand what a negative a does, it will flip the parabola upside down on a graph."

Acknowledgements

The work reported in this paper was supported by a grant, #96066, from the Dwight D. Eisenhower Foundation, administered by the Texas Higher Education Coordinating Board, University Division. The statements made and the views expressed are those of the authors and do not necessarily reflect those of the funding agnecy.

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Geometry On-line

David A. Thomas dave@math.montana.edu
Brian D. Beaudrie beaudrie@math.montana.edu
Montana State University
United States

Abstract: MathML and the Java programming language offer mathematicians and mathematics educators powerful new tools for publishing WWW-based mathematics materials. In particular, these technologies now make it possible to present both geometric information and interactive geometric models over the WWW. This paper presents an overview of these technologies and discusses their potential uses in on-campus and distance education courses.

Java and Geometric Models

Java is a programming language developed by Sun Microsystems for writing client/server and network-based applications (Kramer, 1996). Java programs come in two varieties, applets and applications. Applets run inside your WWW browser, making them easy-to-use. Unfortunately, they do not read or write to your hard drive, nor do they access files on computers other than that from which the applet itself was served. These restrictions exist in part to protect users' computers from viruses and invasions of privacy. Applications run inside a Java Virtual Machine, a program running in the computer's operating system.

Most WWW users know that Java applets are used extensively on commercial web sites to scroll information, animate figures, and structure communication with the site host. Relatively few people are aware that Java may also be used to create interactive geometric models. For instance, a projective view of a cube appears in Figure 1. Seen in your Java-enabled WWW browser, the view may be changed by sliding the vanishing points and the drag point along the horizon line or the two vertices closest to the viewer perpendicular to the horizon line. Used in instruction, WWW-based, interactive models of this sort may be used to demonstrate concepts and motivate further investigation outside of class for students with WWW access.

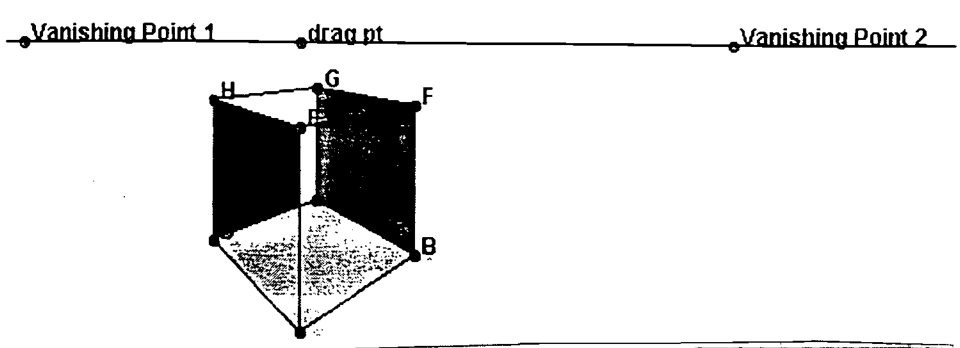

Figure 1: Perspective View of a Cube

Creating models of this sort is surprisingly easy. First, the model in Figure 1 was created using the *Geometers Sketchpad* (http://www.keypress.com/sketchpad) from Key Curriculum Press. Next, the *Sketchpad HTML Converter* was used to convert the sketch into an HTML file containing the Java applet. Finally, the HTML file and the *JavaSketchpad* applet were placed in the same directory on the authors' WWW site (http://www.math.montana.edu/~dave/bc/CD-ROM/amodel.htm). Only two networking skills were required: Downloading the *Sketchpad HTML Converter* and the *JavaSketchpad* applet from Key Curriculum Press, and uploading the HTML file and

JavaSketchpad applet to the authors' WWW site. No programming was necessary. For faculty already comfortable with the *Geometers Sketchpad* and basic HTML, this procedure offers a simple means for adding geometric applets to on-line instructional materials. The procedure does have limitations, however. Several *Sketchpad* features are not supported by the *HTML Converter*. As a result, some sketches cannot be converted. Nevertheless, this procedure does make it possible to begin experimentation with Java-based geometric models.

The *CabriJava Project* (http://www.cabri.net/cabrijava/) is working on a Java applet capable of supporting all of the features of *Cabri Geometry*. *Cabri Geometry* (http://www.cabri.net/index-e.html) is an educational software product similar in form and function to the *Geometers Sketchpad*. Kuntz's (1998) paper "Dynamic Geometry and the World Wide Web" provides an informative introduction to the *CabriJava Project*, including details on how to convert *Cabri Geometry* files to Java applets.

A number of WWW sites feature the use of geometric Java models. The following provide an overview of the diversity of Java-based geometry resources currently available on the WWW.

- Alexander Bogomolny's *Cut-the-Knot* WWW site (http://www.cut-the-knot.com/) includes an extensive section on geometry, including many interactive Java applets.
- The Shodor Foundation's (http://www.shodor.org/master/) *Modeling and Simulation Tools for Educational Reform* site demonstrates the power of Java in simulation environments.
- For creating and viewing polyhedra, a difficult task regardless of the technologies used, Weber's (1998) site *Polyhedra of Point Groups* is truly amazing (http://www.nirim.go.jp/~weber/JAVA/jpoly/jpoly.html).
- *Euclid's Elements* (http://aleph0.clarku.edu/~djoyce/java/elements/elements.html) by David Joyce makes creative use of Java applets to investigate geometry's earliest great achievements.
- The Geometry Center's *Gallery of Interactive Geometry* (http://www.geom.umn.edu/java/) offers a variety of interesting geometric models.

MathML and Geometric Communications

A distinguishing feature of mathematics is its use of a complex and highly evolved system of symbolic notations (Ion & Miner, 1998). While mathematical ideas exist independently of the notations that represent them, part of the power of mathematics derives from its ability to represent and manipulate ideas in symbolic form. There is more to putting math on the Web than merely finding ways of displaying traditional mathematical notation in a Web browser, however. Currently, most mathematical formulae published on the WWW appear as graphic images, typically in GIF format. Because formulae presented in this manner are not machine-readable, little or no automatic processing of their content is possible. Mathematicians need a method for searching, indexing, and reusing WWW-based mathematical content in other contexts and applications. This need is motivating the development of an entirely new approach to WWW-based mathematical publishing. MathML is an important step in that direction.

Just as HTML is a WWW standard for formatting and linking textual materials, MathML is a WWW standard for formatting and linking mathematical notations. Currently, all WWW browsers interpret formatting specifications embedded in HTML documents in a consistent manner. This guarantees that textual information is displayed as intended on users' screens. Java-enabled browsers deploy applets incorporated in HTML documents in a manner consistent with the author's intentions. Recently, *Geometry Technologies, Inc.* and *ICESoftAS* announced the first WWW browser with full native MathML support (http://www.webeq.com/). This collaboration involves *Geometry Technologies' WebEQ* editing and display tools and *ICESoftAS' e-Lite* Java-enabled WWW browser. *WebEQ* is a suite of Java programs for creating and displaying interactive scientific Web documents. Using *WebEQ*, authors can add equations to Web pages by inserting WebTeX or MathML source code in their HTML documents, or by creating them visually using the point-and-click *WebEQ Editor*. WebEQ may also be used in conjunction with other Java-enabled browsers, including the Netscape and Microsoft browsers. The Computational Mathematics Laboratory of the Department of Computer Science at Concordia University, Montreal (http://indy.cs.concordia.ca/mathml/) provides an overview of several other technologies for authoring, editing, and displaying MathML. Each of these technologies approaches the tasks of writing, editing, and displaying MathML. In order to illustrate the challenges associated with writing MathML "raw code", Table 1 shows the binomial equation and its MathML encoding.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

```
<mrow>
 <mi>x</mi>
 <mo>=</mo>
 <mfrac>
  <mrow>
   <mrow>
    <mo>-</mo>
    <mi>b</mi>
   </mrow>
   <mo>&PlusMinus;</mo>
   <msqrt>
    <mrow>
     <msup>
      <mi>b</mi>
      <mn>2</mn>
     </msup>
     <mo>-</mo>
     <mrow>
      <mn>4</mn>
      <mo>&InvisibleTimes;</mo>
      <mi>a</mi>
      <mo>&InvisibleTimes;</mo>
      <mi>c</mi>
     </mrow>
    </mrow>
   </msqrt>
  </mrow>
  <mrow>
   <mn>2</mn>
   <mo>&InvisibleTimes;</mo>
   <mi>a</mi>
  </mrow>
 </mfrac>
</mrow>
```

Table 1: Sample MathML Code

Figure 2 shows a MathML-generated matrix equation for the geometric transformation of translation. The equation is formatted to highlight matrix elements *e* and *f* when the mouse passes over them. Using other MathML options, these same elements may be used as links to related WWW documents created for instructional purposes. Detailed marking of individual elements in complex notation is the basis for MathML's powerful formatting and communication capabilities. To take advantage of those capabilities, a complex syntax must be observed. Since most MathML users would prefer to avoid learning that syntax, an easy-to-use editor is an essential feature of a MathML environment.

$$\begin{pmatrix} 1 & 0 & e \\ 0 & 1 & f \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{pmatrix} x + e \\ y + f \\ 1 \end{pmatrix}$$

Figure 2: MathML-Generated Matrix Equation

Applications in a WWW-based Distance Education Course

The Burns Telecommunications Center (http://btc.montana.edu/html/Distance.html) at Montana State University has facilitated the development and delivery of a number of WWW-based distance education courses for K-12 mathematics and science teachers. These courses play an important role in two programs: the Master of Science in Science Education (http://btc.montana.edu/nten/sciedmasters.shtml) and the Master of Science in Mathematics Education (http://www.math.montana.edu/~dave/msme/). Instructors use a variety of communication technologies, including *FirstClass Client* from SoftArc (http://www.firstclass.com/). *FirstClass* supports both synchronous (chat room) and asynchronous (email and bulletin board) communication formats. Recently, questions have arisen concerning the relative benefits of these communication formats.

A study has been designed to investigate the relationship between communication and achievement Spring Term 1999. Math 527 Geometry for Teachers (http://www.math.montana.edu/~dave/m527/Sp99.htm) is a distance

education course for K-12 mathematics teachers pursuing masters or doctoral degrees in mathematics education. Students spend approximately 10 hours per week on course assignments and activities, including on-line discussions. The course surveys transformation, Euclidean, fractal, projective, and hyperbolic geometry using a variety of powerful technologies and texts by Smart (1998) and Thomas (1998).

Observations of student communication and achievement will take place in a series of small group, problem-solving activities. A sample activity (http://www.math.montana.edu/~dave/bc/CD-ROM/amodel2.htm) follows:

Topic Orthogonal Circles from Harmonic Sets

Focus Point D is given as one of the points in the interior of Circle O through which orthogonal Circle P must pass. AB, a diameter of Circle O, is drawn containing point D.

Tasks

1. In what sense may two circles (curves) be said to be orthogonal (perpendicular) to each other? What would it take to demonstrate that the two circles shown are orthogonal?
2. Move point D along line AB. State a conjecture concerning the movement of point C. State a conjecture concerning about the size of circle P. To prove your conjectures false, what sort of counter examples would be necessary?
3. Using the arrow icon, resize Circle O using the drag pt. Discuss your observations.
4. Using the arrow icon, slide the center of Circle P along the secant containing its diameter. Discuss your observations.
5. Why is the movement of the center of Circle P constrained? Discuss why this procedure generates many orthogonal circles instead of just one.
6. Move point D outside of Circle O. Discuss your observations.
7. State a conjecture concerning the possible locations of the center of Circle P. To prove your conjecture false, what sort of counter example would be necessary?
8. Explain the mathematical basis for the model.

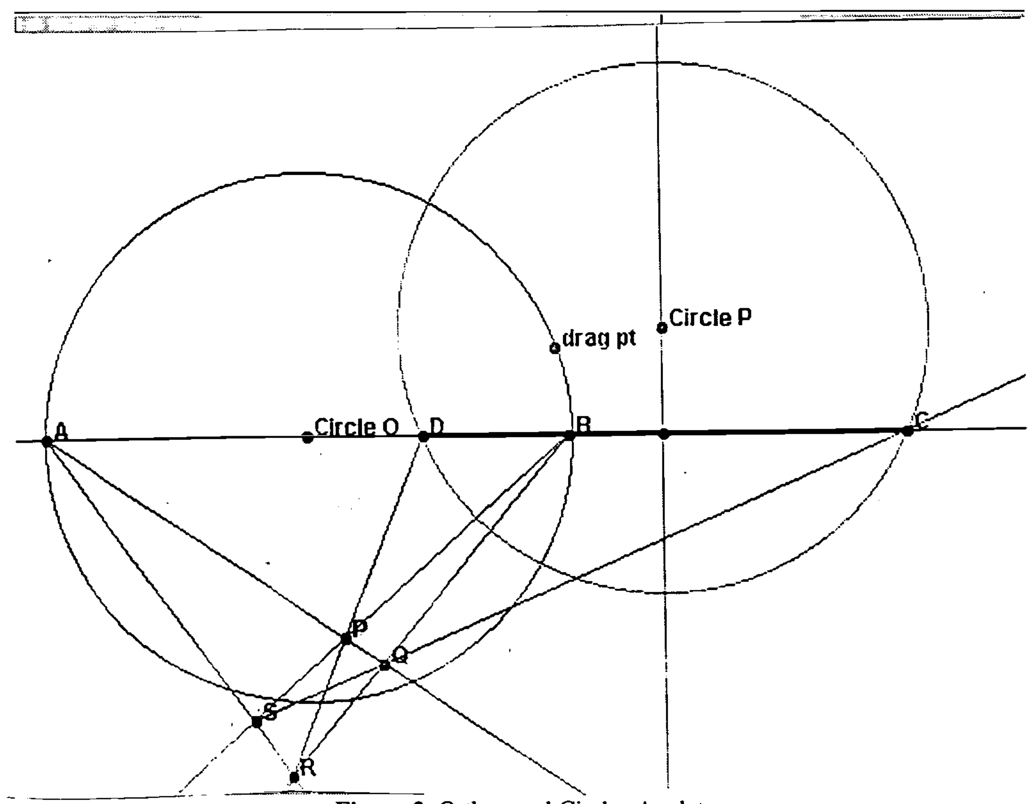

Figure 3: Orthogonal Circles Applet

Each problem-solving activity will require students to make systematic observations, write descriptive statements, formulate and test conjectures, and determine the mathematical bases for the concepts and/or processes embodied in the model. In reaching consensus, students will negotiate both the content and language of their statements. These negotiations will be analyzed using an Interaction Analysis Model (IAM) developed by Gunawardena, Lowe, and Anderson (1997). The IAM characterizes statements using a five-point, hierarchical scale: 1) sharing and/or comparing information; 2) discovery and exploration of dissonance or inconsistency among statements, concepts, or ideas; 3) negotiation of meaning and co-construction of knowledge; 4) testing and modification of proposed syntheses or co-constructions; and 5) agreement statements involving newly constructed meanings. This model will be used to describe the performance of both individuals and their groups in synchronous and asynchronous communication formats in our study. Differences in descriptions will be analyzed in search of communication patterns related to individual characteristics, task content and requirements, and other factors.

Groups will consist of 3-4 individuals with similar personal and academic characteristics. To control for a variety of experimental factors and effects, each task will be conducted in an assigned communication format, synchronous or asynchronous. Group achievement on each task will be determined using a rubric developed by the authors.

Because this study is exploratory in nature, and because the number of students many not be large enough to justify the use of inferential statistics, analysis may be limited to descriptive and graphical methods. If the analysis produces evidence of meaningful relationships between the variables "pattern of communication" and "achievement", additional studies will be designed and conducted in other distance education courses.

Conclusions

Geometry is one of mankind's most enduring intellectual pursuits. While the value of geometry as an educational pursuit may be considered independently of technological issues, modern science and technology are driving a revolution in geometry-based research and applications. One consequence of this revolution is a growing need for a WWW-based, mathematical communication technology. Java and MathML provide the technical means for publishing many of the most engaging and powerful findings of this revitalized mathematical science.

As mathematics educators, the authors are interested in exploiting Java and MathML to improve teaching and learning for students of geometry. While research has established the validity of distance learning in higher education, most findings deal with video- or text-based offerings rather than WWW-based courses. The advent of graphical and symbolic notation tools for WWW-based mathematics communication raises important new questions concerning the use of these technologies for mathematics instruction. The research discussed in this paper represents a first step in the investigation of the educational uses of Java and MathML. Individuals interested in discussing both the theoretical and practical implications of these technologies are invited to contact the authors.

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Teaching Statistical Graphs to Preservice Elementary Education Teachers

Cynthia S. Thomas
Montana State University
United States
cynthia@math.montana.edu

Abstract: Professional associations concerned with teacher education are uniting and coordinating their efforts to define the qualities and qualifications essential in the next generation of elementary school teachers. One aspect of these discussions is the statistical knowledge, reasoning, and communications skills of elementary education majors, including statistical graphs and their technological representations. After reviewing current standards and research findings on this issue, this paper discusses use of the TI-73 graphing calculator to teach statistical graphs in a mathematics course for elementary education majors at Montana State University, and presents a research design for investigating student achievement during preservice training.

Introduction

In the next 10 years, United States elementary, middle, and secondary schools will hire 2 million new teachers to meet rising enrollment demands and replace an aging teaching force. Half of US teachers will retire during the same period (NCES, 1998). Given these data and the fact that 21% of US teachers currently have less than a college minor in their principal teaching area (NCTAF, 1997), the education of preservice teachers must become a national priority. A number of professional associations concerned with teacher education are uniting and coordinating their efforts to define the qualities and qualifications essential in the next generation of teachers. These organizations include The National Council for Accreditation of Teacher Education (NCATE), National Council of Teachers of Mathematics (NCTM), American Mathematical Society (AMS), American Statistical Association (ASA), and The International Society for Technology in Education (ISTE). For the first time, these and other stake holders in teacher education are united in their efforts to raise the standards and expectations of the teacher education programs. This paper discusses an effort currently underway to improve the quality of teaching and learning in one aspect of K-8 mathematics education, statistical graphs and their technological representations.

Essential Academic Competence

In the mathematics content areas of the Third International Mathematics and Science Study (TIMSS), United States fourth graders barely exceeded the international average in five of the six areas assessed, including sets of items designed to sample students' ability to do work in data representation, analysis, and probability (NCES, 1997). United States eighth-grade students scored at about the international average in the same areas (NCES, 1996). In a country with a national goal of having the best-educated children in the world, these results have prompted questions concerning the mathematical competence of United States teachers and the quality of the mathematics curricula in grades K-8. President Clinton's *Call to Action for American Education in the 21st Century* (1997) states that, as a nation, "Strong schools with clear and high standards of achievement and discipline are essential to our children and our society. The United States ranks below average internationally in 8th grade mathematics. We must do better."

To be effective, teachers must know their subject matter so thoroughly that they can present it in a challenging, clear, and compelling way (NCATE, 1998). While there is substantial evidence that teachers in other countries know more mathematics than do US teachers, it is not obvious that the simple step of requiring more mathematics courses for future teachers will remedy this situation (Howe, 1998). I believe that for advanced training in mathematics and statistics to have an impact on the thinking and practice of K-12 teachers, it must directly facilitate that thinking and practice. Few candidate teachers make meaningful connections

between the content encountered in university mathematics courses and the mathematics curriculum they will teach in K-12 classrooms. At the root of this failure are fundamental differences in educational goals and practices at the K-12 and university levels.

The National Council of Teachers of Mathematics (NCTM) offers detailed recommendations for teaching statistics in grades K-12. These recommendations have been endorsed by the American Statistical Association's (ASA) Advisory Review Group Response to the NCTM's Standards Update (ASA, 1998). While both the NCTM and ASA substantially agree on how best to present statistics to young learners, these recommendations have had relatively little impact on university statistics teaching until recently. As a result, most candidate teachers at Montana State University have never had the opportunity to take a university statistics course that embodies those principles and practices. Under the circumstances, it is no wonder that candidate teachers have difficulty transferring what they learn in traditional university statistics courses to their professional thinking and practice.

Additional problems arise among practicing teachers. For instance, instructors in grades 5-8 often have the same mathematics background as teachers in grade K-4, yet they are expected to teach more complex content. The additional challenges inherent in the more ambitious curriculum material often require them to be more like mathematics specialists than their original training may have prepared them to be. These teachers often have had little exposure to some of the mathematical ideas that ambitious curricula will require them to teach their students. Teaching mathematics and statistics in ways that make it understandable by students requires deep, flexible knowledge on the part of the teacher (Silver, 1998). Like today's candidate teachers, these professionals need advanced training adapted to their roles as educators.

NCTM Standards for Data Analysis, Statistics and Probability

NCTM's *Principles and Standards for School Mathematics: Discussion Draft* includes 10 Standards. Five of those Standards focus on content (addressing the mathematics that students should know in four grade bands, pre-K–2, 3–5, 6–8, and 9–12), and five focus on process (addressing ways of acquiring and using that knowledge). Standard Five is Data Analysis, Statistics, and Probability. In grades Pre-K-8, Mathematics instructional programs should include attention to data analysis, statistics, and probability so that all students –

- Pose questions and collect, organize, and represent data to answer those questions;
- Interpret data using methods of exploratory data analysis;
- Develop and evaluate inferences, predictions, and arguments that are based on data;
- Understand and apply basic notions of chance and probability.

Specifically in grades Pre-K-2, all students should –

- Represent data to convey results at a glance using concrete objects, pictures, and numbers
- Describe parts of the data and the data as a whole;
- Identify parts of the data with special characteristics, for example the category with the most frequent response;

In grades 3-5, all students should –

- Organize data using tables and graphs (e.g. bar graph, line plot, stem-and-leaf plot, circle graph, and line graph
- Compare data representations to determine which aspects of the data they highlight or obscure
- Compare related data sets, with emphasis on the range, center, and how the data are distributed
- Formulate questions or hypotheses based on initial data collection, and design further studies to explore them
- Compare the data from one sample to other samples and consider why there is variability
- Create graphs and consider how some presentations highlight or distort certain trends.

In grades 6-8, all students should –

- Choose, create and utilize various graphical representations of data (line plots, bar graphs, stem-and-leaf plots, histograms, scatter plots, circle graphs, and box-and-whisker plots) appropriately and effectively
- Interpret graphical representations of data, including description and discussion of the meaning of the shape and features of the graph, such as symmetry, skewness, and outliers
- Develop and evaluate inferences, predictions, and arguments that are based on data.

Essential Technological Competence

NCATE states that "No vision about the future of teacher education is likely to prove useful if it is not closely tied to a set of assumptions about the future of schooling and the impact of technology on school instruction" (1997). The International Society for Technology in Education (ISTE) recommends that all candidates seeking initial certification use computer systems to run software; to access, generate and manipulate data and to publish results. ISTE also states that teachers of students in grades 6-8 should be prepared to use content-specific tools, software, and simulations (e.g., environmental probes, graphing calculators, exploratory environments, Web tools) to support learning and research. NCTM (1998) also takes a strong position on technology in the classroom, stating as one of its Six Principles that mathematics instructional programs should use technology to help all students understand mathematics and should prepare them to use mathematics in an increasingly technological world.

It is imperative that teacher preparation programs give candidate teachers information about and experiences with calculator-enhanced instruction. Handheld technology can and should play an important role in mathematics instruction (Dunham & Dick, 1994; Heid, 1997: Hembree & Dessart, 1986; Smith 1997). However, common beliefs about the nature of mathematics and the goals of mathematics education work against a general adoption of these technologies (Fleener, 1995; Graber, 1993; Schmidt & Callaghan, 1992; Terranova, 1990). Teacher fears that students will lose computational skills, use calculators as crutches, and not master basic concepts, play an important role in limiting calculator usage (Payne, 1996; Simonsen & Dick, 1997; Smith, 1996; Zand & Crowe, 1997).

As tools for doing mathematics, students should use calculators and spreadsheets to carry out the procedures needed to solve problems. Graphing calculators and easy-to-use computer software enable students to move effortlessly between different representations of problem data and to compute with large quantities of data and with mess numbers, both large and small, with relative ease (NCTM, 1998). For several years, graphing calculators have been important tools in the middle grades math and science curriculum (TI, 1998). The large screen of the TI-73™ helps in building patterns, exploring data and understanding math and science problem solving. The TI-73™ allows students to easily view and edit numeric and alpha-numeric data in the list editor. Then plot data in several new statistic plots including pie charts, pictographs, bar charts, scatter plots, histograms and more. The list-based one and two-variable statistics including linear, quadratic, exponential, and manual-fit regression models allows students to interpret data. The following examples illustrate the use of this technology in teaching statistical graphs to elementary education majors.

Statistical Graphing Activities

Preservice elementary education majors at Montana State University usually enroll in MATH 131, Mathematics for Elementary Teachers II, as freshman. MATH 131 is the second of a two-semester series of math classes that must be completed two semesters before being admitted into the teacher education 'block-classes'. Preparing candidate teachers to deal with the content addressed in national Standards with confidence and competence is one of the goals of MATH 131 at Montana State University. Many MATH 131 students have very weak general mathematical backgrounds and almost no preparation in statistical understanding. These students have insufficient calculator skills and little experience with interpreting data. The activities used in MATH 131 are chosen to give experience in using the handheld technology while giving a great deal of experience in interpreting and evaluating data that they gathered.

Are You Above Average? (Lund, 1995) is used as an introductory calculator activity. It gives initial experiences in collecting, organizing and representing data concerning number of objects memorized after looking at a series of items for 30 seconds. Using compiled class data, students are instructed in creating and entering lists into their TI-73™ calculator. One list is the number of objects remembered and the other the frequency. Both a bar graph and a histogram are created and discussed. Students are asked which is the 'better' representation of the data and must justify their choice. Given the national average of number of objects remembered, students must then make interpretive statements about their personal number and also about group and class averages.

A series of activities using shoe size and height adapted from Jones & Day (1998) is used to introduce box-and-whisker plots, scatterplots and their interpretations. After collecting class data students examine features of both data sets, looking for the range, extraordinary values or outliers, and gaps or clusters. Students describe any important characteristics or patterns that they observe from the raw data. Box plots are constructed with the

TI-73™ calculator and the trace function is used to identify the five-number-summary values: minimum, lower quartile, median, upper quartile, and maximum. Students must give a written interpretation of the data concentrating on inferences that they can make about the entire freshman population at Montana State University and how this information could be helpful for local clothing merchants. The final use of the data is graphing the two pieces of data with height on the x-axis and shoe size on the y-axis. The TI-73™ calculator allows students to manually determine a line of regression. This equation can be stored and then compared to the line of regression that the calculator determines. Students can graph both equations simultaneously. They must interpret the data, justify their interpretations, and use their lines of regression to make predictions about other MSU student shoe sizes given their height.

In a third activity students record the class data of the number of hours of sleep they each had the previous night. By using the one-variable statistic function of the TI-73™ calculator, students record the mean, median, mode, standard deviation and range of the class data. Students interpret their data in relationship to information from the National Commission on Sleep Disorders Research Report (Lund, 1995). They also are introduced to the normal curve and uses of standard deviations when making statements about university students.

These and other activities give students a great deal of experience in using statistical graphs and interpreting them. The TI-73™ calculator is an excellent tool for exploration and manipulation of data for the preservice teachers in the Montana State University teacher education program.

Researching Student Achievement

Using the NCTM Standards and other mathematics education reform documents, I am constructing and validating a model of the knowledge, reasoning, and communication skills necessary to teach statistical graphs in grades K-8. Test items and associated scoring rubrics are also being constructed that address the specific knowledge and skills defined in the model. From these items, a one-hour, paper-and-pencil, group examination will be developed and validated. A mathematics attitude inventory will also be selected for use.

During 1999, this instrument will be administered to a sample of elementary education majors at different stages of the MSU Teacher Education Program. The data obtained will be used to characterize the statistical knowledge, reasoning, and communication skills of these students and to answer the following questions:

- What changes (if any) occur in students' statistical knowledge and skills during their undergraduate careers relative to nationally recognized mathematical and professional standards for elementary mathematics teachers?
- Are statistical knowledge, reasoning, and communication skills related? If so, are the relationships more pronounced at different stages of the teacher education program?
- Are student attitudes toward mathematics significantly different at different stages of the teacher education program?
- Are student attitudes toward mathematics related to their statistical knowledge, reasoning, and communication skills?

Elementary Education majors at Montana State University take three math classes prior to student teaching, MATH 130, MATH 131, and EDEL 333 Teaching Mathematics. Students in these three math classes and those in student teaching will be matched (4-tuples) on the following bases: AGE upon entering Math 130; sex; math placement score (SAT, ACT, or MSU Math Dept Test); number of high school mathematics courses beginning with first year algebra. A minimum of 30 matched 4-tuples will be selected for data analysis.

Findings will be reported to the MSU Elementary Education Program and, hopefully, improve understanding about the program's outcomes, strengths, and needs.

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Mathematics as a Factor in Technology and Curriculum Integration

Nancy M. Wentworth
Department of Teacher Education
Brigham Young University
Provo, UT 84602
United States
Nancy_Wentworth@byu.edu

Abstract: This study reports on a collaborative effort between a university teacher education program and a public junior high school in a program designed to investigate the integration of technology into the school curriculum. Several lesson plans were designed from many different content areas. Many of these lesson plans had a mathematics component. Mathematics content proved to be important to the integration of both technology and content.

Introducing technology into schools is a significant challenge because it requires change in curriculum and teacher practice. The Office of Technology Assessment (1995) concludes that for computer technology to become an integrated part of schools a high-quality preparation of staff is needed. Rutherford and Grana (1995) suggest that resistance to change is caused by an array of faculty fears. Included in these are "fear of change, fear of time commitment, fear of appearing incompetent, fear of techno lingo, fear of techno failure, fear of not knowing where to start, fear of being married to bad choices, fear of having to move backward to go forward, fear of rejection or reprisals" (p. 512). Several studies (Strudler, Quinn, McKinney & Jones 1995; Willis, Willis, Austin & Colón 1995; Roberts & Ferris 1994) show that one of the problems with integrating technology into any curricula is the teacher in the classroom. There are a number of reasons for this: computer illiteracy, computer phobia, disinterest, and lack of equipment, lack of support personnel, rapid technology changes makes it difficult for faculty to stay current, using technology is risky and faculty find it hard to take risks, and using technology is frustrating.

Teacher inservice can help teachers overcome computer illiteracy and phobia, but may not always help teachers integrate computers into their curriculum. Inservice programs that include a full-time, site-based training program, focusing on the individual needs of the teachers have a better chance of achieving the desired change of technology and curriculum integration (Pappillion & Cellitti 1996). The changes teachers must make take time and must reflect the concerns teachers have about technology and the curriculum.

Research Design

The focus of this research project was to investigate an inservice program aimed at developing curriculum that integrates technology into instruction that includes the problem solving process. The university-public school partnership had defined inquiry and professional development as two of its primary functions, so they were jointly committed to helping teachers develop new curriculum that integrated technology into the curriculum (O'Neil 1992; Broughy 1992). Participants had discussed the importance of defining problems for students to solve as a part of the inquiry process and that the problems needed to be authentic and real-world in nature. An earlier project began in a school with only one teacher being mentored by a university professor. The professor spent time helping a classroom teacher learn to use computer programs

that were available at the school. The teachers and students were introduced to a spreadsheet program as a tool in data collection and analysis problems. The students were then placed in groups of four and asked to design and complete a problem that would require the collection and analysis of data. The professor worked with both the students and the teacher to select the problem and analyze the data (Wentworth 1996).

As the program expanded to the whole school, teachers began to think about curriculum that could be enhanced with technology. These teachers were engaged in team planning for interdisciplinary instruction and had available to them the basic technology necessary for this project (computer labs for whole group instruction; spreadsheet, graphics, and word processing software). Participants worked with software that enabled them to integrate technology into their curriculum with minimal acquisition of new skills. Initial work began in group sessions with teachers from one or two disciplines and moved to the classroom when the teachers had planned instruction that needed technology support. The teachers were encouraged to move at their own pace as they used the technology in their classrooms. Reflection and evaluation was an on-going process to keep the project on course, given the increased numbers of persons involved. The approach was similar to the one proposed by Resnick (1996) in his proposal of distributed constructionism. Their worked was shared with others in the group and with their students. In the process of sharing and teaching, participants rethought their work and learned from each other.

The priority activity areas included, but were not limited to:

- Problem solving
- Communicating mathematics in written and visual (graphic) form
- Appropriate use of technology in instruction
- Applications of mathematics skills and concepts (especially data collection, organization, representation, and analysis)
- Establishing relationships and connections between the core curriculum and the materials and activities which are available for classroom instruction

Selection of Participants

Participants consisted of faculty from a junior high school, grades 7-8, in a urban western city. The participants received some initial instruction about the use of technology in the classroom. Time was given to discuss ideas for connecting technology to their existing curriculum. One or two key teachers became the support personnel at the school for all other participants. They focused on the following goals:

- Provide activities and support for the professional development of middle school classroom teachers in the use of technology and writing in problem solving.

- Guide middle school classroom teachers in planning for the integration of mathematics portfolio tasks in their interdisciplinary instruction.

- Provide situations in which middle school teachers refine their own mathematical communication, particularly writing (through the development of a portfolio) and representing mathematics (using spreadsheet and graphics software) for both instruction and assessment; and assist teachers as they provide similar opportunities at the appropriate level of development for their middle school students.

- Give on-site support to teachers as they implement the use of technology and writing in problem solving in their classrooms.

Sources of Data for Project Development and Evaluation

Each teacher participant developed a portfolio related to this project. This portfolio included a written integrated unit, sample lesson plans, sample student work, videotapes of two lessons, a teacher self-assessment of participation in this project, and teacher-determined items (see Stenmark 1991). Anticipated components include but are not limited to writings, photographs of projects, and drawings related to performance tasks completed; selected journal entries; videotapes of presentations; student self-assessment of participation in this project, etc. Each portfolio was evaluated holistically according to specified criteria developed by the project directors. The portfolios were read by all researchers to determine themes or patterns in learning (Miles & Huberman 1996).

Results

Fifteen lesson plans were created and implemented by the teachers, 6 history, 3 science, 2 English, 2 health, and 2 physical education. This represented 62 percent of all teachers who participated in the initial inservice activities. All of these lessons had a mathematics component. An example of a history lesson and an English lesson are presented below. Each has a description of the lesson objectives and a sample of the data collected by students. Then a graph of the data is included. It is these graphs that indicate the mathematics component in each lesson. Note that in the English language lesson students took the data and converted it to percents before they created graphs.

Gross National Product Lesson Plan

Using world data information, students will compare birth, death, and infant mortality statistics with gross national product data. Students will analyze the impact of GNP on these statistics. Students should know that data can be found on GNP and other statistics available for many countries. Students will learn what kinds of information are found about many countries. Students will learn the different life styles and living conditions of many different countries. Students will develop critical thinking skills as they write an analytical paper interpreting the data. Possible student products may include charts comparing GNP and birth, death, and infant mortality statistics, and reports of analysis of the comparison of these statistics.

Table 1 below shows the sample data collected by students. Figure 1 shows how students represented that the data graphically.

Country	Birth Rate/1000	Death Rate/1000	Infant Mortality/ LiveBirths	GNP
China	22	7	33	370
Haiti	43	15	106	440
Philippines	29	7	54	700
Venezuela	20	4	26	2150
Brazil	26	7	68	2540
Soviet Union	17	10	23	9130
France	14	9	6	15500
Japan	10	7	4	17100
United States	15	9	10	21800

Table 1: Student Created Data for GNP Lesson Plan

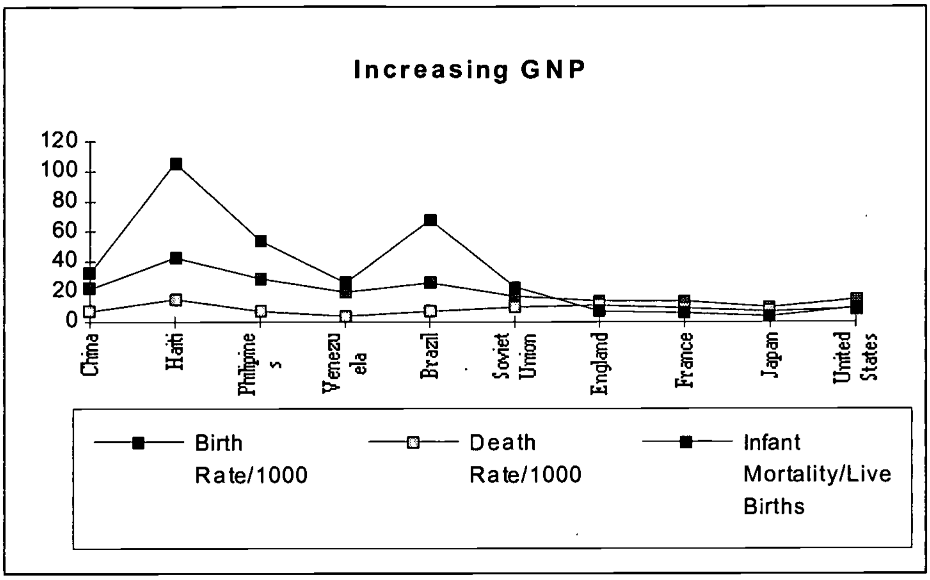

Figure 1: Student Created Graph From GNP Data

Language of Commercials Lesson Plan

Commercials are a part of our world. Students should be aware of how language is used to persuade individuals to buy products. Students will evaluate the uses of language in commercials. Students will understand the uses of language in commercials. Table 2 shows the data collected by students. In Table 3 the students converted the raw data to percents. Figure 2 is a graph created by students using the percents of each commercial type.

Type of Show	Sports	Soap Opera	Action	Comedy
Commercial Type				
Testimonial	12	5	3	3
Scientific	2	13	2	2
Comedy	3	5	4	10
Romance	7	8	6	3

Table 2: Student Collected Data

Type of Show	Sports	Soap Opera	Action	Comedy
Commercial Type				
Testimonial	50%	22%	13%	13%
Scientific	11%	67%	11%	11%
Comedy	14%	23%	18%	45%
Romance	29%	33%	25%	13%

Table 3: Student Collected Data Converted to Percents

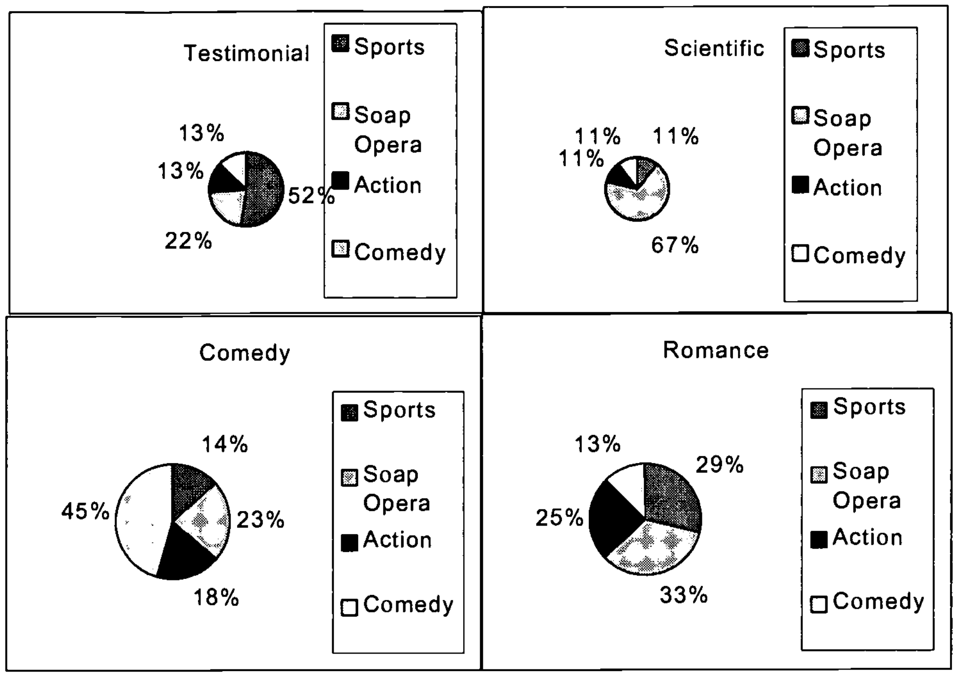

Figure 2: Student Created Graph of Commercials Data

Each example above shows how the use of technology was enhanced with the integration of the content area with mathematics. Teachers and students collected data on these questions and then began to define questions together. The teachers were excited to see students engaging in inquiry in this way. Mathematics as a part of the lesson plans help the students integrate technology into the lessons. Students could interprete the data using mathematics as a tool for thinking about the data collected.

Conclusions

Mathematics teachers seemed to use technology in their classrooms before any other teachers. Other content area teachers were mentored by the mathematics teachers so many of the projects defined during the projects included mathematical components. Teachers worked on the same software and began together, so they supported each other in the learning curve. Teachers were able to consider integration of content area as they included technology in their curriculum. Having a university professor at the school helped the teachers initially try the technology. They worked together with the students to learn the software, and then determine how it could enhance the curriculum. As the year progressed, the professor spent less time teaching how to use the technology and began to help teacher rethink instruction and content. New types of problems were considered because the technology could help the student investigate and seek out answers.

Both students and teachers enjoyed experimenting with the technology. They worked together to define questions that had significance for the content of the curriculum. The questions were complex and interesting, requiring many days to complete. Teachers and students worked several days defining the problem and deciding on the data required to answer the question defined by the problem. Teachers and students felt like co-investigators and learners. The teachers began to feel confident in their abilities to use the technology. The began to trust the students to learn specific content as they defined their own problems.

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The Impact of Web Resources on Teaching and Learning in Mathematics

Harley Weston
Dept. of Mathematics and Statistics
University of Regina
Canada
weston@math.uregina.ca

Mhairi (Vi) Maeers
Faculty of Education
University of Regina
Canada
maeers@uregina.ca

Denis Hanson
Dept. of Mathematics and Statistics
University of Regina
Canada
dhanson@math.uregina.ca

Abstract: Emerging from discussion at an international conference the authors of Math Central designed a survey to determine how web resources are being transformed into the classroom teaching/learning environment, and if these resources made a difference to mathematical learning. This paper refers to some background literature on the potential of computer technology and also on the potential of web resources on learning. Some preliminary results from the survey are included.

Introduction

During a series of technology seminars at the 1998 U.S.- Russia Joint Conference on Mathematics Education, in St. Petersburg and Moscow, there was much discussion on the use of technology as a tool for teaching and learning mathematics. Computer software was demonstrated (e.g., the Verifier created by Sergey Pozdniakov) and web sites were visited (e.g., Math Central, created by Harley Weston, Denis Hanson, and Vi Maeers). While software, websites, and e-mail are useful resources in teaching and learning, it appears that a great deal of time is given to the actual mastery of skills associated with the use of technology. Technology has become the focus, perhaps because it poses a tremendous learning curve for many teachers. Learning about technology needs to be replaced by learning with it and from it, such that the 'tool' becomes invisible. Discussion at this joint conference focused on getting beyond the glitz and glamour of technology for its own sake to pressing questions such as "Can technology make a difference in mathematical achievement?" or "Do students learn mathematics more deeply (with greater understanding) through the use of technology?" or "Does technology make a difference to how students learn mathematics?"

Learning Effectiveness

Potential of Technology

A recent Edmonton Journal published an article entitled "Computers help with Grade 9 math, study shows." The article states that Grade 9 students in British Columbia and Alberta, using computers and a specific courseware called "The Learning Equation (TLE)," showed significant gains in mathematical improvement, as indicated by provincial test scores. The TLE program is highly structured and highly dependent on trained instructor mediation. Hours of teacher inservice precede classroom implementation.

Harold Wenglinsky (1998) analyzed data from the 1996 National Assessment of Educational Progress (NAEP) regarding how students and teachers used computers in mathematics. The final report of his analysis was recently published in Education Week's *Technology Counts*. His major finding was that computers can raise student achievement in mathematics, *dependent on how they are used*. Used in certain ways computers can make a positive impact on raising test scores. His results indicate that students who used computers for simulations and applications (involving higher-order thinking skills) performed better on the NAEP than students who did not have this opportunity. This was also true for grade 4 students who used the computer for mathematical learning games. Drill and practice computer activity did not produce higher test scores--indeed such activity was negatively related to academic achievement. Wenglinsky maintains that it is not computers themselves that make a difference or how often they are used; it is the quality of the student/teacher/computer interaction and the focus on higher-order thinking skills that is critical.

Harris (1996) agrees with the focus on higher-order thinking skills. She speaks of the incapability of any object or machine to bring knowledge to the knower. Knowledge, she says "is a result of the process of knowing, which can only occur as the learner actively *constructs* what he/she knows, using information in this process (14). Knowledge results when one personally transforms information attained through social negotiation of ideas, through justification and acceptance of the publication of one's ideas, and through personal internalization and reflection. Knowledge does not exist as an external commodity to be uncovered. Harris considers the students of today as Information Age Citizens, who must learn not only how to access information, but more importantly, how to manage, analyze, critique, cross-reference, and transform information into useable personal knowledge.

Moersch (1998) states that it is "the manner in which computers are used as tools to support students' thinking and reasoning skills across the curriculum" (50) that is important. Each of the six narratives outlined by Moersch depicts a classroom where technology is invisible or "seamless," where it is a rich tool to investigate, explore, ask questions about, and problem-solve authentic real-world situations. Students in each classroom are engaged in higher-order thinking processes, such as identification of a problem situation, making decisions and choices about strategies, inquiry, reflective thinking, justification of solution, and discussion, group or collaborative efforts. Before computers these teachers would most likely have focused on the same attributes. Technology has made more things possible, has opened up new avenues for discovery and research, more opportunities for problem solving. Moersch states in his conclusion that "these teachers have used existing technology and community resources to transform their classrooms into dynamic centers of purposeful and experiential learning that intuitively move students from awareness to authentic action" (53). In a previous article (Moersch, 1996-97), where in two schools the instructional use of technology was measured, the "level of computer efficiency is influenced directly by how teachers are using computers to develop students' higher-order thinking skills" (54). Moersch (1996-97) defines computer efficiency as "the degree to which computers are being used to support concept-based or process-based instruction, consequential learning, and higher-order thinking skills (e.g., interpreting data, reasoning, solving real-world problems)" (52).

Harlow and Johnson (1998) outline an epistemology that relates to information technology. Bruner (1990, 1996) writes about the importance of story, of narrative, as a way of knowing and states that it is our ability to tell stories of our experience, to provide analogies, metaphors, to communicate our knowledge through narrative that enhances our learning. Our stories, from remembered experience, are formed using tools. Computers and computer-related technologies as tools in the hands and minds of the user or storymaker can create richer stories, richer personal narratives, dependent upon the type of computer use engaged in. Maddux, Johnson, and Willis (1997) have categorized computer use in education as Type I and Type II. Type I applications use computers to teach more efficiently the same content in the same ways to the same clientele as previously. Type II applications address more sophisticated uses that focus on critical and higher order thinking functions, and to do things impossible before. Learners placed in autonomous learning situations, involving computer-related technologies, where personal learning choices and personal goal-directed activity are emphasized, have greater story-making capabilities as they have at their disposal a greater array of story-making devices (text, graphics, charts, spreadsheets, sounb, video, pictures). An epistemology of information technology addresses "its capacity to develop stories" (Maddux, Johnson & Willis, 1998, 18). Learning involves the art of creating narratives from experience. If our experience has been the transmission of a bunch of single unrelated bits of information, with no connecting thread, then our story will be simple, unconnected and perhaps not even capabale of being told. To tell a story means that the story teller has a full understanding of the concept and can embed the concept into a meaningful narrative. This is the essence of learning and perhaps the essence of good teaching--the ability to tell stories and to create a context for others to learn in--the basis of Kieran Egan's (1986) book "Teaching as Story Telling."

Potential of the Web

Interactive web technology or hypermedia is perhaps one of the most sophisticated and complex technologies currently available. Each website is a complexity of hyperlinks within the site and to other sites. Within each site there is information. For this information to become personal knowledge rather than acquisition of facts, the learner needs to interact with the hypermedia environment in an autonomous goal-directed manner. The learning can be mediated by a more experienced learner (perhaps a teacher), it can be demonstrated through conversation, through displays, argument, justification, and so on. In other words, this information, for it to become personal knowledge, must form a narrative of experience which can be storied to others. Can information acquired through web technology become part of a personal learning schema, to be passed on through story to others? If it cannot be storied then, according to Bruner (1996) and Schank (1990), it is not truly personal knowledge. Therefore learning, in the full meaning of the learning context, has not occurred. Individual bits of information could be spouted back, such as answers to specific questions (e.g., times tables) but if the learner was asked to teach the new concept or understanding to others, the learner would not be able to do it in a contextually meaningful manner.

To understand how web-based resources are being used by teachers in the teaching/learning process the authors feel that there are a number of issues that need to be addressed. From a variety of literature sources the following questions have been compiled.

A. Teaching

- Preparing to teach
    1. Do teachers have adequate technology skills to efficiently and critically 'surf' the net for appropriate resources to incorporate into lessons? If not, then how can teachers become 'skilled?'
    2. Can teachers discriminate among the plethora of web resources to select the best resource?
    3. Can teachers then connect the resource to appropriate curriculum objectives?
- Actual classroom teaching
    1. How do teachers implement the web resource? Does it appear as a worksheet, as a slide presentation, as a demonstration, as something on-line, with which children interact?
    2. How do teachers mediate the web resource in teaching?

B. Learning

1. What does the web-based classroom learning environment look like? Is the web tool visible? Do children know that it's a web resource?
2. How do children work with the web resource?
3. What kind of effect does working with this medium have on learning? Does it make learning more interesting, more engaging? Does it enable children to learn differently and/or to learn better?

Measuring the Impact of Web Resources on Mathematical Learning

A survey is currently being conducted on the Math Central site to gather information on these questions. A link to the questionnaire can be found on the first page at http://MathCentral.uregina.ca. It was hoped that results from this survey would help determine how teachers transform web resources into elements in the teaching/learning environment. The following is a portion of the responses to four of the survey questions:

- What kind of material are you looking for when you visit Math Central or other web resources in the teaching/learning of mathematics?

    Word problems; Lesson plans, especially hands-on investigative type; Ideas on activities that teachers have tried and found worked well; Lessons that include not only the activities for students, but also a thorough background of the mathematics concepts involved.

- Has this resource extended the mathematical understanding or mathematical achievement of your students?

Yes

My students are used to doing worksheets and not thinking. The problems I found at your site help them to think about math.

Mostly because the more information I have, the more ways I can present the information to my students.

As in the example above, I like to take problems that I get over Math Central and challenge my students with them. I also find teaching ideas that have been tried by other teachers that they have shared which have been somewhat helpful in my classes.

No

I found that the questions that were provided for a specific grade level did not actually match my students' abilities, so I spent a lot of time modifying and making changes.

- When you find something you like what do you do with it?
(Most respondents selected either or both of the options)

I use it to help me in planning my lesson or activity on a day to day basis.

I use it as a resource in the implementation of my lesson or activity--
i.e., something tangible that the students can interact with.

- Do you think that the Internet and the World Wide Web can make a difference in mathematical achievement?
(Quotes from some of the respondents illustrate their expectations and frustrations.)

"Only if the teachers and students are web literate, and the resources actually are closely related to the curriculum."

'We are a rural school in North Carolina, USA. Like so many schools in similar settings, we appreciate sources that support our curriculum and enhance our available materials.'

"The problem of course is not getting overwhelmed by what is available."

"Sometimes it is difficult to come up with just the right search words for the information I am seeking. I waste more time searching than is necessary, and I am a fairly proficient searcher. For some, the search must be daunting!"

Summary of Survey Results

Preliminary results indicate that teachers are using web resources on Math Central (and on other websites) mainly in the planning stage of teaching, some to learn more about the topic to be taught in class (content knowledge), some to find an activity to use in class with the students. Most of the material from the web has been transmitted to the teachers in textual and graphical format and has been transformed into text (lesson plan).

Closing Remarks

Traditional classroom teaching methods related to mathematics have been associated with direct teaching, workbook or textbook seatwork, drill and practice activity, homework review, blackboard demonstration, and so on--a positivistic behaviourist model. Teachers who generally teach mathematics this way will most likely use technology similarly. As reported in Technology Counts "the computer's most powerful uses are for making things visual. It can make visual abstract processes that are otherwise ineffable" (quote from James Kaput, a math professor at the University of Masachusetts at Dartmouth, in Wenglinksy, 1998) suggests a number of other positive outcomes from using computers--well. He reports higher student motivation, especially when students are using the computer in sophisticated ways, not simply for routine drill and practice activity; the enhancement of a school's educational climate, such as high attendance, low tardiness, and better morale, greater interest in school and in learning. According to Wenglinsky, "one of the real benefits of different types of technology is the way they influence how teachers and students relate to each other."

There is a growing concern in Canada that while research has indicated that technology has made no noticeable difference to student achievement, school boards are more and more quickly getting wired, with little or no thoughtful consideration to how technology will be integrated into the curriculum. Jones and Paolucci (1998) have conducted a mega-analysis of over 800 education technology journals to determine learning effectiveness of educational technology. Their analysis concluded that only about 5% of all the 800 articles reviewed were slanted towards any empirical evidence regarding learning effectiveness. Their article indicates a tremendous need for such studies to be conducted. The Canadian Teachers Federation and in particular the writings of Heather-Jane Roberston and Marita Moll aim quite pointedly at the lack of any valid empirical research base to claim that technology has impacted on student achievement and higher test scores, and that without such evidence we should not be spending tax dollars on computer implementation.

Computers, computer-related technologies, communication technologies, and web technologies can all affect student learning and can impact on mathematics achievement, but it all depends on what teachers and students do with them. Effective teachers will find thoughtful, pedagogically-appropriate ways to transform computer-related technology into rich clasroom learning environments. Technology, and specifically web technology, in the hands of an effective teacher, will simply become one more "invisible" tool in that teacher's arsenal of resources.

School or classroom computer configuration, individual access to computers and/or to the Internet, whatever our vision is of the architecture of an ideal model technology classroom is insignificant compared with how computers are used--what are teachers and students doing with them. Effective teachers generally speaking, will use technology effectively. Effective teachers, who choose to integrate technology into their classroom teaching/learning environment, will generally do it well. If they don't know much about it they will learn, if they want ideas about how to integrate, they will ask. Their already excellent teaching approaches will remain excellent. Their constructivist and child-centered theoretical perspectives will now simply include technology as part of the environment, with children remaining as autonomous as ever. Technology itself will have no affect or impact on learning or higher achievement scores if good teaching is absent. Teachers make the difference, not technology.

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The Challenge-The Issues-A Successful Model In Teacher Education for Integrating Technology in the Teaching and Learning of Mathematics

Dr. Trena L. Wilkerson
Department of Curriculum & Instruction
Louisiana State University
United States
twilker@lsu.edu

Abstract: This paper will discuss the challenges and issues related to designing and implementing a model course to prepare K-12 mathematics teachers for the integration of technology in the mathematics curriculum. A description is given of a course model implemented at Louisiana State University with examples of specific activities and projects designed and developed by the classroom teachers to engage students in the learning of mathematics through the application of technology. Results and impact are described.

Introduction

Mathematics teachers across grade levels are being faced with a myriad of challenges and opportunities through the incorporation and advancement of technology. From the use of graphing calculators to high-tech multimedia packages teachers must confront key issues in integrating technology in the classroom for effective instruction. The National Council of Teacher of Mathematics (1989) in the *Curriculum and Evaluation Standards* argue that the very nature of technology is changing mathematics and its applications. Further they advocate that calculators and computers be available to students and teachers for teaching and learning mathematics. It is critical that students be able to utilize technology for processing information and problem-solving and thus teachers of mathematics must become proficient in the implementation of technology in the curriculum.

It is the responsibility of colleges and universities to prepare teachers in all disciplines to be able to effectively teach in a technological environment (National Council of Teachers of Mathematics, 1991; United States Department of Education, 1996). In order for students in education programs to prepare to teach in this environment, colleges and universities must offer appropriate courses and experiences that reflect the direction dictated by the needs of a our changing society. The Mathematics Association of America (Leitzel, 1991) further outlines the necessity to provide specialized classrooms and laboratory facilities equipped with the latest technology including calculators and computers. This is essential in order to prepare mathematics teachers for the goal of facilitating student learning and understanding. Teacher education programs must include learning environments and opportunities that actively engage both preservice and inservice teachers of mathematics so that they may become successful in the teaching profession and thus prepare their students for a technological world.

Who should use technology? Why should technology be utilized for instruction in mathematics? How can it be used efficiently and effectively? How does one select appropriate technology? These are among a few of the questions being asked by teachers in the classroom. With these questions have come the challenge for colleges and universities to provide a model for integrating technology in the classroom for instruction. This challenge is not only for preservice teachers but for teachers presently in the classroom. Louisiana State University (LSU) College of Education has met that challenge by providing opportunities for classroom teachers to learn about technology and how it can be used in the classroom. This has been done through professional development projects, inservice workshops, integrating and modeling the use of technology in courses and developing courses specific to the use of technology in content areas such as mathematics and science.

In 1997 The National Council for Accreditation of Teacher Education, NCATE, released a report by the NCATE Task Force on Technology and Teacher Education that emphasized the need for teacher education programs to be revised to reflect the growing technological advances necessary for preparing teachers of

tomorrow. The report accentuates the need for teacher education programs to integrate the use of technology in appropriate forms that not only model the use of technology in the classroom but give direction for its place in the thinking and learning process.

The National Council for Accreditation of Teacher Education (1997) in *NCATE Approved Curriculum Guidelines* identifies specific criteria for preparing participants in teacher education programs for the integration and use of technology for instructional purposes. Such criteria as described under the *Specialty Content Preparation in Educational Computing and Technology Literacy* guideline advocate the use of technology to support content areas. Performance indicators include use of advanced features of productivity tools and the development of multimedia products in line with instructional design principles. The *Professional Preparation* guideline outlines the preparation needed to integrate teaching methodologies with the use of technology to support teaching and learning. Performance indicators address designing and practicing methods and strategies for teaching concepts and skills through the use of technology resources.

NCATE's guidelines for teacher preparation programs regarding educational computing and technology point out the need for teachers to use and integrate a myriad of technology applications to enhance student learning (1997). With this reform mindedness and a vision for preparing teachers by providing an exemplary program with essential experiences in technology as challenged by Wiebe and Taylor (1997), Louisiana State University's teacher education program has sought multiple avenues for addressing these issues. One such avenue is through the modeling and integrating of technology in specific courses that prepare preservice and inservice teachers of K-12 mathematics.

This paper discusses the challenges and issues related to designing and implementing a model course to prepare K-12 mathematics teachers for the integration of technology in the mathematics curriculum. A description is given of a course model implemented at Louisiana State University with examples of specific activities and projects designed and developed by the classroom teachers to engage students in the learning of mathematics through the application of technology.

A Model

The technology integration course offered through the Department of Curriculum and Instruction at Louisiana State University focuses on the integration and implementation of technology in the mathematics curriculum at the elementary, middle school, or secondary levels. Over the past three years this course has been implemented several times. Modifications and revisions based on ongoing research in classroom practice have given the course a sound foundation for the focus of technology integration in a content area.

This course provides K-12 mathematics teachers the background and skills necessary to help their students learn with technology. Participants become familiar with the various roles technology can play in a mathematics classroom, develop personal competency in the skills needed to implement each type of application, and develop the background and awareness of the issues involved in making decisions guiding classroom applications of technology. The teachers develop activities and lessons incorporating various technology applications to enhance the learning of K-12 mathematics. Lee and Wu (1998) stress the necessity that teachers not only be computer literate, but application literate. It was on this premise that each learning experience provided in the course involve both the use of the technology studied and its application to the teaching of mathematics across grade levels. Technology is viewed as a viable resource from which to select when planning lessons to develop mathematics concepts.

The education students, preservice and inservice classroom teachers, in these classes analyze issues related to the use of technology in the mathematics classroom developing ideas on possible solutions and directions. The course is designed to give teachers access to and experiences with the appropriate technology and guidelines for implementation. According to Garofalo, Shockey and Drier (1998), "the most effective way to bring about enhanced student learning of mathematics through technology is to prepare teachers to incorporate into their teaching classroom and project activities that will engage students in technology-augmented mathematical thinking" (p. 585). Thus a goal of this course is that the teachers engage in effective, appropriate activities that model the use of technology for the teaching and learning of mathematics while aligning with pedagogical concerns. Connell's (1998) study of the use of technology in two mathematics classrooms taught by constructivist teachers notes the need for technology to be supportive of the underlying instructional approach and philosophy of the class. One teacher used the computer as an exploration tool for the students aligning with the philosophy of the class, while the other utilized the computer as a presentation tool which denotes a behaviorist approach conflicting with the constructivist philosophy of the class. While students in both classes showed significant improvement, the one aligned with the constructivist teaching philosophy

were much greater. To have maximum impact on student learning and understanding the integration of technology must be pedagogically aligned. Thus both the mathematics curriculum and pedagogy are concerns of the course.

Initially students are given a technology survey to assess their background in the use and understanding of technology. This information is utilized by the instructor to guide experiences with technology throughout the course. This is an effort to individualize and structure the course to benefit all participants. Students then begin to work with various computer tools such as word processors, digital cameras, scanners, and instructional software. Authenticity of experiences is key to the successful implementation of the technology by the students. Thus all activities are designed in such a way as to engage the students in mathematical activities that model their use in the K-12 mathematics classroom. These are followed by assignments that have the students design activities and lessons that develop or support mathematical concepts in the K-12 curriculum while utilizing appropriate technology.

The course was built around the following areas: Tools for Instruction and Presentation, Mathematics Instructional Software, Issues of Implementation and Cognition, Internet Usage, and Project-Based Learning. These are supported through readings from Grabe and Grabe's *Integrating Technology for Meaningful Learning* (1998), selected readings from professional education and technology journals, authentic technology assignments, class discussions, and presentations.

Sample Activities and Assignments

Throughout the course teachers were introduced to various technology applications through engaging activities in the context of mathematical concepts and topics. This was followed by assignments that allowed them to apply this new knowledge to the mathematics curriculum pertinent to their experience and grade levels. Teachers worked in various modes both individually and collaboratively with the instructor acting as a facilitator. Assignments were given basic guidelines but were open-ended in nature as to provide opportunities for creativity and flexibility for each individual.

For example, in the course after comparing and contrasting graphing software packages such as *GraphPower*, *Graphers*, and *The Graph Club* through authentic mathematical activities, the teachers in the course constructed specific activities for their students to engage in for which they would utilize the graphing software. These activities focused on the active learning processes necessary for the development and application of mathematical concepts applicable to their grade level curriculum. On several occasions the teachers were able to implement their designs in their own classrooms with their students. This gave them the opportunity to reflect on the specific tasks and issues involved in developing that particular mathematical concept with technology.

Other assignments provided opportunities to evaluate software and examine specific areas to attend to in selection of appropriate software for mathematics instruction. Teachers designed mathematics lessons that utilized the specific software evaluated. Teachers used *Aldus Persuasion* to present their findings and created flyers or brochures to support their work. As with every assignment it was critical for the teachers to experience the integration of all types of technology to understand how they were related.

In an effort to address multimedia software, teachers designed a *HyperStudio* stack that supported or developed a particular mathematical topic or concept. The teachers were to design either a stack typical of what one of their students would produce based on a particular area of study or one in which they as the teacher would use for instruction. This assignment was essentially a culminating activity in which they used multiple media capabilities. The teachers were able to not only gain insight into the effective implementation of project-based learning, but could demonstrate their own understanding and expertise in the use of technology.

Ultimately the participants in the course were able to not only develop skills and expertise in the use and implementation of technology to enhance mathematics teaching and learning, but were able to compile extensive technology resources and applications. The experiences in the university course allowed them to become knowledgeable about both hardware and software needed to ensure an effective, model classroom. Much of what they were exposed to in the course was actually available to them at their school sites. They now felt qualified to implement it appropriately in their instruction. When the technology was not readily available, they personally purchased or had their schools purchase software and hardware they were introduced to in the course for their classrooms and schools.

Teacher Benefits

Both during and after the course, teachers shared their "stories" of integrating technology. They shared their successes and challenges. This sharing revealed positive effects in attitude, expertise, and implementation in the K-12 mathematics classroom. One teacher in particular who was a technology novice showed extreme anxieties about the use of technology at the beginning of the course. A new multimedia station had just been placed in her classroom and she was at a loss as to how to use it, much less use it effectively for instruction! During the course she shared:

> "I will be able to use these things in my classroom. I've learned so many new things! I have time to use the computer *(in the course lab)* and not just talk about how to use it. I was so overwhelmed at first, I almost dropped the course. I'm glad I stuck it out."

This same teacher was able to directly implement technology-based instruction in her teaching of elementary mathematics in her classroom during the course. She was able to reflect and immediately share her experiences with classmates in the course. Linkage of course theory and experiences to their own classroom practice was a vital component of the design of the course. Actual K-12 classroom implementation was essential for validation of their learning experience.

Other teachers in the course noted the benefits of hands-on experiences and authentic activities. In particular, many supported the importance of producing materials that could be used in their own classrooms. They felt less anxiety over using technology and believed they were better equipped to teach mathematics using technology. The teachers were more confident in their ability to make instructional decisions concerning the appropriate use of technology. Many have continued their study of the effective use of technology for instruction by participating in additional related seminars and coursework. To illustrate the impact of their experience the teachers in the course have found they are viewed as the "experts" in the area of technology in their school environments. They are sought after for inservicing their colleagues and for advice on purchases regarding technology.

Summary

It is essential for teachers to actively participate in engaging technology models of instruction in order to prepare themselves to effectively utilize technology for instruction in their own classrooms. The modeling and hands-on experience necessary for effective integration of technology can come through venues such as the course described in this paper. The benefits of such a course model were discussed and samples of successful implementation by mathematics classroom teachers were described. This model represents one method for addressing the growing needs of classroom teachers in relation to the integration of technology in mathematics education. While this is the apparent need at this juncture, it is hoped that in the future, courses such as this will be replaced by students having actual experiences with such learning through their schooling experience prior to entering a teacher education program. Having experienced the full integration of technology in their own schooling will give teachers a true model for instruction!

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Acknowledgements

Special thanks to Dr. Harriet G. Taylor, College of Education, Louisiana State University for her assistance in the design of this course.

PANELS

Spreadsheets: A New Form of Educational Software for School Mathematics?

Sergei Abramovich, Department of Teacher Education, State University of New York at Potsdam, USA
abramovs@potsdam.edu

Hollylynne Stohl Drier, Curry Center for Technology and Teacher Education, University of Virginia, USA
hollyd@virginia.edu

Sharon Dugdale, Division of Education, University of California-Davis, USA
ssdugdale@ucdavis.edu

Simon Mochon, Center for Research and Advanced Studies, MEXICO
smochona@buzon.main.conacyt.mx

Erich Neuwirth, Computer Supported Didactics Working Group, University of Vienna, AUSTRIA
neuwirth@smc.univie.ac.at

John Woodward, School of Education, University of Puget Sound, USA
woodward@ups.edu

Abstract: It has been a worldwide concern that novice mathematics teachers are not well prepared to use technology in the classroom. The lack of such preparation may be due, in part, to a gap between technology offered by schools of education and what the teachers find available at their workplace. The authors believe that spreadsheets have a real potential to bridge this gap. Because of its increasing availability as part of generic packages, a spreadsheet can be considered as a new generation of school-based educational software which is not dependent on financial constraints and commercial availability. This aim of the Panel discussion is to highlight various approaches to the use of spreadsheets in mathematics education and in doing so to familiarize the audience with educational potential of a spreadsheet as a tool for teaching a variety of concepts in school mathematics.

Introduction

Nowadays familiarity with spreadsheets is often treated as one of the components of computer literacy and therefore the proficiency of mathematics teachers in the use of the software for students' conceptual development becomes a crucial factor in incorporating this tool into school mathematics curriculum. The teachers' comfort level with spreadsheets as conceptual tools can significantly affect the development of educationally sound and purposefully oriented activities. In the first section *Hollylynne Drier* discusses how secondary pre-service teachers can use spreadsheets as a tool for modeling applied mathematics concepts in a multiple representation environment. In the second section *John Woodward* focuses on findings from a research project in which spreadsheets were used in the context of reforming remedial and special education mathematics classrooms. In the third section *Sharon Dugdale* introduces a spreadsheet as a bridge between classical and modern mathematics concepts. In the fourth section *Erich Neuwirth* discusses the role of representation paradigms in the process of constructing concepts in mathematics education and shows that both calculation and understanding of mathematical concepts can be supported by the use of the spreadsheet paradigm. In the fifth section *Sergei Abramovich* suggests that the use of a spreadsheet as an interactive manipulative environment can support the development of combinatorial thinking in the elementary mathematics classroom. The integration of spreadsheet-enabled mathematics pedagogy in a broader context of an interdisciplinary education is the content of the last

section in which *Simon Mochon* shares findings from a project aimed at the investigation of the role of modeling with spreadsheets across a range of subject areas.

Spreadsheet as a multiple representation environment

One highlight of the Panel is how secondary pre-service teachers can use spreadsheets as a tool for modeling mathematical concepts in a multiple representation environment. In much the same way that one uses the laboratory to discover and test scientific laws, the pre-service teachers' work with spreadsheets includes the variation of several numeric parameters that control a phenomenon in a realistic situation followed by the observation of the corresponding changes in graphic form. Such modeling activities are aimed at the conceptualization of relationships among numerical, graphical and algebraic representations of mathematics concepts. Two examples of using spreadsheets in such contexts include maximizing area of a rectangle given a perimeter and controlling projectile motion (Garofalo, Shockey, Harper, & Drier, 1999).

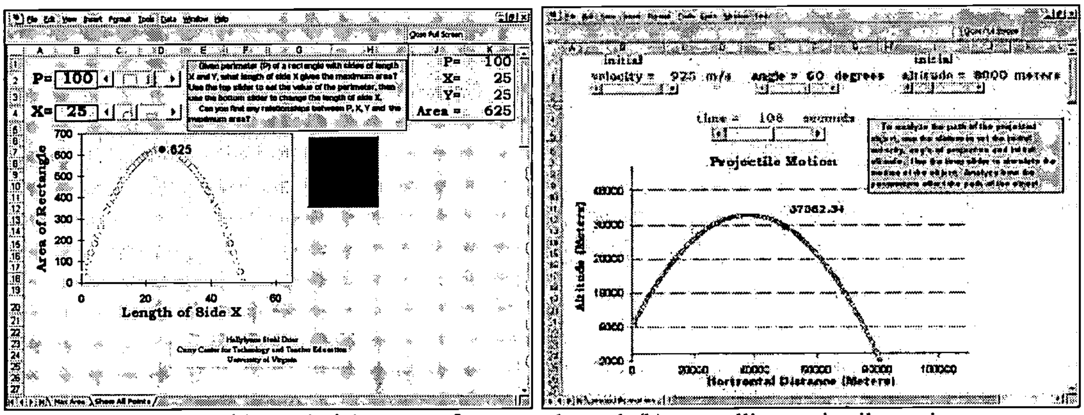

Figure 1: (a) Maximizing area of a rectangle; and (b) controlling projectile motion

The area problem can be used in mathematics classes from middle school to calculus. The spreadsheet environment allows the students to use sliders to change parameters of the problem and dynamically observe the results in numeric, geometric, and graphic forms (Figure1, (a)). This environment facilitates the search for patterns that can lead to generalizations. Through repeated experimentation within the environment, students should recognize that the value of the parameter X that results in the maximum area is one fourth of the perimeter P. Calculus students could confirm this relationship using the first derivative of the equation $Area = X(P-2X)/2$.

The spreadsheet-oriented study of parametric equations and trigonometry can be connected with the study of projectile motion in physics. The projectile motion environment (Figure1, (b)) was originally conceptualized by Jerril Burnette, a preservice teacher at the University of Virginia. With the ability to manipulate time, students can animate the motion of the object and explore how long it takes for the object to reach its maximum altitude and when the object will hit the ground. By varying the other parameters, the students can explore how each affect the path of the object and which values will maximize or minimize altitude and horizontal distance. Manipulating different parameters and visualizing the path of the object can make the mathematical equations used to describe projectile motion more relevant and meaningful.

The modeling activities promote interactive and open-ended exploration of mathematical concepts, take advantage of spreadsheet capabilities that allow the learner to extend beyond or significantly enhance what could be done using paper-and-pencil environment, and give teachers and students an opportunity to discover mathematical concepts in a laboratory-like setting. Creating and using such simulations allow teachers to use a spreadsheet to help students make connections between numeric, algebraic and graphic representations of real world phenomenon.

Spreadsheets in remedial and special education mathematics classrooms

The Workplace Literacy Project (Woodward, Baxter, & Robinson, in press) was funded by the US Department of Education, Office of Special Education Programs. The purpose of this project was to address the type of instruction often called for by a number of national policy documents (see US Department of Labor, 1991) and mainstreamed publications (see Reich, 1991) in the 1990s. These documents strongly suggest that successful workers in the future will need to demonstrate a capacity for higher order thinking, a proficiency in interpersonal skills, and conversance in a range of common, technological tools. The target audience for innovative approaches developed by the researchers were secondary students with learning disabilities as well as students in remedial mathematics classrooms. Throughout the project, the researchers worked with remedial and special education mathematics teachers to create classroom environments where students took a much more active role in their learning. At times, teachers initially modeled new ways of thinking and acting. However, teachers quickly moved from this kind of teaching to periods of sustained classroom dialogue and small group, cooperative learning. In addition to instruction that focused on the conceptual dimensions of core middle school mathematics topics, students worked on mathematical problems that spanned several days. The problems often integrated their mathematical investigations with written and oral communication. Calculators, spreadsheets, and word processors were typically available as tools for problem solving and communication. Spreadsheets were particularly important as tools for modeling data that had been collected from authentic sources. The focus of the Panel discussion in this context is mathematical problem solving that is both conceptually oriented and extends to the world of work.

Bridging classical and modern concepts with spreadsheets

A critical aspect of technology in mathematics education is that it does not simply facilitate a traditional curriculum, but offers new avenues of exploration and ready access to new mathematical domains. Students working with spreadsheet-based mathematics can be just a keypress away from mathematical frontiers. For example, by entering a negative number into a spreadsheet model of the well known divide-and-average square root algorithm, students can find themselves confronted with seemingly chaotic behavior as the spreadsheet's successive calculations no longer converge to a square root. Familiarity with advanced mathematics, however, is not an imperative in this setting. Rather, through the exploration of a square root model requiring only basic algebra and reasoning skills, the concept of chaos arises naturally as an extension of a familiar algorithm (Dugdale, 1998). Preservice teachers used a combination of tabular and graphical spreadsheet representations to investigate this remarkable phenomenon. Their explorations took a variety of paths, and several of these paths eventually merged to explain the function's behavior and establish order in the chaos. The spreadsheet environment was instrumental not only in having the unexpected problem arise in the course of a familiar topic, but also in providing the tools necessary to pursue the problem to conclusion.

Uniqueness of a spreadsheet as a numerical environment

Outside of mathematics, spreadsheets are probably the most widely used programs for any type of numerical calculation. One of the reasons of such a uniqueness of a spreadsheet as a numerical environment is that calculations can be set up by "point and click" at a cell without the need to use variables as in most of the other numerical environments. Cells are the equivalent of variables. This is very natural, because the cell contents can be varied. A mathematical model or the equivalent of a formula is the connection and relation between the cells of a sheet. Therefore, a spreadsheet as a numeric environment enables an alternative representation of mathematical structures which can be visualized by spatial arrangements instead of named variables. Consider the binomial coefficients as an example. The table containing these numbers (Figure 2) can be described very easily: the first row contains 0's everywhere but the first position which contains 1. All cells in the first column and below the first row contain the value directly above, i.e. 1. For all other cells the value is the sum of the value directly above and above and to the left. This visual

definition is a complete description of the table which, in turn, makes it possible to derive mathematical results about the binomial coefficients (Neuwirth, 1995).

Consider all the numbers in the first row. Each number contributes to the cell directly below and to the cell below and to the right. This implies that the sums of all the numbers in each row double from row to row. Because such sum in the first row is 1, one can see that row sums are just the powers of 2. This example demonstrates that the visual representation not only makes it easier to calculate the numbers, but it is extremely helpful for gaining insights into the mathematical structure also. Talking about "directly above" and "above and to the left" is the colloquial expression of the fundamental concept of spreadsheets, relative references. This concept implies that "a formula is more than just a formula", namely it is a prototype object. In the binomial spreadsheet one has to create a basic formula (add the value above and the value above and to the left) just once, and then copy this formula across the table. Therefore, this one formula contains the essence of the whole structure of the binomial coefficients.

Another important feature of spreadsheets is automatic recalculation. If a value of a cell changes anywhere in the sheet, all other values, which depend on it, will automatically be updated. So it is very easy to study parameterized mathematical structures. If, for example, the shape of a graph depends on a parameter, just typing one value will automatically update the shape of the graph without any need to start running a new program like it would be necessary with most of the other types of mathematical software. Modern spreadsheets offer even more convenient features. Direct manipulation user interface elements like sliders (see Figure 1) can be connected to cells. So by moving a slider the content of a cell can be changed and the rest of the spreadsheet will update immediately. This can be used to create animation affects by "manually" changing a value. Animation speed and direction are easily controlled. Using these features, students can create mathematical models which are very user friendly for both designers and users.

To conclude this section note that spreadsheets offer innovative ways of working with mathematical structures because they allow us to think about structures in a visual metaphor without the need to do bookkeeping about the order of calculations. Thinking about mathematical structures occurs in a static descriptive context, and spreadsheets support this paradigm better than other tools like programming languages (or computer algebra systems). In addition, direct manipulation user interface elements can be connected with spreadsheets, and in this way dynamic aspects (like animation) are made easily accessible.

1	0	0	0	0	0	0	0	0	0		1
1	1	0	0	0	0	0	0	0	0		2
1	2	1	0	0	0	0	0	0	0		4
1	3	3	1	0	0	0	0	0	0		8
1	4	6	4	1	0	0	0	0	0		16
1	5	10	10	5	1	0	0	0	0		32
1	6	15	20	15	6	1	0	0	0		64
1	7	21	35	35	21	7	1	0	0		128
1	8	28	56	70	56	28	8	1	0		256

Figure 2: Binomial spreadsheet

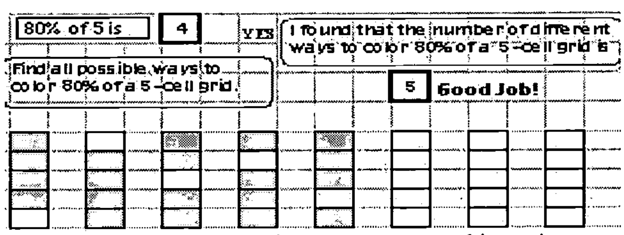

Figure 3: Percentage task as a route to combinatorics

Spreadsheet as an interactive manipulative environment

The appearance of spreadsheets as mathematical/pedagogical tools has created serious problems in the preparation of elementary teachers. A spreadsheet is often construed as an innovation which brings a change to the subject matter from a computational perspective alone. While spreadsheets do aid in computation in many powerful ways, such utilization of the software in mathematics classroom can further perpetuate authoritative discourse aimed at the production of correct answers. A static meaning structure of an associated text be it the word of a teacher or a spreadsheet-based verdict of a computer is unlikely to be taken as a thinking device by a student. Yet, an egalitarian, student-centered, and meaning-making classroom is the focus of the current mathematics education reform. The principal assumption of the changing pedagogy dwells on the notions of reflective inquiry, dialogic discourse, conceptual development; and it measures the quality of an educative growth of a student in terms of the diversity of thinking.

As far as a spreadsheet as a text is concerned, it is not immediately apparent how its 'authority' can challenge a conventional belief that there is only one way or the best way of acting and representing on the universe. The lack of instructional materials and paucity of pedagogical precepts concerning the alternative use of computers make the incorporation of spreadsheets into methods courses for pre-service

and in-service elementary mathematics teachers an important issue. How can a teacher afford an open-minded instructional performance, promote an internally persuasive discourse, and support a cognitive heterogeneity in a seemingly contradictory computer-entrusted didactic situation? Examples of using a spreadsheet as an action-oriented intellectual milieu structured by a non-authoritative pedagogy are another part of the Panel discussion.

In particular, it was found that a spreadsheet can be used as a manipulative environment aimed at an early development of combinatorial reasoning by proceeding from interactive arithmetical tasks which allow for the variety of enactive representations (Abramovich & Stephens, 1998). Consider, for example, the following task: Shade 80% of a 5-cell grid. This task may raise several follow-up questions, among them: Is there only one way to shade 80% of a 5-cell grid? In how many ways one can color 80% of a 5-cell grid? The variance in action has an immediate pedagogical implication advising that a problem may have more than one correct answer. Cognitive heterogeneity and structural flexibility in quantitative situations invite new modes of reasoning dealing with the emergence of a choice. A freedom of making a choice can turn the search of a way to accomplish a task into the quest for all such ways.

In such setting a switch from one level of an individual's task awareness to another becomes meaning generative. An interaction among different such levels in the context of percentage tasks gives birth to new kinds of exploration which bear a visible mathematical significance. By elevating the activity to a higher cognitive level, one can arrive at a new class of problems which require qualitatively new counting techniques. This makes it possible to establish a link between arithmetic and combinatorics and facilitate the development of a system in enumeration strategies. It appears that the use of a spreadsheet as a manipulative intellectual milieu with a hot link to numeric notation is conducive to an early acquisition of basic combinatorial concepts. Figure 3 presents an example of such an activity explored in a computer lab of an elementary school with a group of 6^{th} graders.

Modeling, Spreadsheets, and Worksheets: A useful combination for teaching

The integration of spreadsheet-enabled mathematics pedagogy in a broader context of an interdisciplinary education is yet another highlight of the Panel. This section presents findings from a collaborative Mexico/UK project (Sutherland, Rojano, Mochon, Jinich, & Molyneux, 1996) aimed at investigating the role of modeling with spreadsheets across a range of subject areas (physics, chemistry, and biology). The spreadsheet was introduced into the students' classroom (high school level) with the purpose of creating a link between the different mathematical representations this environment has to offer and the science being modeled. The proposed approach included the construction of spreadsheet models within topics in science (collisions, satellites, chemical equilibrium, periodicity, diffusion, population growth, etc.) followed by the quantitative analysis of the phenomenon involved, which enhanced students' understanding of the scientific ideas related to the model.

Within the spreadsheet, the students constructed an "artificial world" as an image of the physical world they (or the teacher) were interested in exploring. One important aspect of this project is the way the students were guided through a worksheet to "discover" the model. The main structure of the worksheets was the following. First a problematic situation was presented and reflected upon with questions and few calculations. Based on this initial paperwork, the spreadsheet model was constructed (we found it helpful to give the students some feedback of the results they were supposed to obtain). After this, through questions and suggestions, the students were encouraged to analyze the results, reach conclusions, and work on extensions to the model.

Another aim of this study was to observe cultural differences between the two groups of students and to determine how this approach contributes to a change in the mathematical practices in the classroom. One of the findings was that Mexican classrooms followed a "top to bottom" approach, from general ideas and formulas down to specific examples, while UK classrooms followed a "bottom to top" approach by starting with specific problematic situations from which generalizations were obtained. This was reflected in the way of thinking of the students and their interaction with the spreadsheet. For example, at the beginning of the study, Mexican students relied more on symbolic representations whereas UK students felt more comfortable with graphic representations. This, however, was changed gradually during the experimental classroom year.

Through this experience we found three main ingredients of the effective teaching of sciences: *Modeling*, *Spreadsheets*, and *Worksheets*. Each one has important characteristics that make this

combination very attractive for the teaching. In fact, the coupling of spreadsheets with a strategy of mathematical modeling and supported with worksheets has been applied in Mexico in two different subsequent studies described briefly in the next two paragraphs.

A question that came to mind after this experience was, how successful the previous approach would be without a spreadsheet itself, since many schools don't have access to computers. A second project performed in Mexico included the development of some of the same models in the classroom "without the help of spreadsheets". In this new study the students followed the same chart-type format but instead of using a computer, pencil, paper and a calculator were used. The students performed only the first sequence of calculations of the models and then the 'complete' results were given to them in both table and graphic formats which enable them to discuss the scientific content. Again we observed the students to grasp the scientific ideas, although they didn't have available the richness of the spreadsheet model to investigate further.

Currently in Mexico, the Secretary of Education is sponsoring a national project to teach mathematics with technologies at the secondary level. Within this project we have use this *Modeling, Spreadsheets, and Worksheets* approach to teach math. Activities using worksheets have been developed in a wide range of topics in the mathematical curriculum, with the spreadsheet as the supporting environment. The activities are both expressive, where the students construct their own spreadsheet and exploratory, in which previously constructed spreadsheets are used by the students to access some mathematical topic by changing the values of some cells and observing the effects (examples of topics in this exploratory mode are: *Equivalent fractions*, *Systems of two linear equations*, and *The urn model*).

Conclusion

Many efforts of current mathematics education reform are aimed at the development of new forms of software in support of non-authoritative, student centered classrooms based on constructivist applications of educational computing. Design of computational environments like those presented by the Panel contributes to these efforts. The Panel argues that spreadsheets can be considered as a new generation of school-based educational software for school mathematics. It appears that the proficiency of mathematics teachers in the use of a spreadsheet as a tool for conceptual development and educative growth of all students becomes a crucial factor for the reform to be a success. A comprehensive and regularly updated list of resources about educational use of spreadsheets (projects, articles, and books) can be found at http://sunsite.univie.ac.at/Spreadsite/.

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Implementing Technology in Secondary Mathematics and Science Classrooms: Do We Have Common Goals? Barriers? Models for Change?

Gregory Chamblee, Julie Sliva, Scott Slough & Cynthia Louden

Abstract: The infusion of technology in today's mathematics and science classrooms is a top priority of many school districts. This paper discusses similarities and differences between the technology goals, barriers and change models currently being used to implement technology-based mathematics and science curricular changes. Separate lists for barriers in mathematics and science were developed. Findings were that the disciplines of mathematics and science do have many common goals, barriers and implemenation strategies. Change models served mathematics and science teachers equally well. Recommendations focused on utilization of technology because it enhances mathematics and science learning, removal of barriers as an implementation mandate, and the efficacy of change models for decision making in the technology implementation process.

Mathematics and science educators include the use of technology as a common goal in their recently developed standards. The National Council of Teachers of Mathematics *Curriculum and Evaluation Standards* (NCTM, 1989) suggest a framework for the types of activities and content that should be taught. Both the NCTM process standards and position on technology usage will be used to discuss essential technology skills. Similarly, the National Research Council's *National Science Education Standards* include suggestions for science education reform in content and professional development. It is by inspecting the science and technology goals and these two strands that we will address essential science and technology skills. This paper will further explore whether mathematics and science educators have common technology implementation goals, barriers, and strategies. Models of curricular change during technology implementation will also be discused.

Mathematics Goals

The National Council of Teachers of Mathematics (NCTM, 1989) states that the use of technology "will increase a students' ability to understand and explain the mathematical complexities of real-life problems; the classroom dynamic in which teachers and students become natural partners in developing mathematical ideas and solving mathematical problems; and, will transform the mathematics classroom into a laboratory much like the environment in science classes, where students use technology to investigate, conjecture, and verify their findings (p.128) ." Further, students should "use problem-solving approaches to investigate and understand mathematical content, formulate problems from situations within and outside mathematics, develop and apply a variety of strategies to solve problems, verify and interpret results with respect to the original problem situation, and generalize solutions and strategies to new problem situations (p.75)."

With these statements in mind and using the process standards as a guide (Mathematics as: Problem Solving, Connections, Communication, and Reasoning), it is our belief that mathematics teachers need to create rich technology-based instruction that includes the use of integral technologies such as databases, spreadsheets, and calculators. Specifically, databases may be used to engage students in organizing data into a database, retrieving data according to certain criteria, analyzing and making conjectures on the basis of their samples, discussing and validating their conclusions, and developing persuasive arguments. Spreadsheets can be used to facilitate students making conjectures and hypotheses as well as to provide multiple representations of data. Similarly, the use of a graphing calculator can be used to gather data, analyze data and represent data. Graphing calculators can provide additional advanced capabilities that many spreadsheet and database applications do not have.

Science Goals

According to the American Association for the Advancement of Science (AAAS, 1993) scientifically literate people should understand the interdependence of science, mathematics, and technology. Science instruction should include mathematics and technology as tools for observing, thinking, experimenting, and validating. This merger of mathematics and technology into scientific inquiry holds promise for a scientifically literate society. Technology is one way of defining the human experience. Paleontologists use the technology of tool making as one of the chief indicators of emerging human culture. Technology allows us to interact, shape, or more fully understand our environment. The distinction between technology and science blurs as technology becomes more sophisticated. Modern scientific research requires computers for data collection, analysis (statistics), and display. Technologies shape science as they develop, providing motivation and direction for theory building. For example, knowledge of subatomic particles increases with the expanding technology to control collisions between smaller, faster particles and to detect smaller particles as a result of these controlled collisions.

The *National Science Education Standards* grew from the work of the AAAS and several other groups dedicated to the improvement of science instruction. As with mathematics, it is our belief that rich technology- based instruction is integral in nurturing the development of students as active science inquirers. The science and technology standards " establish connections between the natural and designed worlds and provide students with opportunities to develop decision making abilities (NRC, 1996, p. 106)." Using databases, spreadsheets and calculators will assist students with their developing scientific inquiry skills.

Barriers to Technology Implementation in Mathematics

There are a variety of technology usage barriers in mathematics classrooms. These barriers include: (a) a lack of consistent goals for teacher technology literacy, (b) training, (c) money, (d) teacher attitude, and (e) lack of technology-based textbook materials (Dwyer, Ringstaff & Sandholtz, 1991; Chamblee, 1995; Sandholtz, Ringstaff, & Dwyer, 1997). While the above list of barriers is not exhaustive, patterns of barriers can be categorized as personal, curricular, or technological concerns. For change to occur, barriers must be addressed. The personal category can be addressed by creating personalized staff development opportunities and on-site expert-novice mentoring opportunities. The curricular category can be addressed by correlating technology materials with current adopted textbooks and providing in-service opportunities that that technology usage managing in the classroom. Finally, the technological category can be addressed by connecting professional development instruction to currently available technology and by exploring technology leasing options.

Barriers to Technology Implementation in Science

A variety of barriers also exist for the usage of technology in the science classroom. These include: (a) time, (b) training, (c) administrative support, (d) money, (e) lack of research (f) student access to inappropriate material, (g) space, (h) safety concerns, (i) pedagogical concerns, and (j) assessment issues (Becker, 1991, 1994; Hadley & Sheingold, 1993; Honey & Henriquez, 1993; Honey & McMillan, 1993; OTA, 1988, 1995; Sheingold & Hadley, 1990; Louden, 1997; Slough, 1998). Teachers lacking in technology literacy tended to focus on the lack of time, training, and support along with the student access to inappropriate material and the concern that technology would require them to change their teaching. Access to inappropriate material, both adult and incorrect science content were considered to be major barriers. Teachers who were more comfortable with using technology in the classroom focused the remaining of the barriers with the loss of lab space, safety concerns, how to change their teaching style to accommodate the promise of technology, and the lack of money to continue the build appropriate infrastructure-especially for telecommunications applications (Slough, 1998).

Implementation Strategies and Change Models

Along with goals, implementation strategies must be developed and implemented in order to overcome all barriers. Since the introduction of hand-held technology in the mathematics and science classroom, many staff development initiatives have been undertaken to overcome these obstacles. This section discusses

properties mathematics and science models need in order to successfully implement technology in the classroom.

Implementation Strategies

Several implementation strategies are suggested: (a) employing full-time technology coordinators and network administrators on campus, (b) using technology—specifically telecommunications—in the professional activities of teachers, (c) continuously reporting proof that technology works, (d) sharing concerns about technology implementation, and (e) requiring individual accountability for teachers and students (Slough, 1998). Teachers teach; they are rarely technology experts. Districts need to hire full-time, on-campus technology coordinators and system administrators. In general, teachers will not implement what they do not first use. Attempts need to be made to **gently** coerce teachers into using technology in productive ways. For example, administrators could require teachers to submit grades only over the network. A district-wide e-mail discussion list might also encourage teachers.

Teachers want to know that technology works before they implement it in their classroom with their students. They want more than research reports; they want local teachers who can share their successful experiences utilizing local resources to help local students learn. Teachers typically feel isolated in the classroom. Technology, especially telecommunications can be used to overcome some of the isolation. If the teachers knew that other teachers had similar concerns and that these concerns were part of the change process, they might be more likely to implement technology. When districts spend money they expect results. Teachers need to be held acceptable for using technology meaningfully to help students learn in ways that were not possible without technology. Students need to be accountable for their learning, beyond a grade on an assignment. Finally, students need to be accountable when they access inappropriate material.

Change Models

Many technology implementation models today are based on concerns theory. In general, concerns theory suggest that any type of curricular change is a process, not an event (Fullan, 1982). Change is a highly personal experience accomplished by individuals (Hall & Hord, 1987). It involves developmental growth and is best understood in operational terms; therefore, the focus of change facilitation should be on individuals, innovations, and context (Hall & Hord, 1987). Two examples of models are the Concerns Based Adoption Model (CBAM) (Hall & Hord, 1987; Bailey & Palsha, 1992) and the Stages of Instructional Evolution (SIE) (Sandholtz, Ringstaff, & Dwyer, 1997). While concerns models differ in the number and description of individual stages, researchers (Hall & Hord, 1987; Bailey & Palsha, 1992: Chamblee, 1996; Slough, 1998) conclude that technology training needs to be matched to the needs and concerns of individual teachers at appropriate times. Currently, many staff development models lack this feature. Integration of this feature will require more time pre-assessing teacher needs and personalizing instruction. It will also require having more content specific technology experts available in the schools and creating more specialized staff development opportunities with follow-ups throughout the year.

Conclusions

Many similarities exist between technology goals, barriers, and implementation strategies when implementing technology in mathematics and science classrooms. Technology plays a significant role in the mathematics and science classroom only when it is used to enhance mathematics and science learning, not when it is used for technology's sake. Barriers, regardless of their origins, must be overcome before implementation can take place in the mathematics and science classroom. Change models offer a theoretical framework to guide decisions for implementing technology in the mathematics and science classroom.

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A New Paradigm for the First Two Years of General Education: The Integrated Curriculum for A Science or Engineering Program of Study

Charles J. Martin
Department of Computing and Mathematics
Embry-Riddle Aeronautical University
Email: martinc@cts.db.erau.edu

Abstract: This panel of faculty will describe the contents and results of a program of study for freshmen engineering students at a small private university. Entering freshmen engineering student volunteers are placed into specifically designed sections of calculus, physics, humanities, social science, and introductory engineering courses required of all engineering students. All courses incorporate active learning, formal teaming, use of common computer technology both in and out of class, team design projects, and a variety of well-documented assessment practices. Although the students were drawn from engineering, the underlying philosophy is applicable to a wide spectrum of programs of study as well as the general education component of many degrees.

Introduction

Elements of the content of these courses, along with how active learning, teaming, use of computers, team design projects, and assessment of the program were incorporated and will be described.

A panel of faculty involved in this project will participate in the presentation. Professor Elliot Palmer will describe how we integrated the calculus and physics sequences giving specific examples of this integration. The second panelist, Dr. John Watret, will illustrate a typical class session and using the web course as they pertain to mathematics. Dr. Roger Osterholm will talk about the role of the humanities courses in the program and Dr. James Ladesic will discuss the use of design projects and active learning in the program. I will present the overall assessment data: how it was gathered and how it has been used.

Brief Description of the Integrated Program as Applied to Engineering: The ICE project

Our engineering students take the following courses: three semesters of calculus, followed by differential equations; three semesters of physics; four semesters of humanities; World History; three semesters of initial engineering courses: (introduction, orientation, engineering graphics and statics) and one semester of fundamental courses (dynamics, fluid mechanics or solid mechanics).

In this project, all courses are taught using cooperative learning, and all students are assigned to teams of four. The same teams and groups stay together in each course. Every fourth week there are subject matter exams and a team project in engineering. Classes are taught using active learning exercises and computers daily.

All students are eligible who are calculus ready and who can enter our regular freshman English course. Teams are formed by high school class rank so that each team has a student from the top 10%, the top quartile, the middle quartile and the bottom quartile for the first semester.

Assessment studies show that this program benefits all students regardless of high school rank. The number of unsuccessful students -- those getting D, F, W, or Audits -- has been halved over the traditional courses. In addition, students like this method of teaching because they are actively engaged in learning.

A New Paradigm for the First Two Years of General Education: The Integrated Curriculum for A Science or Engineering Program of Study
The Physics Sequence

Elliot Palmer
Department of Physical Sciences
Embry-Riddle Aeronautical University
Email: palmere@cts.db.erau.edu

Introduction

It is not uncommon for faculty members to look at a curriculum and ponder what can be done to improve its effectiveness. In the case of an engineering program, this task is complicated by the multidisciplines involved. Students insist that the subject matter is unrelated, and the faculty insists the students are over compartmentalized. For a variety of reasons many faculty members recommend calculus as a co-requisite for physics instead of a prerequisite. A close examination of the topic sequence in a typical engineering three-semester curriculum would show that the math and physics topics are very poorly matched and out of sequence. For example, vectors don't normally appear until the third semester math course as opposed to being one of the very first topics in a physics sequence. If, indeed, the presentation of the curriculum were more effective, one would also hope for the increase in motivation and retention.

At ERAU the initial step was to realign the math and physics sequences. The physics team took the lead by laying out the topical sequence, but the math team bore the brunt of the work in almost totally reordering the math. Following a suggestion from Texas A & M, the physics sequence opened with geometric optics to allow time for the math team to introduce elementary calculus (derivatives and anti-derivatives). Considerable effort was put into selecting a textbook that was very readable from the student point of view. Serway's *Principles in Physics* fit this need nicely. At this point the engineering and humanities team members joined the effort in working out the teaming aspects of the program. Very close coordination was maintained throughout. Use of computers in the physics curriculum consisted of limited use of spreadsheet and MAPLE applications until the third semester where the laboratory experience relied heavily on computer assisted data acquisition and analysis.

The results after repeating the first semester twice are remarkable and repeatable. In a calculus based engineering sequence physics course, the unsuccessful (D, F, WD, AU) rate typically falls between 30% and 40%. After two sequences of the ICE curriculum, the unsuccessful rate has dropped to 15% to 17%. Other positive spin-offs are: the spirit of interdepartmental cooperation and the physics and math topic alignment to better reinforce each other.

A New Paradigm for the First Two Years of General Education: The Integrated Curriculum for A Science or Engineering Program of Study

John R. Watret
Department of Computing and Mathematics
Embry-Riddle Aeronautical University
Email watretj@cts.db.erau.edu

Abstract: This panelist will describe how the calculus sequence was integrated with the physics sequence. The specifically designed courses incorporate active learning, teaming, use of technology and team projects. A major component of this program is the use of the web. Each course has its own website on which are posted all daily lessons, tutorials and reference materials.

Introduction

In order to see how far out of line the topics in the calculus and physics sequence were, a matrix of the topics was drawn up. The topics in calculus were listed along the top and the physics topics were listed down the side. The result was as expected, not a straight line, but a scattergram. There were topics being used in physics in the first weeks that were not being covered in calculus until the third semester.

With this information in hand, the mathematics and physics faculty worked to realign the contents of these sequences. It was decided to allow the physics sequence to take the lead and to align the mathematics topics to be covered before being needed in physics.

Web course

One of the goals of the Integrated Curriculum in Engineering (ICE) was to maximize the use of technology throughout, with a web site for each course a key feature. The Department of Information Technology assisted in setting up the templates for these courses. The templates included the following areas: syllabus, classroom, reference and communication.

Once the alignment of topics was decided upon, the mathematics faculty then began the process of writing the daily worksheets and posting them on the course website. We adopted a standard template to be used on all the mathematics courses. The information posted to the web includes the objectives, class exercises, text reference and homework. The students were then able to access these worksheets on their laptops through the campus network.

A typical calculus class in the ICE program involves a brief lead in to the topic. The students explore the topic further in their teams by working through the class exercises on the worksheet. Also, the students had the computer algebra system, Maple, on their laptops. Having access to Maple allowed the students to solve slightly more challenging problems while still applying the basic concepts.

In my presentation, I will illustrate the daily content both by web-site exploration and by handouts for the audience. Illustrations will include a typical class content, a team problem, and some reference material we have made available to the students.

Conclusion

Realigning the calculus sequence with the physics sequence and integrating technology in the curriculum have been positive changes to our program and major factors in the success of the ICE Program.

A New Paradigm for the First Two Years of General Education: The Integrated Curriculum for A Science or Engineering Program of Study
The Humanities Component

J. Roger Osterholm
Department of Humanities and Social Sciences
Embry-Riddle Aeronautical University
Email: osterholmr@cts.db.erau.edu

Four Sections of the Humanities

Four distinct Humanities courses and a further history course are offered in the Integrated Curriculum in Engineering at ERAU. These serve as a basis for the general education component for engineers and may well do so for science students and for virtually any curriculum.

The four Humanities sections are Introduction to Composition and Literature (HU-122, Freshman English I); Themes in the Humanities (HU-145, Freshman English II); Speech (HU-219, Public Speaking); and Technical Report Writing (HU-221). In their second semester the students also study a concentrated semester course in World History, SS-110, taught by Professor James Libbey of the Department. This course is a standard ERAU offering, but it is also slanted in many ways to support the sciences. These courses are distributed through four semesters, covering two years of academic work.

Integrating the Humanities and Technological Components

These Humanities courses are integrated to varying degrees into the ICE program. The Freshman English I (HU-122) is most integrated, for it covers several topics and styles of value in physics and engineering. In addition to covering many general and literary topics, as offered in the valuable *Norton Reader* and assorted literary texts, including a novel, the course provides direct examples of writing a laboratory or technical report, discussions of ethics, basic logic, some history of science, and the basics of the scientific method. These coordinate well with many of the engineering and physics topics through the term. One of the first diagnostic readings is an article from a physics journal surveying the development of Harriot's Law of optics. The first diagnostic writing is a survey of student ten-year goals, which feeds their first lessons in AE-101, a course designed to promote effective studies and career planning.

The Freshman English I course stresses mostly writing well and clearly. Many rhetorical topics and strategies are discussed and practiced, with about half the writings conducted as team work. A sample research paper is a team assignment, and all their work is discussed and explained online in a complex Web course for which each student must have a laptop computer. The hour examinations, which are primarily subjective or essay tests, are individual tasks that also demand a large amount of individual writing.

Themes in the Humanities (HU-145, or Freshman English II) focuses on the rationality of a few major periods, like the Greeks and Roman, the Enlightenment, the Romantic Age, and the middle of the twentieth century. Rationality, of course, stresses the scientific and philosophical backgrounds and their reflection in the literature and other arts of the periods. The basic source for this course is a two-volume CD-ROM on art history, and the whole course, like all the others, is explained in several files on a Website.. This course somewhat supplements the World History course that the students take at the same time.

Speech and Technical Report Writing are similarly integrated, although perhaps not to such an intimate way as Freshman English I. Nevertheless, Technical Report Writing can be, at the student or team option, closely related to an engineering or other scientific problem relevant to their major curriculum. In both course students further practice using their computers for presentations and research.

A New Paradigm for the First Two Years of General Education: The Integrated Curriculum for A Science or Engineering Program of Study
The Engineering Component

James Ladesic
Department of Aerospace Engineering
Embry-Riddle Aeronautical University
Email: ladesicj@cts.db.erau.edu

The Aerospace Engineering Perspective

The ICE program was introduced at ERAU in the freshman year though the combined efforts of a diverse, inter-departmental faculty team. From the Aerospace Engineering prospective this activity supported a desire and a need to improve the freshman student experience, to address attrition and to improve overall student academic performance. Earlier efforts in 1994 initiated to reduce attrition in the freshmen year of the Aerospace Engineering (AE) program were directed at refining a student success oriented course along with a comprehensive effort to assist entering students adjust to college life.

Previously, starting in the early 1980s, all AE freshmen took a two credit Introduction to Aerospace Engineering course, AE101, in which they worked in teams to engineer a simple yet technically correct design of first a rocket and then of an airplane. Instructions describing the nature of the design process, presenting procedures and necessary equations while also providing needed design data, were given as handouts for each. These projects were accompanied by a traditionally delivered broad-brush treatment of related theories, some curriculum and career discussions, a few videos and a field trip or two. The course was intended to assist the student in affirming their career choice and, for that purpose, was well received. However it yielded only marginal aid in addressing looming attrition statistics which often approached 50% in the first semester. Similarly it was uncertain as to what affect it had on overall student academic performance in subsequent courses although intuitively the AE faculty believed it to be positive.

New elements were integrated into and around AE101 during the 1994 academic year that addressed time management, study habits, note taking and test taking and also the out-of-the-classroom quality of student life. In AE101 the association of the physical science, mathematics and communications were emphasized throughout the projects. Teams were still expected to produce a simple design in response to a stated mission, and also develop a short summary report and deliver a brief presentation of their designs. Initiatives that addressed the other aspects of student life included arranging collective common housing exclusively for engineering students, the implementation of an intrusive peer mentoring system, making available Supplemental Instruction for Math and Science and involving students in social activities with upperclassmen, organizations and faculty. Retention/attrition data for 1992 had been reduce from mid '80's 45%+ downward to 30% and by 1996, with the new initiatives in place, had reduce even further to 24% with nearly all other factors remained constant during that period. While these activities did indeed improve retention there remained a lack of connectivity in the curriculum and student academic performance in advanced classes had not appreciably improved. Also, without formal instruction or training, students working in teams were often confronted by conflicts that they were ill equipped to resolve

ICE has significantly broadened the scope of the teamwork component in the freshman program. It has provided the faculty with formal training in collaborative learning/teaching environments, and has successfully integrated topics in math, physics, communications and engineering. The AE101 student projects base has been expanded and designed to blend with the topics used in Physics and Calculus. Further, it fortifies the communications component of the freshman year in a meaningful way for the students. Best of all student academic performance, when compared with a control group of traditional students of similar academic capability, has increased upwards of 20% in grades and success rate. ICE works!

Computer-based Mathematics and Physics for Gifted Remote Students

Raymond Ravaglia, Richard Sommer, Marc Sanders, Gary Oas
Education Program for Gifted Youth
Stanford University
USA
{ravaglia, sommer, sanders, oas}@epgy.stanford.edu

Charles DeLeone
Department of Physics
University of California Davis
USA
deleone@solid.ucdavis.edu

Abstract: Since 1985 the Education Program for Gifted Youth (EPGY) at Stanford University has been developing a series of stand-alone multi-media computer-based distance-learning mathematics and physics courses from the elementary school through the university level. Because these courses are used in situations where students do not have access to regular classroom instruction, we have had to make essential use of the computer both as an instructional agent and as a tool for media-distributed learning. We discuss our experience over the last fourteen years developing software and delivering effective instruction.

Introduction

The Education Program for Gifted Youth (EPGY) at Stanford University is a continuing project dedicated to developing stand-alone multi-media computer-based courses and offering these to remote advanced middle-school and high-school students through Stanford Continuing Studies. Since 1992, EPGY has taught advanced placement calculus and physics to over 600 advanced middle school and early high school students. The present enrollment in all EPGY courses is over 1700, with almost 160 in such university-level courses as Multivariable Calculus, Differential Equations, Linear Algebra, Number Theory, Optics, Thermodynamics and Modern Physics. (See www-epgy.stanford.edu for a complete list of courses offered.) EPGY is presently in the third year of a development effort funded by the Alfred P. Sloan Foundation to create 14 additional university-level courses in mathematics and physics. When these courses are put into place, it will be possible for an ambitious student who starts calculus in his or her seventh grade year, and who takes one course per quarter during the academic year, to finish high school five courses short of a degree in mathematics and five courses short of a degree in physics.

The EPGY course software, unlike traditional applications of computers in education, is intended to be the primary means of instruction, and not merely to supplement a regular class. In fact, as all EPGY students are physically remote, students never meet face to face with the instructor or each other. Because of this it has been necessary for us to think about the different ways of using the computer to facilitate student learning, and not to just treat the computer as an expensive broadcast tool. The EPGY course environment consists of interactive multimedia exposition, on-line exercises using symbolic computation, and automated reasoning to check student work. The course environment also contains facilities for collecting extensive data on all aspects of actual student usage of the software. Every time a student views a lectures, answers a question or proves a theorem, all relevant information concerning this event is preserved. The students send this information by e-mail to Stanford where it is automatically seeded into a database. This data collection allows course developers to isolate those areas in the course where students are having the most difficulty, so that they can refine them by adding new material to explain common mistakes, or by adding more detailed explanations to areas generating the most questions. It also makes it possible to see which features of the software prove useful to students and which are sources of frustration. In this panel discussion we focus on some of the features of the EPGY courses that have proven effective with students.

Multimedia Presentation of Proof-Saturated Mathematics

In the last year, as we have begun to focus on the development of courses beyond the level of the first year of calculus, we have been forced to find effective ways to present mathematical proofs to students. The need to do this stems from a variety of factors ranging from the complexity of the subject matter to the wide variation in the preparedness of the students taking the courses. An example (see Figure 1) from the Abstract Algebra course illustrates our approach to teaching abstract, rigorous, proof-saturated mathematics in this technology-enhanced environment.

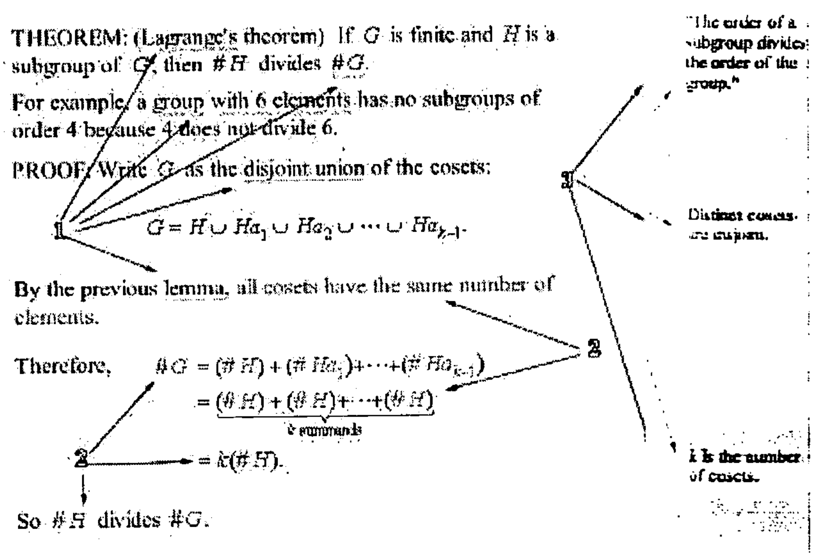

Figure 1: A sample EPGY course lecture.

Hypertext links, see "1" in Figure 1, afford students the non-linear browsing which is often necessary when reading multilayered, proof-based mathematics. Through these links, students have access to previously discussed material, such as definitions (e.g. subgroup, coset, order), notations (e.g. *#H*), theorems and lemmas (e.g. the previous lemma being used in the proof), as well as miscellaneous information (while dominant links are indicated, any term or expression can have a link associated with it as its "home page"). Some links that are presented are exploratory links that may access interesting, but somewhat tangential, topics which students are encouraged to investigate. Each link (and in particular the depth of any given link path) accessed by each student is recorded as part of the assessment of that student's progress. Additionally students are able to create links that point between their notebooks and the course lecture screens. This allows students to quickly return to specific points in the course.

Color coding, see "2" in Figure 1, is used to connect ideas, statements, formulas, etc. with other such objects so that students can more easily and quickly make the necessary deductions when following a proof. Often, when a conclusion of some argument or sub-argument appears, it is colored along with a central premise which leads to that conclusion. Color also is frequently used to tie together a previous result with a particular application of, or reference to, this result.

Margin notes, see "3" in Figure 1, are asides, remarks, comments, etc. which may be relevant to the learning and understanding of a proof, but are not part of the proof itself. In some sense they act as the difference between what a lecturer would *say* when presenting a proof and what he or she might *write* as a proof. Ideally, margin notes should become less common in the more advanced courses, as those students learn to fill such gaps themselves.

Animation, though not shown here, is used prinicipally to maintain continuity throughout proofs and

discussions. For example, in proofs requiring more than one page-screen, animation is used to move the most important and relevant statements onto the next screen in such a way that further reference to them can be made smoothly, without disrupting the general flow of the argument. In a way that static textbook examples cannot capture, animations are also used during computations to emphasize the dynamic components of the process one goes through in doing the computation.

Assessment, Feedback and Symbolic Computation

The ability to provide students with immediate feedback to their work is one of the great strengths that computer-based courses have. Immediate feedback is particularly important in the distance learning context where students face additional difficulties in submitting and retrieving written solutions to problems. Providing immediate feedback requires the ability to assess student work. Ideally this should include assessment both at the level of being able to answer standard questions, as well as understanding why a solution is correct. The types of questions students are asked in the course are of the sort that instructors traditionally ask after lectures or on examinations. They consist predominately of questions requiring closed-form mathematical expressions as solutions, though we have been experimenting with interactive proofs and will discuss these below. In free answer questions several issues must be taken into consideration.

One important issue is ease of input. If students have to type complex mathematical expressions in an input language, the odds that an incorrect response is caused by an error in typing will make meaningful evaluation impossible. Care must be taken to provide students with a convenient means of input that does not require a great effort to learn, together with the ability to see their input formatted, so that they can verify that what the computer has understood is in fact what they wished to express. The EPGY structural input system addresses both of these concerns.

Another issue is flexibility in answer form. Students should not have to constrain their answers to fit a particular form, outside of those constraints which an instructor would reasonably place upon them in a traditional class. The correct approach is to process the answers symbolically, taking into consideration their mathematical meaning, and considering possible correct answers in terms of equivalence classes. This minimizes the need to require that students conform to an arbitrary input standard, allowing the computer to understand natural variations of correct answers, thereby accommodating different approaches to a problem which can result in equivalent correct answers with different forms.

A simple example from the first year of algebra shows the range that a student's answer can take. Suppose a student is asked to factor the expression $12t^2+t-35$. One will likely want to accept as correct any of the following answer variants: $(3t-5)(4t+7)$, $(4t+7)(3t-5)$, or $(5-3t)(7+4t)$, not to mention several others with essentially the same form. On the other hand, the response $t(12t+1)-35$ should be rejected. Whether or not the student's answer is correct can be determined by passing the student's input and the author-coded answer plus specification of equivalence class to a symbolic computation program for evaluation and comparison. Exploiting the fact that the answers are mathematical expressions increases the flexibility for student input and simplifies author coding.

An additional benefit of this approach is the ability to automatically diagnose common student errors. There are a number of almost correct and incorrect answers that deserve special treatment. Errors in choice of variable, e.g. $(3x-5)(4x+7)$, errors caused by transposition of a factor or of the minus sign, e.g. $(4t-5)(3t+7)$ or $(3t+5)(4t-7)$, should be detected so that the mistake made by the student can be explained.

A more difficult problem than determining if a student's answer is correct is that of evaluating the student's entire solution. The link between understanding and the evaluation of work at this level is the sentiment back of the perennial dictum of "show your work." One step EPGY has taken towards being able to perform this sort of evaluation has been to make use of an interactive derivation system. The derivation system is an environment in which students can formally manipulate mathematical expressions by applying inference rules. A derivation system differs from a raw symbolic computation environment, such as Maple or Mathematica, by having the logical structure necessary to represent mathematical inference and logical dependency. This enables the derivation system to detect when students make fallacious inferences while

working a problem. In the environment the student supplies the rule and the derivation performs the appropriate calculation. The results of the calculation are preserved for the student to further manipulate. A derivation of a problem is the set of steps from the statement of the problem to the solution. By requiring students to explicitly justify their inferences, it becomes possible to examine the process that a student goes through to produce an answer and not just the answer itself.

Symbolic Mathematics and Interactive Theorem Proving

The derivation system described above lacks the logical apparatus necessary to prove general mathematical theorems. We are just now looking for ways to integrate past work in interactive-theorem proving with the derivation system to create a more general theorem-proving environment that can be used to teach proof writing interactively on the computer in university-level mathematics courses beyond calculus. In this system students' mathematical and logical reasoning will be verified automatically. This should be a valuable tool for restoring deductive reasoning as an essential component in the advanced mathematics curriculum.

Our goal is to have a theorem-proving environment that is versatile and easy to use; it will be a hybrid system that uses automated reasoning to verify logical inference, and computer algebra to verify mathematical reasoning such as algebraic manipulation and numerical computation. Our aim is to allow students to freely apply valid logical intuitions and their prerequisite knowledge of mathematical facts in order to write proofs in our proving environment that are as close as possible to those one would be expected to produce in traditional versions of the same courses.

Students will use palettes to select proof strategies, inference commands, axioms, definitions, theorems, and mathematical symbols. With a structural input system like the one presently contained in our derivation system, students will be able to construct expressions quickly and efficiently. The user interface will consist of:

- A *workspace* for entering mathematical statements;
- a *proof history window* with a scrollable view of the entire proof;
- an *inference rule menu* for verifying steps in the proof;
- a *justifications menu* for selecting from a database of axioms, definitions, and previous theorems, as well as previous proof lines and a student-created database of lemmas;
- a *goal window* for viewing the current proof goal and various sub-goals that allow students to organize their proofs and apply good forward and backward proof strategies; and
- a *proof structure menu* for selecting from a list of proof structures such as proof by contradiction and proof by induction.

The incorporation of the theorem-proving environment into our Linear Algebra, Multivariable Calculus, Linear Algebra, and Ordinary Differential Equations courses, will occur incrementally over the next two years. We will carry out extensive testing with our students to refine both the theorem-proving environment and the changes in the course curriculum necessitated by the use of such a tool. Once interactive theorem-proving is running smoothly in these courses, we will work toward including it in other advanced courses such as Number Theory, Abstract Algebra, and Real and Complex Analysis, as well as in the courses below calculus, namely high school algebra and pre-calculus. It is our belief that an easy-to-use proof-writing tool can be applied to teach deductive reasoning in mathematics at an early age, and our hope is that this will allow deductive reasoning to once again be recognized as an important part of the advanced mathematics curriculum.

Improving Remote Interaction with Human Instructors

Even though the goal of EPGY is to automate as much of the instructional process as possible, interaction with human instructors remains an important component of the EPGY course model. Traditionally this interaction has been provided by asynchronous means such as telephone and e-mail. While effective, they

constitute only a first step in providing robust interaction between instructors and students. There are several points to be made on this subject.

The first point is ease of communication. Any time a student wishes to send e-mail from within the course he or she may do so by simply selecting an option from a menu at the topic of the screen. The program will automatically append to this message the student's name and exact location in the course. This makes it possible for students to say things like "I do not understand this exercise" without having to figure out how to describe the exercise in question.

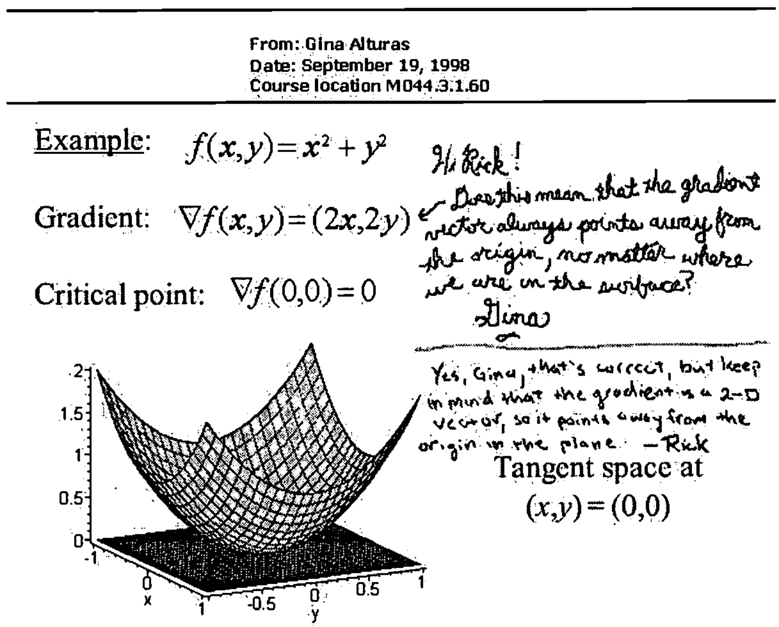

Figure 2: A sample e-mail message from an EPGY course.

An important component of e-mail communication in these courses is the ability to send graphics and sound in addition to text. The illustration above shows a message sent by a student to an instructor in the multivariable calculus course. The student has taken the screen image from the lecture she was in and has annotated it using a graphics tablet. The instructor has made his own annotation to her message as part of his reply. The student or the instructor could have included digitized sound in the message as well. Allowing handwriting and speech in messages makes asynchronous mathematical communication much more natural and it also frees students from having to learn outmoded linear notation.

The final point we wish to make here is the need to move beyond viewing asynchronous communication as the ideal mode of student/teacher interaction in the distance learning context. For the last several years we have experimented with using a variety of shared whiteboard conferencing environments in conjunction with internet telephony to create a cost-effective virtual classroom. In this virtual classroom one has the essential elements of any mathematics classroom: one has a common space on which to write (in this case the computer screen rather than the chalkboard) and one can talk whenever one is given permission to do so. The virtual classroom allows for the sort of immediate teaching experience that is common in traditional office hours or discussion sections, but which is usually thought of as unobtainable in the distance learning context. We expect this feature, as it becomes thoroughly integrated into the our courses, to have a profound impact on both future education and future course development at EPGY.

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Poster/ Demonstration Papers

Design as an Environment for Integrating Mathematics, Science, and Technology.

Ronald J. Abate
Specialized Instructional Programs
Cleveland State University, USA
E-mail r.abate@csuohio.edu

Abstract: Teachers concerned with mathematics and science standards are looking for appropriate learning contexts for engaging their students in solving complex problems. Experiences with teachers participating in an in-service math, science, & manufacturing collaborative suggest that the techniques of design based problem solving respond favorably to the calls for reform of middle and secondary science and mathematics education. This Poster/Demo provides an overview of Project Team, the aforementioned collaborative. Project Team paired university faculty with teachers to 1. provide engineering internship experiences, 2. develop technical and pedagogical skills, and 3. create curriculum materials for classroom implementation. For three years Project Team promoted teaching that emphasized design as a learning context for "real world" problem solving in science and mathematics. Support for the use of design activities is based upon anecdotal data collected from the collaborative participants and the classroom implementation experiences of selected Project Team members.

Computers, Concrete Manipulatives, and Candy: Keys To Beginning Number and Problem Solving Skills In A Bilingual Early Childhood Setting

Trisha Ainsa, Ph.D.
Department of Teacher Education
University of Texas at El Paso, U.S.A.
tainsa@utep.edu

Abstract: Technology can help develop a cycle of learning that includes awareness, exploration, inquiry, and utilization for young children. (Bredekamp & Rosegrant, 1994) Susanne Thouvenelle, in an introduction to Technology: Practical Strategies for Introducing Computers Into the Early Childhood Classroom, states that the observation of typical ways in which young children interact with computers in their classrooms illustrates how they can use the computer for problem solving as well as to construct their own understanding of the role of technology in their young lives. (Ainsa, 1995). Reflecting this philosophical background, a math activity initially utilizing "m & m's" as manipulatives, and then progressing to computer software activities, was piloted and evaluated in five early childhood classrooms.

The purpose of this study was observation of the children's response, enthusiasm, and learning as a result of the combined technology/manipulative curriculum activity. Through analysis using teacher observation of learning and frequency response. there are strong indications that the treatment yielded a positive, successful learning experience. The baseline data obtained in this study is useful to other teachers and scholars. Further study could include more controlled research methods. The project was a successful and different approach to learning. The most rewarding aspects of the program, according to the children, were candy and computers. Both seem to be high on children's scale of fun and learning.

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Application of The CPU Project Simulations in Science Instruction

David Kumar, Florida Atlantic University, USA; Mary Baker, The School Board of Broward County, Florida, USA; Karen Tobias, Deerfield Beach High School, USA

The CPU Project *(Constructing Physics Understanding in a Computer-Supported Learning Environment)* builds on previous work incorporating computer technology to build a constructivist-oriented, guided inquiry learning environment. The CPU Project, funded by the National Science Foundation grant ESI-9454341, meets the goals of:

- Encouraging elementary teachers to teach physical sciences
- Improving understanding of physics in high school physics classes
- Integrating technology in science education

There are seven content units, each divided into cycles to construct a relevant model: Motion and Force, Waves and Sound, Static Electricity and Magnetism, Current Electricity, Light and Color, Underpinnings, and Nature of Matter. The CPU pedagogy of guided inquiry encourages a rethinking of the roles of teacher, students, and materials and is based on cycles of:

- **Elicitation** of students' ideas
- Guided **development** in which students modify or discard their old ideas and/or develop new ones in a movement towards target ideas
- **Application** of target ideas to new situations

Numerical Methods in Singular Stochastic Control Problems.

Hatim Benamar
Mohamed V University
Morocco
hatim97@rocketmail.com

Awatef Sayah
Mohamed V University
Morocco
sayah@fsr.ac.ma

Abstract: The problem of routing control in open queuing networks under conditions of heavy traffic is dealt with. The discrete processes of the physical problem converge weakly to a diffusion. The limit optimization problem is a stochastic singular control problem. The value function is characterized as the unique viscosity solution of the associated Hamillton-Jacobi-Bellman equation (HJB). Numerical schemes are then constructed, in order to approximate the value function. Their convergence is obtained from the comparison result of viscosity sub and super-solutions of the HJB equation.

Inquiry Based Learning in Collaborative Online Projects for Math and Science

Carol Brown
Instruction & Curriculum Leadership
The University of Memphis
United States
cabrown@memphis.edu

In nearly every area of our profession, we as educators are involved in some form of communication. Our success is driven by our ability to communicate our theoretical ideas and personal perceptions effectively. Coupled with this, we find that a large amount of time is spent communicating within a collaborative relationship.

Cooperative learning models have been effective for guiding children to work within a group environment (Johnson & Johnson (1989). Children learn to help one another by sharing material and information to achieve a goal or complete a project.

The purpose of this study is to demonstrate how Internet online projects provide opportunities for collaborative learning among groups located at distant geographic locations. A descriptive analysis of a random sample of projects (N=75) shows the potential for using group dynamics as a tool for creative problem solving. A rubric was developed to measure collaboration, product generation, and creative communication.

Design and Formative Evaluation of an Introductory Computer Course on the Web

Nora Coto Busby
AlignMark
United States
NBusby@alignmark.com

Alan Maples
Computer Information Systems
Cedar Valley College
United States
AMaples@dcccd.edu

Hal Spiegel
LeCroy Center for Educational Telecommunications
United States
HSpiegel@dcccd.edu

A development process was used by a team consisting of a faculty member, instructional designer, and Web developer. A front-end analysis was conducted to determine how introductory computer courses were taught in the distance learning format, what content topics were covered, and what technological trends were being advanced by computer science textbook publishers. A list of content topics was developed and validated by an advisory committee. The advisory committee also critiqued first and second draft course designs. From the critiques, it was determined that a problem-based learning design was appropriate for the course. One-on-one formative evaluation with students began with the third draft design and modifications made. The revised design was then converted into a template for full course production. During full course production, one small-group section of the course was offered. Student and advisory committee recommendations were collected and used to make final revisions to the Web course design.

Prototyping Science Education for Non-Science Majors

Margaret Byrne, Manager, Academic Support Unit, University of California, Davis, USA
mmbyrne@ucdavis.edu

Richard H. Falk, Professor, Section of Plant Biology, University of California, Davis, USA
rhfalk@ucdavis.edu

The University of California at Davis, like many California institutions, is faced with a growing student population and must address issues such as quality of learning, classroom space, the technology needs of specific disciplines, the learning needs of an increasingly technology-savvy student body and efficiency/cost-effectiveness.

One approach is to examine the use of Web-based courses. Biological Science 10, a traditional lecture-discussion course aimed at non-science majors, was restructured to diminish the need for physical classroom space and to provide "anytime, anywhere" learning through the use of the Web. It may be examined at http://bio2000.ucdavis.edu/bis10/.

We discuss instructional design issues, the learning/teaching challenges associated with non-science students facing a science course and the use of technology to improve science education as well as outcomes and student attitudes about "learning science". The entire process of course development, from prototyping to formal offering, is presented. The problems that we encountered and their solutions are discussed.

Beliefs About the Computer Use in Education Held by the K-12 Teachers in Turkey

Nergiz Ercil Cagiltay, Middle East Technical Univ., Ankara, Turkey
nergis@rorqual.cc.metu.edu.tr
Jale Cakiroglu, Indiana Univ., USA
jcakirog@indiana.edu
Erdinc Cakiroglu, Indiana Univ., USA
ecakirog@indiana.edu
Kursat Cagiltay, Indiana Univ., USA
kursat@indiana.edu

Recently the Turkish government has initiated a new information technology project. The main concerns of the project are to bring computers to the public schools, to educate teachers about the use of technology, and to start to use computer based educational technology in the curriculum. In terms of its budget and its scope, this is a very big project for Turkey and the success of the project is very important for the country.

The success of such a project depends mostly on the teachers who will be the key people in enacting the curriculum. Their beliefs about the computer use in education are very important in this sense. Unfortunately, there is not enough research on this aspect of the project in Turkey. Here our aim is to find out how the teachers use and how they perceive the use of computers in education in Turkey.

The following questions will be addressed in this study:

- How do teachers use computers in school and in the classroom?
- What are their beliefs about computers in educational settings?
- What are the teachers' concerns and needs in terms of computer use and curriculum?
- What is the current availability of computers to the teachers and their students?

The Great Scavenger Hunt: Initiating Inservice Teachers to a Technology-Rich Environment

Linlin "Irene" Chen
Department of Urban Education
University of Houston Downtown
cheni@zeus.dt.uh.edu

Scav-en-ger hunt n: a party contest in which usu. couples are sent out with a time limit in which to acquire without buying one or more articles that are esp. difficult to obtain

Webster's New Collegiate Dictionary

Project STAR (Students and Teachers Achieving Results) is a technology-based professional development program intended to provide integrated mathematics, science, and technology experiences for all secondary science and mathematics students in Houston Independent School District (HISD) schools. But if teachers are to understand how to facilitate learning in a technology-rich environment, they must be allowed to experience it themselves. The Technology Teaching and Learning (TTLC) at University of Houston Downtown (UHD), collaborating with HISD, provided such a learning environment for research and skills development for the teachers participating in ProjectSTAR. This allowed teachers to engage in development opportunities that placed them in the learner's role, using technology in all phases of the process. The impact of this model of in-depth teacher development, occurring on the campus of major universities that are engaged in preservice teacher education, is felt both at the public school and at the university level.

The Study on Generic Structure for the Development in the Classroom of the Mathematics Lesson with the Support of the Computer

Miguel Delgado and Teresa Ulecia
Departamento de Matemáticas Fundamentales
Universidad Nacional de Educación a Distancia
c/Senda del Rey, s/n, 28040 - Madrid, Spain
miguel@mat.uned.es
tulecia@mat.uned.es

This Poster presents an abstract structure applied to Mathematics, based on the PEMD-Principle (*)"A material is educational material when there is a training strategy to use it". The structure facilitates the computer's incorporation to teaching, respecting the educational focus that every teacher applies.

It consists on distributing in an appropriate way the area to develop in a Didactic Units' set with a homogeneous structure. Every unit can be adapted to the teaching rhythm, presenting situations and strategies which do not harm it and which permit the reiteration of the processes that are being promoted. Besides, each unit preserves both the teacher's and the student's liberty to choose on contents and liberty to establish the way to follow with students.

The Didactic Units' structure has been experimented in the Teacher Formation Course " The computer in Mathematics classroom " for the last five academic courses, achieving a certain valuation included in this Poster.

(*) Of Strategies and Didactic Materials

Educating "Everyday Maths and Science KnowHow for All" Electronically

S.A. du Plessis
Du Plessis Creative Performance Support Systems
South Africa
Dupcpss@mweb.co.za

I.S. du Plessis
Du Plessis Creative Performance Support Systems
South Africa
Dupcpss@mweb.co.za

Summary of Poster / Demo: We have developed and are planning to publish monthly an interactive multimedia course with the title "Everyday Maths and Science KnowHow for All -Discover the Magic of Maths and Science in Your Everyday Life". One of the purposes of the course is to install a love for and understanding of mathematics and science in as many people as possible. Our course will be distributed electronically to subscribers (via email or as downloads from our website) and via snail-mail (to subscribers who do no have access to the Internet, like the majority in our country's disadvantaged communities). A percentage of our income is also earmarked for community development. Each month the course will contain chapters with the following titles: "KnowHow and Software for the Day", "A Fascinating History", "Classical Quotes", "Mistakes in Everyday Maths", "Maths in Unexpected Places...", "Entertaining Numbers", "Mathematical Humor", "Educational Puzzles", "Educational Games", "A Look at the World Around", "More MathMagic and MathFun", and "Freeware: Pick of the Week".

Multimedia Design and Mathematical Understanding

Franz Embacher
Institute for Theoretical Physics
University of Vienna
Austria
fe@ap.univie.ac.at
http://merlin.mpi.univie.ac.at/~fe

Modern multimedia techniques have the capacity for supporting the process of understanding mathematical concepts in a novel way. The deepest impact of electronic media on mathematics education is to enable students to construct abstract concepts by their own activities. This does not necessarily imply lengthy step-by-step projects for every mathematical notion. It particular, it is possible to get acquainted with some of the central mathematical ideas in a relatively direct and easy way.

This approach is illustrated by relying on **maths online**, a project residing at the University of Vienna whose goal is the creation of a coherent online program suitable for school teaching and self-learning, covering a range of six years mathematics education. Its web site

http://www.univie.ac.at/future.media/moe/

is freely accessible. Using examples out of this program, it is argued that even details of the mathematical setup and the user interface design may be crucial for the success of multimedia learning tools.

A New Technology for Teaching Math Problem-Solving

Rob Foshay, Ellen Cree, and Corrie Bergeron
PLATO® Education
Rfoshay@PLATO.com
http://www.plato.com

Despite the wide-spread interest in teaching high-level problem-solving skills in the context of authentic mathematics problems, use of computer technology for this kind of teaching has generally been limited to the use of tools for computation and data analysis, "flat" problem scenarios, and a few applications of intelligent tutoring.

To overcome these limitations, TRO Learning, Inc. embarked four years ago on a research and development project, funded in part by the Advanced Research Projects Agency (ARPA). The result of this effort is the Problem-Solving Activity (PSA) architecture for the PLATO® computer-based learning system. *Math Problem Solving* for secondary mathematics applies the PSA architecture to a series of 19 problem-solving activities using multimedia authentic problem-based simulations supported by a unique intelligent subsystem for cognitive coaching. 17 key instructional design features derived from research have been incorporated into the PLATO PSA Architecture, and *Math Problem-Solving*.

A Robot's View of Reality: Children Learning From and Through the Topological Panorama Camera

Gerald Knezek
Department of Technology and Cognition
University of North Texas
United States
gknezek@tenet.edu

Rhonda Christensen
Texas Center for Educational Technology
University of North Texas
United States
rhondac@tenet.edu

Janet Gelphman
The Gelphman Camera Company, Inc.
Dallas, Texas
United States
topocam@aol.com

Theresa Overall
The Lamplighter School
Dallas, Texas
United States
Theresa_Overall@acd.org

Dana Arrowood
Department of Teacher Education and Administration
University of North Texas
United States
dana@unt.edu

Abstract: The Topological Panorama Camera (Topocam) is a new educational technology based upon the 150-year old panorama camera. This digital imaging camera moves along a modular track as it scans a scene through a vertical slit or line. The camera's images make motion visible and easily measurable, allowing learners of all ages to investigate motion in new ways. A Texas Instruments Math/Science Technology Grant awarded by the Dallas (Texas) Women's Foundation enabled 63 first through sixth grade girls to learn by conducting experiments on the Topocam during the summer of 1998. Content mastery as well as attitudes toward science, self-reported creative tendencies, and empathy (a caring concern for the thoughts and feelings of others) improved ($p < .05$) during week-long guided discovery sessions conducted for six groups. Changes in pre-post attitudinal response patterns indicated the Topocam sessions fostered enthusiasm for scientific learning. A complete report is available at http://courseweb.tac.unt.edu/topocam.

Using Programming to Teach Algebra
A Demonstration of DrScheme

Janice Larson
Computer Science Department
University of Houston
United States
jlarson@pdts.uh.edu

Karen North
Computer Science Department
Alief ISD
United States
knorth@cs.rice.edu

Educators typically use manipulatives, spreadsheets and algebra software to teach abstract mathematical concepts concretely. But, a more effective method is to teach algebra through programming. DrScheme, developed at Rice University, allows students to write and evaluate programs without first learning input/output or memory management. Students are introduced to the principles of computing through simple functions and graphics.

DrScheme works like an enhanced pocket calculator. (Felleisen, 1998) Students can work with data definitions, variables and conditional math problems. With four programming levels, beginners have fewer construction rules and greater detail in error messages. Higher levels contain more advanced programming constructs. The programming environment evaluates individual expressions or complete programs. Because they write software, the student "teaches" the computer, which enhances their own learning by applying algebra concepts.

Teachers may attend free workshops at Rice University to learn about program design. Instructional materials, including the software, are free and available on-line.

Reference

Felleisen, M. (1998). The TeachScheme! project. [On-line]. Available: http://www.cs.rice.edu/CS/PLT/Teaching/.

Web Page Construction by Middle School Science Teachers: Assessment of Content Knowledge and Classroom Implementation

Christy MacKinnon, Univ. of the Incarnate Word, USA, mackinno@universe.uiwtx.edu; Eliza Carrie Griffith, Univ. of the Incarnate Word, USA, egriffit@universe.uiwtx.edu; Judith Fowles, Northside Independent School District, USA, jfowles@tenet.edu

Abstract: As a requirement of a graduate course in instructional technology, middle school teacher participants were required to construct a web page that included at least two complete lesson plans on life/earth science, in which appropriate instructional technology was integrated. Teacher participants had the option of completing a third lesson, or design a home page. The web pages were assessed according to a rubric that included student learning objectives, nature of student activities (in terms of the "5E" instructional model), type(s) of technology integrated, and student assessment plans. The web pages demonstrated application of computer technology skills and content knowledge in the creation and/or revision of lessons on life/earth science topics. The poster will present examples of participant developed web pages and activities. Analyses will be presented of pre-post tests and classroom observations of technology implementation will be summarized.

Developing an Educational Leadership Database Using URL Submission

Angus J. MacNeil
Educational Leadership
University of Houston-Clear Lake
United States
MacNeil@CL.UH.EDU

Sandy Boyd
Student
University of Houston-Clear Lake
United States
Boyd@CL.UH.EDU

Hans C. Olsen
Educational Leadership
University of Houston-Clear Lake
United States
Olsen@CL.UH.EDU

Abstract: This paper reports the development of a database for an educational leadership program. It outlines the need for databases to support leadership programs and describes how they may be used most productively. Hardware and software requirements and resources for the development of such databases are included, as is a step-by-step process to enable others to develop their own databases. This information gives faculty members an easy way to track the progress of present and past students. It also provides a simple method for students to submit information about them and keep that information current even after graduation. Furthermore, it gives faculty members data for informed program decisions and for and for modeling the collection and use of such data for prospective school administrators.

TROUBLESHOOTING IN THE CLASSROOM

Monique Micheaux-Gordon, South Central District, Houston ISD,USA
mmicheau@swbell.net
Pameolin K. Nelson, Eckert Intermediate School Aldine ISD, USA pamnel@flash.net

Abstract: Waiting days or weeks for a technician to come to your classroom to repair your computer is not only an inconvenience for the teacher but a disappointment for the students. There are basic and simple troubleshooting techniques that can be preformed in the classroom by the teacher which take only minuets. Learning these techniques will help relieve some of the headaches caused by down computers.

Designing Innovative Science Instruction Supported by Multimedia Technology for Students With and Without Disabilities

Prisca Moore, Katherine Maurice & Amber Langerman, Carthage College, USA; Andrea Heiman, Vernon Elementary School, USA

This paper describes the ongoing work of faculty and education students from Carthage College in designing, implementing, and evaluating instructional research projects in which they work collaboratively with elementary and middle school science teachers to develop and teach thematic units which incorporates multimedia technology as tools for students with and without learning disabilities. These instructional materials and lessons reflect national and state standards in science and mathematics education and are grounded in the most recent advances in research in learning and teaching. Multimedia technology is as a tool for the students to acquire knowledge and to express or demonstrate their knowledge using multimedia application programs to create multimedia compositions and presentations. These units have documented the powerful impact of integrating multimedia technology for motivating students to become actively involved in learning and for improving students' perceptions of themselves as learners.

EXPANDING THE HORIZONS OF THE CLASSROOM

Pameolin K. Nelson, Eckert Intermediate School Aldine ISD, USA pamnel@flash.net
Monique Micheaux-Gordon, Technology Department, Houston ISD, USA
mmicheau@swbell.net

Abstract: Telecommunication expands the horizons of the classroom, opening doors to real audiences and exciting interactive activities from locations around the world. Teachers will discover how to integrate telecomputing within existing curriculum framework using the components of the Internet. They will gain insight into ways in which to locate lesson plans, simulations, online and pen pal projects, listservs, newsgroups, and virtual tours via the Internet. Examples of sample lesson plans and student projects will be displayed.

A Hypermedia Supported Problem-based Learning Environment: *Alien Rescue*

Douglas C. Williams
University of Southern Louisiana

Susan Pedersen
University of Texas at Austin

Liu Min
University of Texas at Austin

Alien Rescue is a hypermedia program that draws on the principles of problem-based learning to engage students in grades 5 and 6 in an inquiry approach to science learning. Its science fiction premise takes students to a newly operational international space station where they are charged with developing a solution plan for a complex problem. In the course of their work, students learn about both our solar system and the tools and procedures scientists use to gather that information. *Alien Rescue* is designed according to the standards set forth in the National Science Education Standards. This poster session focuses on the program features afforded by the CD ROM format, particularly the narrative presentation of the problem situation and the variety of cognitive tools students can use in the collection and analysis of data and presentation of findings.

Resources And Applications On The Web's Environment: A Framework For Distance Education

Luiziana Rezende
Mathematical and Natural Science Center
Federal University of Rio de Janeiro
Brasil
luiziana@lci.ufrj.br

This poster describes the most important resources of the web environment and its applications in distributed environments of learning for Distance Education, identifying advantages and disadvantages of its utilization. One of those is the interaction between tutor and manager of the recourses to make the informatic tools practicable, wondering the quality of the pedagogic process.

Inserting the telematic resources on the educational ambient are causing structural and on its organization deep changes requiring a new pedagogic enfoque and new dynamics on learning, including since the knowledge to make the informatic tools useful to the radical changes in the positions of teacher and student.

Use the recourses of Distance Education, in a new perspective, with the network technology, permits the creation of learning in distributed ambient, favouring the co-operative and different work.

The poster presents some informatic tools that are being used frequently in distributed environments of learning for Distance Education and others are a big challenge, that needs a lot of research and integration between the human areas and technic to its support.

Pre-service Student Teachers and Computerized Multimedia Data Bank in Science Education

Mohammad A. Safadi
Department of Biological and Chemical Education
Arab College of Education
Haifa
Israel
Safadim@hotmail.com

One of the important objectives of the Israeli science curriculum is to help pupils at the different grades build a computerized data bank .Student teachers at the department of biological and chemical education of the Arab College of Education were guided to build a computerized data bank in different subjects. We chose to present one of the data banks which we consider very successful and very helpful for other students , teachers and pupils at schools. The data bank contains records of information about many plants and proposed outdoor science research activities . Pictures of each plant photographed in the four different seasons, illustrating the changes that each plant undergoes, the name of each plant in three different languages , Latin , Arabic and Hebrew, textual data containing information about each plant as well as each picture, proposed field research activities for the teachers and the students, proposed teaching methods for outdoor research activities. The photography of the plants and the activities took place in the northern part of Israel, Galilee and Carmel and in the northern sea shore. The pictures were introduced into the computer using the scanning technique. Captured video files were prepared using video adapter card. The aim is to help teachers and students overcome the obstacles in teaching the material of the curriculum ,to help teachers encourage students creativity and conduct field research activities and to encourage students to use multimedia in the class presentations and help them in preparing computerized data banks. The data bank will be useful for teachers and students at the different grades. It will be useful also as a tool for conducting science education research .We are planning to take this data bank a step further and place it on an internet site to give international access.

A Prototype of a Stand-by System for Secondary School Mathematics

Peter Schmidt, Johanna Berewinkel, Guido Körwers, Torsten Müller
Institut für Informatik, Universität Bonn, Germany
email: peter@uran.informatik.uni-bonn.de

The goal of the project is to develop a stand-by system which is able to support students during their whole secondary school education when they work at mathematics on their own. The main structural elements of the stand-by system are the *mathematical objects* (the task types, concepts, theorems, procedures, and subfields), several *main functions* (solve, exercise, discussion, represent, learn, diagnose), and some typical *working situations* of the students.

The prototype is an extended first version of a coherent stand-by system and it will integrate the shells for the main functions solve and exercise, a tool to process a semantic net, subsystems of formula manipulation and of graphics, and some knowledge bases in the context of text tasks which lead to linear equations and of mathematical theorems and proofs in the domain of calculus. The programming language is Java

http://www.cs.uni-bonn.de/~peter/msetdemo.html (contains an extended version of this abstract)

Integrating Technology and Hands-on Activities in the Middle School Science Classroom

Tammy S. Seneca
Brusly Middle School: Science 7
West Baton Rouge School Board
tamssen@aol.com

This poster session will concentrate on the incorporation of a combination of technology instruction and hands-on experiments within the middle school science classroom. It will demonstrate how to incorporate technology and hands-on experimentation into the following subject concentrations: calculations, simulations, data collection, writing, information access, networking, and presentations. We will examine the use of spreadsheets, databases, critical thinking and brainstorming software, presentations, Internet use, and ideas for using hardware such as laserdisc players, digital cameras, scanners, and TV/VCR.

This session will provide concrete research- based information to bring back to their school district in support of this media. It will also provide the teacher with real-world applications for the new technology standards.

The goal of this session is to provide some direction when making technology choices. We will concentrate on how to incorporate the various forms of technology into the classroom in a way that will be meaningful and worthwhile.

A Computer-Based "Laboratory" Course in Mathematical Methods: The *Legendre Polynomials* Module

Richard J. Jacob, Physics and Astronomy, Arizona State University, Tempe, AZ 85287, USA, and
Richard R. Silbar, WhistleSoft, Inc., Los Alamos, NM 87544, USA, silbar@whistlesoft.com

For the last three years one of us has been teaching a workshop course in mathematical methods for undergraduate science majors. Students work through paper-based tutorials at their own pace containing many pencil and paper exercises. The eighteen tutorial modules cry out for conversion from paper into a computer-based course that is suitable for self-paced, independent learning.

With support from LANL's Technology Commercialization Office we have built a prototype of the module on Legendre polynomials. Using a previously built style template, there were no serious problems in making this conversion. To ensure that the student actually does the exercises, we devised a model that requires that equation elements be dragged into a solution box in correct order before credit is given for doing that exercise.

Legendre Polynomials consists of 87 content pages, supplemented with 15 multiple choice question pages. It takes about six hours for a student to complete.

A Description of Telecommunications Use in the High School Science Classroom

Scott Slough, Department of Early Childhood Education and Reading, Georgia Southern Univ., USA
sslough@gasou.edu

Little is known about how to implement telecommunications technology, especially in the high school science classroom. The purpose of this study was to examine and describe the high school science environment within an emerging telecommunications-rich setting in an effort to provide a better framework for implementation of telecommunications technology in science classrooms. Data was collected through open-ended ethnographic interviews with 24 high school science teachers from a single district who had been in an emerging telecommunications-rich environment for at least two and one-half years. This paper will focus on teachers' use of telecommunications and students' perceived use of telecommunications. A five-stage Concerns Based Adoption Model CBAM including awareness, personal, management, impact, and collaboration stages provided a theoretical framework for data analysis and subsequent discussion. Separate lists of teachers' use of telecommunications and teachers' perceptions of student's use of telecommunications by stages of implementation were developed, including users and non-users alike.

Courses with CLASS: Web-Based High School Math and Science Courses

Kevin Smith
Department of Distance Education
University of Nebraska-Lincoln
United States
ksmith3@unl.edu

Katie Morrill
Department of Distance Education
University of Nebraska-Lincoln
United States
kmorrill1@unl.edu

Abstract: This poster/demo session is a report on the work done at the University of Nebraska - Lincoln with a Star Schools grant-funded project called CLASS (Communication, Learning, and Assessment in a Student-centered System). The CLASS project is creating an accredited high school sequence for delivery on the World Wide Web. The courses we are creating are asynchronous web-based courses that students can take from their home, school, or learning center depending on their need. All of the courses are highly interactive with rich graphic environments that enhance the learning. At the present time there are 20 courses available for enrollment. To give you an idea of what the CLASS project has to offer and what kinds of things we are doing in the math and science courses, we will give a brief demonstration of some of the courses.

The Project

The CLASS Project's goal is to make available on the World Wide Web a complete, accredited, high school diploma sequence. The Department of Distance Education of the University of Nebraska-Lincoln is the recipient of $18 million in federal funding to develop the sequence. When completed in 2001, CLASS will have available to students 54 courses from which to choose to complete these requirements.

The Department of Distance Education is uniquely suited to provide this diploma sequence. Among its units is the Independent Study High School (ISHS). The ISHS is the only university-based, fully accredited, independent study high school in the United States. In operation since 1929 and accredited by both the North Central Association of Colleges and Schools and the Nebraska Department of Education, the ISHS currently serves about 15,000 students annually in 136 countries.

Examples of the courses, along with additional information on CLASS can be found at http://class.unl.edu.

Implementation and Scalability Issues for Web-Based Assessment

R. Arlen Strader
Department of Educational Psychology
Texas A&M University
United States
strader@tamu.edu

Robert J. Hall
Department of Educational Psychology
Texas A&M University
United States
bobhall@tamu.edu

Michael S. Pilant
Department of Mathematics
Texas A&M University
United States
mpilant@math.tamu.edu

Abstract: This paper describes a web-based, test-authoring tool. Software features include a flexible environment for constructing on-line exams; scalability for both large and small groups of students; data collection capability (e.g., student response, response time, student confidence, and help requests); and printable test results. Questions are tied to one or more educational objectives; exams, based on these objectives, are then constructed using a specified subset of questions for all students or a random subset of questions for each student. The instructor, to enhance the usefulness of the final report as a study aid, can add detailed explanations for each question.

To date, the instrument has been used reliably in statistics courses (of ~20 students) as well as a freshman mathematics course (~1100 students). The tool has been used to create midterm pretests with study prescriptions, demographic surveys, and prerequisite-skill exams. Questions or output can include text, pictures, and/or interactive *JAVA*™ applets.

USING RESPONSE SURFACE MODELS TO MAXIMIZE PERFORMANCE IN ATHLETICS

Wei-Han Tan & Wei-Fu Tan
8503 Hetton Heights
San Antonio, TX 78250
12th grade and 9th grade
Northside Health Careers High School
San Antonio, TX

The purpose of this investigation is to see if statistical models and computers can be used to find a swimmer's optimum combination of initial 50 meter time, 100 meter split time and first 150 meter split time to minimize their total 200-meter time.

To the researchers' knowledge there has not been an experiment that uses statistics and computers to study swimming in this way.

This experiment uses many statistical applications including multiple regression, policy capturing, response surface models and evolutionary operations with the data-analysis aid of Student SYSTAT. Each individual's judgment data is modeled by multiple regression. After the first empirical data is collected, the response surface is shifted toward their actual swimming capabilities. As data is collected, the model will change until no substantial improvements can be made.

This application is the third year of investigating the potential of this methodology to optimize performance in sports.

West Virginia Reinventing Education Project

Roberta Taylor
Reinventing Education Consultant
IBM Corporation
bunnyt@us.ibm.com

Donna Landin
WVDE/IBM Reinventing Education Coordinator
West Virginia Department of Education
dlandin@access.k12.wv.us

Abstract: The Reinventing Education project was established under a $2 million dollar grant from IBM to the West Virginia Department of Education. Its purpose is to define and validate criteria for creating instructional plans that use the power of the Internet to address the West Virginia Instructional Goals and Objectives and improve student achievement and learning. A Criteria for Excellence was created, then employed by a group of pilot teachers to develop lesson plans that would be peer reviewed, validated by field testing, observed during classroom implementation, and repeatedly revised. The resulting lesson plans have resulted in significant learning improvement and have been placed in the Best Practices database to share with teachers across the state. The original pilot teachers represented sixth through twelfth grade mathematics. However, during the summer of 1998, additional teams representing reading language arts, social studies, and science began similar work.

Using Technology to Enhance a Literacy Curriculum: Literacy in a Science Context

Joan Thormann, Ph.D. Technology in Education
Lesley College, Cambridge, MA USA
thormann@mail.lesley.edu

Abstract This poster session will display a technology-enhanced human physiology curriculum for inclusive upper-elementary classrooms. The display will include portions of the curriculum, work sheets, assessments and a demonstration of the MBL equipment.

This poster session involves a display of *Literacy in a Science Context*, a curriculum published by ASCD and developed at TERC in Cambridge, MA. The curriculum was based on federally-funded research with special and regular education teachers who were trained to use a technology-based human physiology curriculum to improve the literacy skills of students, particularly, students with learning disabilities

The curriculum guides students' use of microcomputer-based labs (MBL) and telecommunications for collecting data on, and conducting investigations about, the human body. Students collaborate to collect, make sense of, and report on real-time data about the functioning of their own bodies; they talk, read, and write about their science activities. The curriculum includes lessons on data analysis, to establish a firm foundation for the understanding and analysis of the human physiology data that is collected. Many of the activities involve students working with technology tools in collaborative groups to enhance learning and communication skills. Sample activities of how technology was integrated into a curriculum and examples of the technology that was used in the curriculum will be displayed..

Grant, C., Storeygard, J., Thormann J. & Weir, S. (1996). *Literacy in a Science Context: A hands-on human physiology curriculum* together with *A guide to assessment and professional development.* Alexandria, VA: ASCD.

Internet-based Interdisciplinary Elementary Science Methods Instruction

Bob Warren, Ph.D.
Dakota State University
United States
warrenb@pluto.dsu.edu

Abstract: Pre-service education students at Dakota State University take a portion of their elementary science methods through an interdisciplinary Internet-based unit. During the unit, students do not attend their scheduled on-campus class. They work individually and in groups, on the Internet. Students experience distance learning and multimedia (i.e., video clips, sound clips, e-mail, discussion boards), web-browsing, individual and cooperative learning. Upon completion, students evaluate their Internet-based learning experiences and explore how they could develop similar projects appropriate for teaching science to elementary students. Students then develop Internet-based science units and use them during their practice teaching experiences. Successful units are placed, for reference, in The Resource Room in a unique Virtual Campus Training School web-site.

Acknowledgments:

Funded by a State of South Dakota Governor Janklow's Faculty Award for Teaching with Technology

ROUNDTABLE PAPERS

Hong Kong Secondary Students' Perception of Biotechnology and Its Implications on School Science Curricula

Sing Chan, Chung Lui, Joseph Tsang
Hong Kong Institute of Education
Hong Kong
slchan@ied.edu.hk

Abstract: Biotechnology has tremendous applications in the areas of agriculture, environment, fuels and chemicals, food and drink, gene cloning, and medicine. Also, when biotechnology applies to humans especially in genetic engineering, it stimulates controversial debates on bioethical issues. While biotechnology is increasing in the news, awareness of its overall significance remains limited. This is especially true for high school students. Many western governments have been planning to bridge the gap. In Hong Kong however, the pace is comparatively slow. This study is unique in being the first in Hong Kong to inquire into the student perception (knowledge and attitudes) of biotechnology. Based on the findings, this study is to make recommendations for integrating biotechnology in the science classes.

Introduction

"Duplicating a person is possible!" This stunning news hit the headlines all over the world, including major newspapers in Hong Kong such as South China Morning Post (SCMP), Ming Pao Daily, and Sing Tao Daily on March 3, 1997. That news was released only days after the newspapers got wind of Dolly the sheep which was made by cloning by Scottish biotechnologist. As SCMP (p.21) reports: "The news caused a furore because if we can do this with sheep, why not with a person? Parts of Deng have been conveniently retained for research: why shouldn't scientists strip out the DNA and produce 1,000 Dengs to rule forever?" SCMP also reports the comments made by biochemist Mary Waye of The Chinese University of Hong Kong: "I think it will certainly affect our teaching because it means a great deal in basic knowledge. It's a very surprising, very exciting piece of work that will mean re-writing a lot of textbooks."

While biotechnology is increasing in the news, awareness of its overall significance among the general public remains limited. This is also true for high school students. Due to the importance of biotechnology education, there is a worldwide trend of extending this from college to secondary school level (Paolella, 1991; Well, 1994; Sweeny, 1998). In England, the Royal society report (Royal Society, 1981) indicated that biotechnology can make a valuable contribution to the education of future citizens. In 1987, the British Association for Science Education published a series of books (SATIS, 1987) and it has included biotechnological issues in the series. The National Curriculum for Science (DES, 1989) also incorporates a significant amount of biotechnological content.

Surveys about the public perception of biotechnology (Walter, 1995) and the status of secondary school level biotechnology instruction (Biermann, 1990; Bittisnich, 1995; Zeller, 1994) have been made in western countries. To provide biotechnology training for high school teachers, many institutes have provided technical assistance (Duvall, 1992, Ahmed, 1996). Computer-assisted learning materials are designed to bridge the gap between theory and practice in the field of biotechnology (Jenkins, 1997). Laboratory manuals have also been written to guide secondary students to perform biotechnology experiments in schools (Henderson & Knutton, 1990; Taylor, 1988).

In the classroom, bioethical issues are getting more attention recently, and it is a rather popular practice to include such a topic in selected courses such as Biology or Ethics in the school curriculum (Cross & Price, 1996; Dreyfus, 1995; Kormondy, 1990; Lovat, 1994; Morris, 1994). However, when biotechnology applies to humans especially in genetic engineering, it triggers off the controversial debates on bioethical issues, such as genetic manipulations. In the classrooms, bioethical issues are likely to be increasingly in the spotlight in coming years (Miho et al., 1998; Simpson, 1996), and there are several justifiable reasons for placing bioethical issues in the curriculum (Brody & Engelhardt, 1987; O'Brien, 1996).

In Hong Kong, the Industrial Support Fund since its set-up in 1994 has approved biotechnology projects up to HK$222 millions (Tsang & Lo, 1998), indicating its emphasis on this industrial area regardless the change of sovereignty from Britain to the Republic of China. While many western governments have been planning to bridge the gap between biotechnological advancements and the secondary school curricula, the pace in Hong Kong is comparatively slow. As Hong Kong science educators, we are planning to introduce relevant and updated biotechnology elements into our Science curricula, in order to provide students basic biotechnology knowledge as well as positive attitude towards advances in science and technology. Before we can develop a meaningful curriculum with biotechnology elements for our secondary schools, it is important to understand the students' perception of this subject, that leads to this study.

Method

Pilot Study

The pilot study had three stages: 1. construction of a draft questionnaire by referring to reports on the student attitude towards genetic engineering (Lucassen, 1995), animal research (Richmond et al., 1990) and technology (Griffiths & Heath, 1996), 2. preliminary interviews to gather information pertaining to refine the draft, 3. field testing of instruments for reliability studies, and 4. validity studies including checks on ambiguities and anomalies, and test-run of the data collected by computer data processing. As a result of analysis of the pilot survey, a finalized version of the questionnaire was constructed for the main survey.

Main Survey

After piloting, the finalized questionnaire was administered in May 1998 to 20 random secondary schools located in different regions of Hong Kong. These 20 schools were geographically stratified to provide a fair representation of all the secondary schools in the territory. In each school, only the Biology stream students of Form 4 (Grade 10) and Form 6 (Grade 12) levels (one class each) were requested to respond.

A total of 1,120 valid questionnaires (892 Form 4 and 238 Form 6) were processed. In order to examine the hypotheses, two overall variables were created: ATTITUDE and KNOWLEDGE. Each variable represents the arithmetic average of the students' responses to overall statements. For each statement, the values could range from 1 to 5. The higher the Attitude score means the more acceptable attitude towards the practice of biotechnology, and the higher the Knowledge score means the more adequate the students' understanding of the basic principle underlying biotechnology, and vice versa.

Result

Table 1 summarizes the attitude of students (N=1120) toward the statements which address the practice of biotechnology. The general trend is that students tend to accept (mean between 3 and 4) those biotechnological applications that are beneficial to mankind, as revealed in the areas of agriculture (average: 3.89), environment (4.11), fuel and chemical (3.72), food and drink (3.85), and medicine (3.89). On the other hand, students tend to be more reserved towards animal duplication (3.06) and bioethical issues (2.30).

With respect to these areas, it will be interesting to compare the statistical results with written comments by the students, which are summarized below:

In the area of **agriculture**, students mildly accept (mean: 3.73) the use of genetically engineered bacteria as insecticides and pesticides. From the written comments, most of the students who advocate the practice think that it can help extinguishing harmful pests without chemically polluting the environment. Some hesitant students challenge whether human has the right to manipulate other living things, and they are skeptical of any unnatural interference to the ecological system. Generally, students strongly accept (mean: 4.18) the idea of breeding plants for crop improvement as it may solve the problem of food shortage, helping the people in poor countries and saving land in developed countries. About using culture medium to culture plant tissue and plant cells for the purpose of breeding, students mildly accept (mean: 3.75) the idea, thinking it can save the rare plant species from extinction, and can help promoting the growth of valuable plants.

Students' (N=1120)
Overall Attitude towards Biotechnology

Variable		Mean ATTITUDE	Dev	Std Score
Agriculture				
BACTERIA		3.73		1.11
BREED			4.18	
	.89			
CULTURE			3.75	
	.95			
	Average	3.89		
Environment				
BIODEGR1				
BIODEGR2		3.91		1.03
SEWAGE			4.09	
	.94			
	4.11			
Fuel and Chemical				
ETHANOL			3.64	
	.97			
METHANE			3.62	
	.99			
BIOFUEL			3.91	
	1.00			
	3.72			
Food and Drink				
VEGETABL		3.72		1.15
FERMENTA		4.27		.87
SCP				3.55
		.96		
	3.85			
Gene Cloning & Duplication				
DUPLICA1		2.54		1.32
DUPLICA2		3.57		1.26
	3.06			
Medicine				
PROTEINS		3.91		1.00
VACCINE			4.15	
	.89			
CANCER			3.58	
	1.14			
PHARMACE		4.00		.98
GENE				3.82
		1.05		
	3.89			
Bioethics				
ORGAN			2.45	
	1.28			
SEX1				
SEX2				2.84
		1.25		
CLONING			1.91	
	1.15			
MEAT1			1.80	
	1.07			
MEAT2			2.67	
	1.21			
	2.30			

5= accept strongly, 4= accept mildly, 3= neutral, 2= reject mildly, 1= reject strongly

Students' (N=1120)
Overall Knowledge
in Biotechnology

Variable	Mean Std KNOWLEDGE Dev Score
Agriculture	
BACT.K	2.19
	1.01
BREED.K	2.35
	1.08
CULT.K	2.10
	1.03
Average	2.21
Environment	
BIOD1.K	2.41
	1.12
BIOD2.K	2.08
	1.00
SEWAGE.K	2.41
	1.17
	2.30
Fuel and Chemical	
EHTA.K	2.53
	1.23
METH.K	2.25
	1.16
BIOFUE.K	2.34
	1.12
	2.37
Food and Drink	
VEGE.K	2.44
	1.09
FERM.K	3.34
	1.19
SCP.K	2.23
	1.08
	2.67
Gene Cloning & Duplication	
DUPL1.K	2.35
	1.11
DUPL2.K	2.38
	1.13
	2.37
Medicine	
PROT.K	2.13
	1.07
VACC.K	2.12
	1.07
CANCER.K	2.07
	1.04
PHAR.K	2.05
	1.03
GENE.K	1.95
	1.01
	2.06
Bioethics	
ORGAN.K	1.98
	1.05
SEX1.K	2.32
	1.18
SEX2.K	2.11
	1.07
CLONING.K	2.09
	1.11
MEAT1.K	2.00
	1.05
MEAT2.K	2.04
	1.04
	2.09

5= very adequate, 4= adequate, 3= neutral, 2= inadequate, 1= very inadequate

Table 1: Students' overall attitude towards Biotechnology and overall knowledge in Biotechnology.

In the area of **environment**, students generally strongly accept (mean: 4.34) the use of natural microbes to biodegrade the chemical pollutants, because it naturally solve the pollution problems, and is economical as well.

Comparatively, they accept with a lesser degree (mean: 3.91) the idea of using genetically-engineered microbes to biodegrade the chemical pollutants, though some students worry about the cost and mutation. They also accept strongly (mean: 4.09) the idea of disposing sewage by aerobic and anaerobic processes. In general, students are in strong support of environmental protection.

In the area of **fuel and chemical**, all students mildly accept (means: 3.72, 3.62, and 3.91) the biotechnological applications. In general, students commend the innovative ideas of producing ethanol from sugar crops, claiming that kind of fuel is better for environmental protection. They also admire the economical practice of producing methane from wastes, and the pollution-free practice of converting chemical into electrical energy by biofuel. However, some were skeptical about the outcome after depletion of sugar canes or biofuel.

In the area of **food and drink**, students mildly accept (mean: 3.72) the production of new bio-engineered strains of vegetables such as tomatoes and Soya for human consumption. Some praise this practice as a good way to alleviate global food shortage. Others are cautious whether the products are carcinogenic. However, they strongly accept (mean: 4.27) the practice of making bread/beer/yogurt/soy sauce by fermentation as they consider this as a safe and common way for food making. The idea of producing single cell protein food with fungi and algae is mildly accepted (mean: 3.55). While some students hold it as a good way for increasing the productivity of cattle, some are skeptical about its practicality for human consumption.

In the area of **gene cloning and duplication**, students' views depend on how the techniques are applied. In general, they tend to reject (mean: 2.54) the ideas of duplicating animals (e.g. sheep or horses) just for human consumption or utilization, because they feel that the practice is inhumane, unnatural, and unnecessary. On the other hand, they tend to take a more acceptable stand (mean: 3.57) towards the idea of duplicating animals (e.g. pandas) for species preservation, though some still insist that this is also unnatural and unnecessary.

In the area of **medicine**, students generally favor all biotechnological applications. They think that the associated techniques are beneficial to mankind, promoting medical research and advancement, and preventing epidemic diseases. However, some object the ideas of using mice for experiments, saying that torturing animals is not acceptable.

In the area of **bioethical** issues, students generally disapprove gene manipulation. Duplicating human organ on animal body for medical use is disagreed (2.45) as a very cruel technique and unethical. Interestingly, they do not like the idea of parental choice for the sex of fetus (2.12), even if the fetus is at risk of a sex-linked disease (2.84). They think it would violet the nature by human interference. They reject the idea of duplicating human beings by cloning method (1.91) because it is against the natural system, some say that it is challenging God's will. They also think that it is a disgusting practice to sell meat from genetically-engineered animals for human consumption (1.80), even though consumers are informed about it (2.67). They think cheating is unethical and there is no need to consume such kind of meat when there are plenty of good natural food to select.

Table 1 also summarizes the students' self-evaluation of their knowledge in the 6 areas of Biotechnology. Students are instructed that they can regard themselves as having adequate knowledge if they know the basic principle underlying the statement. In average, they tend to view themselves as fairly inadequate (between 1.95 to 2.53) towards all topics, except the principle of fermentation which they have a much higher mean score (3.34). This is because the principle of fermentation has been taught in secondary school.

Conclusions and Implications

The general trend of students' attitude towards biotechnology is that they tend to accept those biotechnological applications that are beneficial to mankind, as revealed in the areas of agriculture (average: 3.89), environment (4.11), fuel and chemical (3.72), food and drink (3.85), and medicine (3.89). On the other hand, students tend to be more reserved towards animal duplication (3.06) and bioethical issues (2.30).

To agriculture, students mildly accept the use of genetically engineered bacteria as insecticides and pesticides. They strongly accept the idea of breeding plants for crop improvement. About using culture medium to culture plant tissue and plant cells for the purpose of breeding, students mildly accept the idea. To environment, students are in strong support of environmental protection. To fuel and chemical, all students mildly accept the biotechnological applications. To food and drink, students mildly accept the production of new bio-engineered strains of vegetables for human consumption. However, they strongly accept the practice of making bread/beer/yogurt/soy sauce by fermentation. The idea of producing single cell protein food with fungi and algae is mildly accepted. To gene cloning and duplication, students' views depend on how the techniques are applied. In general, they tend to reject the ideas of duplicating animals just for human consumption or utilization, because they feel that the practice is inhumane, unnatural, and unnecessary. To medicine, students generally favor all

biotechnological applications. To bioethical issues, they generally disapprove gene manipulation. They reject the idea of duplicating human beings by cloning method because it is against the natural system.

When students are asked to self-evaluate their knowledge in biotechnology, they tend to view themselves as fairly inadequate (between 1.95 to 2.53) towards all topics, except the principle of fermentation which they have a much higher mean score (3.34). This is because the principle of fermentation has been taught in secondary school.

Secondary students have overall positive attitude towards biotechnological applications as revealed in the areas of agriculture, environment, fuel & chemical, food and drink, and medicine. However, their self-evaluated knowledge in Biotechnology is inadequate(between 1.95 to 2.53) towards all topics (except the principle of fermentation). Therefore, we should provide them more training, in the form of lectures, experiments, visits, projects, and workshops. On the other hand, since students have different attitudes towards biotechnological applications, it is good to apply other teaching methods such as issue-based method, case-study, discussions and, active debates to facilitate the reflection of attitudes.

In order to help Hong Kong students familiarize with the rapid global development of Biotechnology, they are much encouraged to use the computer to browse World Wide Webs through Internet. Many Biotechnology related Websites are easily located. Some of them are listed below for easy reference.

Website location (sorted in this order)	**Website Title**
http://biotech.chem.indiana.edu/pages/education.html	BioTech Education
http://chroma.mbt.washington.edu/outreach/outreach.html	Center for Molecular Biotechnology Outreach Program
http://juliet.stfx.ca/people/fac/rjmackin	Biology Book Marks: Biotechnology
http://mendel.berkeley.edu/dog.html	Dog Genome Project
http://schmidel.com/bionet/biotech.htm	Molecular Genetics
http://www.ansi.okstate.edu/breeds/	Breeds of Livestock
http://www.biology.arizona.edu/molecular_bio/problem_sets/Recombinant_DNA_Technology/recombinant_dna.html	Recombinant DNA Technology Problem Set
http://www.biotech.wisc.edu/Education/cattlecloning.html	Biotech Education: Cattle Cloning
http://www.cato.com/biotech/	The World-Wide Web Virtual Library
http://www.cw.com.tw/magazine/190-9/191/191c3.htm	Biotechnology: Opportunities and Strategies
http://www.hkib.org.hk/	The Hong Kong Institute of Biotechnology Ltd.
http://www.nal.usda.gov/bic/	Biotechnology Information Center (BIC)
http://www.ornl.gov/TechResources/Human_Genome	Human Genome Project
http://www.stic.gov.tw/stic/infowww/biotech/index.html	Taiwan: Network of Biotechnology Information

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Applying WEB-Based and Other Visualization Tools to Teach Calculus

Olga M. Ramirez,
Wendy A. Lawrence-Fowler*,
Gerald Brazier,
John E. Bernard,
William Heller,
Roger Knobel
Department of Mathematics,
*Department of Computer Science
The University of Texas-Pan American
USA

The traditional teacher-directed, skill-driven, student-passive lecture model has primarily characterized instruction in Calculus I classes at the University of Texas-Pan American. Peer tutoring and advising interventions are used as supplements to assist students enrolled in these classes, hoping to ameliorate the associated high attrition and failure rates. Yet, as currently delivered, entry-level Calculus I, a prerequisite course for most science and engineering programs, still impedes many capable aspiring minority students during their program of study. Prior financial limitations for additional staff, equipment, and programs have made necessary interventions, i.e., providing an electronically enhanced teaching and learning environment conducive to active, discovery-oriented, group-supported learning impossible. This project will develop and implement model enhancements that integrate WEB-based and other visualization tools (e.g., computer and graphing calculator modeling and simulation techniques) with effective student retention strategies (e.g., Tinto's Interactionalist Theory of Departure [Tinto, 1993], Astin's Theory of Involvement [Astin, 1984], Bean's Theory of Institutional Fit [Bean, 1980]) and widely accepted mathematics learning theories and instruction practices (e.g., J. Bruner's Theory of Instruction [Bruner, 1974], G. Polya's Problem Solving Process [Polya, 1957], Z. P. Dienes' Multiple Embodiments [Dienes, 1974]) to improve Calculus I curriculum and instruction.

In doing so, the challenges lie in both comprehending the students' level of mathematical understanding and in trying to identify, create, and align curricular materials to maximize learning. Accordingly the proposed project's curriculum will embody an interactive, hypermedia learning and teaching environment that incorporates student-centered activities. The locally created hypermedia Calculus I curriculum modules will serve as medium for presentation and demonstration and provide a personalized environment for each student. As a result of the project, mathematics faculty will be better able to help students gain greater understanding of different types of significant mathematical knowledge (e.g. concepts, generalizations, procedures, and facts) while promoting and nurturing reflection about methods for cultivating problem solving, reasoning, and communication skills.

The ultimate project goal is to increase completion of degree programs (hopefully with a decrease rather than increase in time to completion) and subsequent access to careers in science and engineering for minority students. Specifically, the objectives are as follows:

1. *Increase the number of minority students, particularly women, in the natural sciences, mathematics, and engineering by increasing success rates in mathematics courses taken by these students.* A profile that includes affective and cognitive background measures of students taking the Calculus I course will be compiled to assess their needs and establish benchmarks for project gains. As the project progresses, Calculus I students will receive support in dealing with the initial shock experienced when facing the expectations of a college level mathematics course requirement. Students will be informed and prepared to handle new and challenging expectations. They will receive support, tools and strategies essential for success. To help them understand that success in mathematics is not just the appearance of knowing, but rather that knowing consists of ability to utilize processes of mathematical inquiry grounded on true understanding of mathematical concepts, generalizations, procedures, and facts, faculty will work to empower these students to become functionally literate self-managers, as well as independent learners able to work cooperatively with others. Focus on investigating factors related to minority students' work with mathematics and why minority, at risk students,

particularly those who are first generation college students and from low socioeconomic classes, fail to stay in college until graduation will be foremost.

2. *Develop cost-effective, exemplary, pedagogically- oriented electronic lessons/activities that provide enhancement to the mathematics curriculum and that will be the basis for classroom presentations and a student-centered learning environment.* Students become proactive in their own education through exploratory learning. The power of hypermedia can be used to motivate students and to improve learning through the enhancement of classroom presentations and self-directed instruction. The close tie between lecture, the hypermedia affords the student an individualized source of information to further their understanding and internalization of mathematical knowledge and skills. By utilizing the World Wide Web, and other computer or graphing calculator modeling and simulation in teaching appropriate Calculus I topics such as finding limits and roots, integrating, and differentiating (numerically and symbolically), manipulating algebraic expressions and equations, illustrating epsilon-delta relations by window-sizing, showing linearization of a differentiable curve, graphing complicated functions, graphing polar and parametric equations, graphing surfaces, illustrating Reimann Sums, verifying the Fundamental Theorem of Calculus, and illustrating Taylor polynomials and error analysis, to say the least, faculty will, by way of new instructional mediums, advance students' ability to examine the corresponding networks of mathematical content and to formulate meaningful connections between them.
3. *Provide a model of WEB-based and other scientific visualization tools to use in creating an exemplary student-centered teaching and learning environment for UTPA science and engineering faculty.* Taking advantage of equipment available in the newly formed Multimedia Curriculum Development Laboratory, faculty will develop support material for Calculus I, which explicitly recognize the diversity and interaction among skills that students must master. Faculty will integrate existing software resources (i.e. Electronic Classroom Notes, University of Arizona animations) with software resources to be developed in the project. Hypermedia instructional modules integrate computer-based instruction, resources, and other tools for visualization for mathematical problem solving. Classroom instruction uses the same hypermedia materials. Availability of these materials outside of class fosters means to support student success by providing opportunities for students to review and study course content at their own pace, yet sustains discovery and discussion occasions for active group involvement. The integration of the scientific visualization materials for animation and graphics serves as a model for other UTPA science faculty.

It is anticipated that the project will reduce attrition and failure rates in Calculus I and, in turn, in various science and engineering majors. More generally, quantitative deficiencies of our students will be reduced. The following individual and institutional outcomes critical to success in a science or engineering degree program will result from the implementation of the WEB-based and other visualization-oriented teaching and learning modules for Calculus I:

1. permit systematic, and frequent interaction and communication between students and faculty;
2. permit systematic and frequent interaction and communication between students and other students;
3. enhance the quality of the instructional program for science and engineering majors and as a side effect of the instructional program for non-science majors;
4. improve science and engineering skills through the improvement of critical courses in mathematics;
5. upgrade faculty skills and training through instruction and mentoring in the use of information technology;
6. increase the total number of science and engineering majors and graduates;
7. increase the number of Hispanic scientists and engineers;
8. increase the enrollment of Hispanics in graduate programs in science and engineering;
9. develop and enhance formal and informal networks among science and engineering educators via the visibility afforded by the networked nature of the project of UTPA to train scientists; and
10. sustain a cyclical and on-going review and modification process of instructional programs for science and engineering majors. Together, these outcomes positively impact the project 's main goal to increase minority access to careers in science, mathematics, and engineering.

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Acknowledgements

This project is funded in part by the United States Department of Education Minority Science Improvement Program (MSIP).

Electronic Portfolios in Science for Professional Development and Student Assessment

Judy Reinhartz, Professor
The University of Texas at Arlington

Don M. Beach, Professor
Tarleton State University

The session focused on the use of digital cameras to design and construct a portfolio to document classroom events for the purpose of professional development for middle school teachers, to provide student opportunities to demonstrate their science learning, and subsequently to use this documentation in assessing teacher effectiveness and student performance. In this project, middle school science teachers and students were trained in the use of the digital camera as a way of capturing science teaching and learning episodes. The pictures selected for inclusion in the portfolios by both middle school teachers and students represent growth over time and serve as a mechanism for self-reflection and analysis.

Even though more and more technology is found in K-12 classrooms across the United States, Abdal-Haqq (1995) notes that less than 10% of teachers feel "... competent to use multimedia and presentation packages, electronic network collaboration capabilities, or problem solving applications" (np). The use of the digitalized images in portfolios is one example of how middle school teachers have infused technology in their science classrooms. Students also learn to use the digital camera to capture images to build science portfolios. During individual conferences with their teacher, students have the opportunity to demonstrate their science knowledge by explaining the reasons for selecting and including items in their portfolios. Such interactions provide "... insights into their students' growth not possible through traditional assessment measures" (Rief, 1990, p. 50). Their teachers also have opportunities to select the artifacts for their portfolio which are deemed important, and provides evidence of professional growth. As part of a word-processed document, teacher and student portfolios come alive and serve as a "moving picture" of instructional accomplishments. A digital camera is a relatively new technological tool, and its use in science classrooms is limitless (Robin, 1998).

Electronic portfolios become windows into students' and teachers' heads and a means of understanding "... the educational process at the level of the individual ..." (Paulson, Paulson, & Meyer, 1991, p. 52). Portfolios allow their developers to assume ownership, and they also establish new relationships between and among teachers, students, and members of the school community (Sills-Briegel., Fisk, & Dunlop, 1996). Darling-Hammond (1996) says that portfolios are purposeful collections of a teacher's learning, disposition, and development. Campbell and Colleagues (1997) provide the most comprehensive view of portfolios when they describe them as "... an organized, goal-driven documentation of ... professional growth and achieved competence in the complex act called teaching" (p. 3).

For teachers, the portfolio provides a mechanism for revisiting past instructional events and to think about what changes if any, need to be made. It also records the on-going attempt to implement hands-on experiences which support constructivist teaching practices and the use of alternative assessment strategies and educational technology in their science classrooms (Wolf, 1989). The portfolio becomes the basis for professional growth of specific knowledge, skills, and teaching strategies (Wolf, 1996; Pheeney, 1998). For students, the visual representations provide an on-going record of their science learning and the science topics they are interested in pursuing in the future. In addition, their portfolio becomes a part of the assessment process to use to measure comprehension and mastery for them and their teachers and parents. Danielson (1996) sums up the benefits of constructing portfolios when she says, "Creating a professional portfolio can benefit a teacher in Many of the same ways that teachers have observed portfolios benefiting students. For example, when students select for aportfolio their best work of writing ... similarly, teachers who are asked to submit a portfolio ... have discovered the power derived from selecting and commenting on their best teaching. (p. 38) And Van Wagenen and Hibbard (1998) link teacher portfolios to student portfolios when they say, "A teacher's portfolio enables us to do exactly what we ask our students to do: self-assess, self-evaluate, and self-regulate" (p. 29).

When the teaching and learning process is viewed through digitalized images, the nuances and complexities emerge as teachers and students reflect on the outcomes of their efforts. The research has shown that as teachers think about their teaching practices, this reflective experience impacts their ability to improve instruction (Raines & Shadiow, 1995). There is similar evidence that has emerged for student learning. The current view of teaching and learning encourages teachers and students in "... reflection, self-assessment, naturalistic inquiry in classrooms, case-

based methods, and the development of portfolios" (Beach & Reinhartz, In Press). The use of a portfolio brings attention to the multidimensionality of the teaching-learning process, and both teachers and students are active participants in assessing their own knowledge and abilities.

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SCIENCE PAPERS

Creating "Interactive Science Activities on the Web" (ISAW)

Richard L. Bowman
Department of Physics
Bridgewater College
Bridgewater, Virginia 22812
United States of America
rbowman@bridgewater.edu

Abstract: The project, "Interactive Science Activities on the Web" (ISAW), grew out of the concept that the largely untapped strength of the World Wide Web resides in its universality and its interactive nature. ISAW is a program of web-based science activities that includes interactive simulations written with JavaScript, information and additional references on each topic, and laboratory exercises for students. This paper will examine the rationale and underlying design of ISAW, the present implementations of selected ISAW activities including a brief discussion of JavaScript (and "cookies"), and an outline of future ISAW developments. At present ISAW includes four web pages generating iterative function systems fractals and a planetary orbit simulation and laboratory exercise. Additional ISAW components are in preparation. Visit ISAW at: <http://www.bridgewater.edu/departments/physics/ISAW/>.

Introduction

The pervasiveness of the World Wide Web in most countries and cultures today has made available to students and teachers a vast amount of information that is accessible relatively easily and quickly. With its capability of rapidly displaying graphics (whether diagrams, graphs or photographs) and its vast resource of information, the Internet has been readily adopted as a teaching tool by science instructors at the secondary and college levels. However, using the Internet primarily as an advanced encyclopedia of copious quantities of information does not fully tap its potential. The Internet is becoming an even more powerful pedagogical tool due to its ability to be interactive as well as its almost universal availability and the uniform "feel" of its interface regardless of the type of computer being used to connect the user to the World Wide Web.

For classes in the humanities, interactivity via the World Wide Web can take the form of email discussion lists, newsgroups, web-based forms, and text-based virtual spaces such as those possible with MOOs (Brooks 1997, Haynes & Holmevik 1998). Science and mathematics instructors can also benefit from these types of interactive uses of the Internet (Bowman 1998b,a). In addition, science and mathematics teachers need interactive mathematically-based simulations that encourage students to "experiment" with different values for parameters in the models underlying the simulations.

This paper describes the design, construction, use and planned expansion of a web-based series of interactive simulations undertaken by the author in the area of physics and astronomy. The project is known as *Interactive Science Activities on the Web* (ISAW).

Designing ISAW

The mission of ISAW is to design and implement interactive science simulations that have clear pedagogical purposes and whose concepts cannot be easily explored with real, hands-on experiments. Simulations cannot replace working with actual physical objects, but they can effectively augment hands-on learning. ISAW projects should also be moderately easy to write and simple to integrate into class

assignments or laboratory exercises. The goal is to create a tool that is truly usable by teachers at both the high school and college levels.

Constructing ISAW

JavaScript was chosen as the language for the ISAW simulations due to its relative ease of use and its broad implementation. A number of science simulations have been written as Java applets (TIPTOP 1998, Hwang 1998, STEM 1997). However, learning Java generally fits a rather steep learning curve (Cary & Alexander 1998), and Java applets are not easily modified since only the semi-compiled code is actually read by the user's computer. Other approaches have also been tried, such as commercial simulation software (Coleman 1997) and the ActiveX environment (Rebello & Sushenko 1997), but they lack universality.

JavaScript is easily programmed by anyone experienced in using a computer language since JavaScript is, broadly speaking, similar to C and even BASIC or Fortran. (The author does not know the former but has written extensively, although not routinely, in the latter two languages.) JavaScript (or JScript to Microsoft) code is passed to the user's computer as part of the ASCII file from which the web browser displays the visible web page. Users may easily examine the JavaScript source code, modify it or incorporate it into their own projects.

There are two drawbacks to using JavaScript as the source code for science simulations. First, JavaScript has not yet reached a level of maturity where its basic structure is identically interpreted by all browsers or even all versions of the same browser. For example, the author has tested each of the completed simulations on Microsoft Internet Explorer (version 3 and 4) and Netscape Navigator (version 3). A number of re-writes were completed before the same JavaScript code would execute properly in each of these browsers. Secondly, interpreting JavaScript code may take from several seconds to a minute or more depending upon the processor speed of the computer running the web browser displaying the simulation. All of the simulations to date finish in under two minutes on the author's 75 MHz Pentium-based PC and are executed more quickly than that on faster PC's.

Numerous good sources of information for the JavaScript (or JScript) language exist: books (Goodman 1996, Reynolds & Honeycutt 1997), a web-based meta-FAQ (Thompson 1998), a very prolific newsgroup (comp.lang.javascript), and online help from the browser publishers (Microsoft 1998, Netscape 1997a,b). The beginning JavaScript author should start by reading Danny Goodman's book and/or by examining the source code for web pages using JavaScript. For example, they can go to the ISAW site and examine the relevant source code. The basic programming strategy in JavaScript is to create functions (modules of script) that can be called again and again to perform their duties. This "object-oriented" approach enables the programmer to reuse old code in new programs. Below I will highlight only a few aspects of the language with an emphasis on some special topics needed for the ISAW project.

JavaScript was not originally designed to plot data. However, several persons have since generated a work-around that is fairly efficient. The procedure scales two 1-pixel-by-1-pixel graphics (a black dot and a white dot) to spread across the appropriate regions of the screen so that a plot of data is displayed. The generic functions are listed below..

```
function make_1d_array(n) {
  this.length = n;
  for (var i = 1; i <= n; i++) {
    this[i] = 0;
  }
  retum this
}
function make_2d_array(n, m) {
  var a = new make_1d_array(n);
  for (var j=1; j<=n; j++) {
    a[j] = new make_1d_array(m);
  }
  return a
}
```

```
function plot_2d(graph, size) {
//
// graph is a 2d array of 0's & 1's (0=white & 1=black),
//   and due to the algorithm used for efficient plotting, graph
//   should be dimensioned and plotted with a size of one more
//   than the actual area to be viewed. For example is a size of
//   201 is used, the visible area will be 200 X 200 pixels. (6-97)
//
  var i, j, last_color, t, wd;
  for (j=1; j<=size; j++) {
    last_color = 0;
    wd = 1;
    for (i=1; i<=size; i++) {
      t = (graph[j])[i];
      if ( t != last_color ) {
        if (last_color == 1) {
             document.write ("<img src=sb.gif height=1 width="+wd+">");
        }
        else {
             document.write ("<img src=sw.gif height=1 width="+wd+">");
        }
           last_color = t;
        wd = 1;
      }
      else wd++;
    }
    wd = wd--;
    document.write ("<img src=sw.gif height=1 width="+wd+"><br>")
  }
}
```

The author needs only to generate the necessary (x,y)-data pairs and to pass them to the "plot-2d" JavaScript function.

A web page is by its very nature static. The HTML code is interpreted and the appropriate display is generated by the web browser. To change the display, JavaScript (as it interfaces with the HTML code) must calculate or assign new values to the necessary parameters and then re-display the window. After the new values have been set, they need to be stored out of the way of the browser's refresh routines. Thus the advent of "cookies." These small files find a home in the user's temporary Internet disk cache and store the parameters and their new values. At the appropriate time before a web page is refreshed, JavaScript reads the appropriate cookie and re-assigns the necessary variables.

The ISAW author used the basic cookie functions written by Bill Dortch (Dortch 1996). Some crucial modifications had to be made to enable two pieces of information to be stored for the planetary orbit simulation so that it would run properly on all versions of the web browsers that were tested. Any interested JavaScript programmer can examine the pertinent code to find out how to use cookies appropriately.

With an understanding of how to make graphs and how to handle cookies in JavaScript, the ISAW projects followed the usual routine of planning the necessary mathematical calculations, turning them into code, and then finding loads of time for debugging. To many science and mathematics teachers, this type of challenge, when solved, provides a deep satisfaction and reward. To this the ISAW author will readily attest.

Using ISAW

At the ISAW site (http://www.bridgewater.edu/departments/physics/ISAW/), the user finds an introductory web page describing the rationale for the project, emphasizing its characteristics (visual, interactive and web-based), and an index for all simulations completed or planned. Clicking on a hyperlink

pointing to a completed simulation brings up a page of information on that topic with references and links to the actual simulation and to a laboratory exercise page, if available. The completed simulations include four fractal generation pages and one planetary orbit plotting page. The lab exercise for the planetary orbit simulation has been used at Bridgewater College by the author in his introductory astronomy course for non-science majors. Students found it appropriate to their level and reasonably easy to use.

Expanding ISAW

A number of additional simulations are in the planning stages. For example, a projectile motion exercise will enable participating students to calculate and experiment to find several values of initial speed and angle of launch so as to have a baseball hit a target. In the astronomy category, a simulation allowing students to design their own planets is under construction. Users would set such variables as mass, diameter, constituents of the atmosphere, and distance from the Sun. From these parameters, the simulation would calculate habitability values.

Experience with the already completed JavaScript simulations in the "Interactive Science Activities on the Web" (ISAW) site has shown that the project is doable and useful in teaching. But as John Wallin (Wallin 1998) has pointed out, web-authoring projects of this kind require a lot of time, creativity, skills, and energy. Thus we are left with the question: Does the science and mathematics community have enough of these resources to revamp its delivery of education to students?

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Candle In A Box: Creating a Model Through Which Students Can Explore Experimental Design

Richard A. Cooper
Department of Mathematics
Trinity University
United States
rcooper@trinity.edu

Robert V. Blystone
Department of Biology
Trinity University
United States
rblyston@trinity.edu

Sherry A. Whitmore
Department of Biology
Trinity University
United States
swhitmor@trinity.edu

Abstract: We sought to create a visualization-based methodology, which would allow undergraduate students to become involved in experimental design. By experimental design we mean collecting, organizing, analyzing, and interpreting numerical data obtained from a constructed model. Once developed, our experimental design methodology became metaphorically known as "Candle in a Box." The methodology is here briefly outlined. Students placed digital temperature probes into a cardboard box to determine where a heat source was located within the closed box. The temperature data were output as three-dimensional volume visualizations that could be animated through time. Many different experimental situations can be simulated through modification of the box's volume. This quantitative methodology allows students to query and explore varied data images. Working cooperatively with the students, we continue to expand this lab experiment as an interactive lab exercise and Web site.

Introduction

In an ideal lab learning situation students employ interactive methodologies built around the scientific method. When students collect and analyze numerical data, they gain a deeper understanding about some process or principle of science. The design of such a learning situation places two burdens upon the instructor: 1) the creation of a viable student-centered laboratory experiment with several testable hypotheses, and 2) the creation of a learning environment which can be assessed at several levels. To these ends we found that digital temperature recording produced numerical databases very rapidly. With proper visualization software these databases can be expressed as three-dimensional volumes. By using a large cardboard box students can create controlled environments in which variables can be explored. With student-constructed models based on these elements, students can then use mathematical concepts such as interpolation to investigate the temperature data. The series of exercises derived from the Candle in a Box metaphor has students building testable physical models, which quickly reveal the level of student understanding.

Cost-efficiency, digital interfaces, and student involvement were additional considerations in the development of the methodology. Clearly the use of computers in modern research has become ubiquitous. Digital-based modeling and simulation drive engineering design and increasingly the same is true for "traditional" scientific research. Today's students should have access to digital modeling and simulation experiences. Expense, student lack of numerical skills and instructor inexperience with modeling approaches

have hindered students' learning opportunities. Recognizing that most learning environments have temperature-measuring equipment and computers with spreadsheets, we used this technology in developing the Candle in a Box model.

The Students' Experiment

Methods

The initial experimental concept is simple: how would one find a lighted candle in a closed box? A 2 x 1.5 x 1.5 foot cardboard box provides a convenient 4.5 cubic foot space to explore. An electric light provides a safe alternative to the metaphorical candle. We used eight direct-coupled digital temperature probes distributed by Vernier Software of Portland, Oregon, to sample the box space. The two long, continuous sides of the cardboard box were pierced with four holes each and the temperature probes inserted with their recording tips spaced to define a centered, one-foot cube inside the box. Two probes each were connected to a serial interface box (A to D converter) and the interface box to a computer (Macintosh). (See Figure 1.) Using Data Logger 4.5.9 software (provided by Vernier Software), temperatures were recorded every six seconds and simultaneously graphed on each of the four computers. Four teams of students were involved, with each team responsible for two probes and two data sets. Students had to consider how to calibrate the multiple recording devices. It would be possible to record the temperature with standard bulb thermometers instead of digital probes.

Figure 1: Left Image - the open 2 x 1.5 x 1.5 foot box with temperature probes defining a one cubic foot volume outlined in red. Right Image - the open box with a heat source and connected to the computer.

At a recording rate of 10 times a minute for 10 minutes, each temperature probe produced 100 data points. With eight probes, the lab students collected 800 pieces of information, which needed to be compiled into a spreadsheet. An immediate question arose: was the sampling rate appropriate for the questions being asked? This is no trivial matter. A related question evolved: do eight sampling points adequately describe the volume for the question being asked; or again, do the data resolve the question? With all the data in one spreadsheet, a standard coordinate graph of the eight sampling sites can be drawn and examined for obvious indications of the placement of the heat source. (See Figure 2, left image). The students quickly learn that data can be arrayed in different ways to reveal different aspects of the exercise; for example, displaying the temperature difference by time increment would show the rate of change of the temperature of each probe. Just a few minutes of computer-driven data collection can create a spreadsheet with thousands of information bits. Learning to organize the data becomes an important part of the exercise.

Results

The experiment evolved the following protocol: 1) at time zero minutes, begin temperature recording by all eight probes; 2) at time one minute, establish the base line temperature and turn on the heat source; 3) at time five minutes, turn off the heat source; and 4) at time ten minutes, end the temperature recording. The recording interval exhibits three discrete periods: no load, heat load, and cool down or anticipated return to equilibrium. With these data, students can determine values of parameters in mathematical models, validate mathematical models representing physical or biological phenomena or principles, and learn and practice interpolation and extrapolation. They also have the means to verify their calculations by rerunning the experiment and varying the sampling rate or the length of recording time. For example, they can extrapolate when the box temperature would return to the base line value and then verify the accuracy of the prediction by recording temperatures for the calculated period.

Figure 2: Left Image - a traditional coordinate graph plotting the temperatures versus time for eight recording probes. Right Image – visualization of the interpolated temperature volume over time from two of the probes performed with Noesys suite software.

We enhanced the analysis and interpretation aspect of the exercise by introducing volume visualization software. Using the Noesys suite software (Fortner Software, Sterling, Virginia), temperature data can be entered into a three- or four-dimensional spreadsheet and visualized as a volume or a volume through time (see Figure 2, right image). The software can also interpolate the volume and provide animations to aid the students' understanding of the phenomenon or principle being studied. The T3D feature of Noesys is used to render and visualize isometric surfaces from the interpolated data. Using the software to slice the rendered solid in different planes, the students then can determine visually the location of the heat source. These volume visualizations, interpolations, and slices provide students with interpretability prospects not easily performed with traditional graphing.

The Faculty's Experiment

Introduction

Many educational issues are addressed by the Candle in a Box methodology. Perhaps the most important is the concept of layering; the process in which a student revisits a topic in successive layers. Too frequently in a semester of lab experiences, students perform a variety of techniques superficially and explore certain topics only once. This is similar to an athlete working on a sport a week: football, baseball, dance, and archery. In our case, with each repetition, the temperature measurements become more complex as do their interpretations. With each repetition, the experimental design prospects grow. At first the disciplinary approach to the exercise appears to be a cross between physics and engineering. However, as the model develops it becomes clear that other disciplines such as biology, geology, and mathematics can utilize the model. Students learn first hand from the modeling experiences that the practice of science is both multidisciplinary and collaborative. The box as a modeling environment does something that computer-based virtual reality models do not: the students have a real physical object to relate to, the box. In this design, the students learn to compare the simple experiment to the complex visualization of data.

Methods

We had several goals with this project: 1) to create a lab experiment that would focus on experimental design, mathematics and data collection for biology students, 2) to create a lab experiment that would focus on experimental origin of data and applications for mathematics students, 3) to create a method for students to learn to work with experimental design and with each other, 4) to create a lab exercise with a simple foundation and with increasingly sophisticated layers of data-processing, 5) to create a flexible teaching and learning methodology which would allow for improvements and ease of evaluation, and 6) to encourage instructors to design laboratories that would incorporate more innovative features including, inquiry-based learning, student journal-keeping in addition to the traditional lab book notes, and frequent student feedback.

Discussion

We thought that student involvement in and "ownership" of the experiment was critical to the success of student learning in this lab exercise. We encouraged this ownership in four areas. First, we placed primary emphasis on asking for, listening to, and incorporating student ideas and comments. For example, we originally had designed and created a much more complex experimental format involving a sampling matrix with 27 probe points, filling much of a laboratory room. Students suggested a simpler model, one they could work with more easily for design purposes: a box instead of a room.

Second, students were encouraged to take charge and take responsibility for the experiment as much as possible. For example, we asked students to seek alternative ways to analyze the data and to experiment with the Noesys software for effective and creative processing.

Third, students were asked to design an experiment using the basic model. Once students gained experience with the methodology and analysis, they and the instructors proposed experimental variations. Some of the ideas included the following: 1) opening one side of the box and installing a fan, 2) placing tubing, with either chilled or heated water pumped through it, into the box, and 3) using dry ice rather than a heat source. These modifications were all based on the original, regular one cubic foot sampling arrangement. It was at this

point that the idea of different contours for the box volume was introduced. By using Styrofoam, newspaper, and cut cardboard, the box volume could be given other shapes. Further, the placement of the recording probes could describe positions other than that of a cube within the box.

Fourth, to work with applications of the model, students were asked to model "real world" situations. For example, using the existing equipment, could the temperature volume of a lake be simulated? Not only would the students try to model a hypothetical lake, but also they would have to do library research to determine what is known about lake temperature distributions. If they created a "virtual" lake, the students could model the following hypothetical situation: what would happen to lake temperatures if an electric power plant were built along the shore and it used lake waters for cooling? Other ideas were proposed such as finding a tumor in the human body or locating fish in the ocean. The Candle in the Box model had found applications beyond its original intention.

Summary

The Candle in a Box exercise offers some real challenges and possibilities. Learning how to use the software was a challenge to both the instructors and the students. The significant difference in the screen coordinate system and the typical mathematical coordinate system proved to be a challenge for many of the students. Pacing the exercise and allowing sufficient time for the completion of the collaborative work proved to be a challenge for the instructors. The difference in the students capabilities made it difficult to get students to engage in the experiment and to evaluate the learning.

One of the successes involved the interaction between mathematics and biology. Getting the students to engage in a discussion with the instructors about the interface of mathematics with biology was a highlight of the exercise. This metaphor is a starting point for experimental design for many different problems and offers to the student a strong sense of abstraction. Another problem faced by the faculty was how to incorporate this methodology as a central piece for a scientific visualization course that spans the sciences and mathematics. A web page has been developed as an on-line laboratory manual for the experiment. It includes such things as the calibration of the temperature probes, the use of the Data Logger software, the placement of the probes, and the recording of the data into the Noesys spreadsheet. Numerical and graphical results of the students' analyses could be placed on the web page, then the students could compare their analyses with those of other students. In this manner the page becomes a teaching tool for the current class and can be used by other classes in the future.

Acknowledgments

We gratefully acknowledge the help of the students in the Fall 1998 section of the Biological Imaging and Visualization course at Trinity University, our very capable student assistant Julie Stephens, and our web consultant Seven Bohannon.

The authors' efforts are being funded through an NSF CCD grant(95-54805) where synergistic relations between statistics and biology education are being sought.

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Chemistry On-line Homework System

Carla Fredrick, Jim Schnepf, Cody Zilverberg
Computer Science Department
College of St. Benedict/St. John's University
United States
ctfredrick@csbsju.edu, jchnepf@csbsju.edu, cjzilverberg@csbsju.edu

Robert Fulton, Phil Karjala
Chemistry Department
College of St. Benedict/St. John's University
United States
rfulton@csbsju.edu, pkarjala@csbsju.edu

Abstract: Modern computer technology provides opportunities to develop effective computer generated homework systems. We have designed a system to generate conceptually based question to supplement the equation based questions that have been used in the past. The system also produces individualized feedback for the student in a tutorial and for the instructor by outlining common misconception held by the class. The system is web-based to improve availability to the student and self-graded to free up instructor time and to give the student immediate feedback

Effective Use of Homework

Homework is a well-established pedagogical tool used to motivate students and to focus their study on particularly important concepts. It can also be used to provide students feedback on their progress, to help instructors evaluate student learning, and to provide information to instructors about misconceptions commonly held by the class as a whole. Widely accepted as a valuable learning tool, homework does have its weaknesses. There is little control over the possibility of students copying assignments and sharing answers, because it is done outside of the classroom setting. While in some contexts this cooperation may be an effective learning approach, it is not very useful to the instructor for evaluating student performance or uncovering common misconceptions. Furthermore, generating homework questions, grading homework assignments and analyzing the results are often very time consuming for instructors. Additionally, for students there is often too long of a turn-a-round time between submitting their work and getting feedback.

In an effort to overcome many of these shortcomings and to take advantage of the tools now available, we have designed an on-line homework system for use in General Chemistry. The prototype currently provides for the individualized on-demand generation of conceptually based homework questions with immediate feedback for the student. The complete system will incorporate automatic grading and record keeping, tutorial feedback for the students and feedback to the instructor about common misconceptions held by students.

Computerized Models

Framework Model: The framework model consists of a "questionnaire" that the instructor uses in advance to enter the questions and correct answers. Typically, the questions are multiple choice, fill in the blank or true/false. Some systems allow numerous extra questions to be stored in the database of the program so that there is some variation from class to class, student to student or year to year. This type of system, however, does not relieve the instructor from test making duties at all.

Fixed Questions Model: The fixed question model stores questions in a database and displays them one at a time. Most current computerized approaches of this kind have a limited number of questions covering each concept area. At the end of a section, the student generally selects an option to submit their answers. However, students soon figure out the answers after the first round, they can then repeat the process and improve their score. Students,

through the use of "trial and error" runs, can quickly cycle through the entire question bank and remember "the correct answer to #3 is c" for each question without actually understanding the underlying concept.

The more established systems, such as PLATO, have a larger database and question pool so it takes longer for a student to run through each possible question, thus more difficult to abuse the system. In order to avoid this problem, the question bank must be considerably oversized within each subject area. The opportunity for the student to run through the questions over and over still exists, but a system with a large database that shuffles the question will significantly discourage the student from doing so.

With a database system, this can be avoided; if the questions are randomly presented they will be different for each student. But when two students are presented with two different problem sets, it is difficult if not impossible to guarantee that the questions selected are of the same degree of difficulty. If questions are chosen randomly from a large database, it is also impossible to guarantee that all of the areas that need to be covered in the section will be tested. For example, in a chapter on cells in biology, there may be four areas studied: 1) a cell's function, 2) its composition, 3) how it reproduces, 4) the different types of cells. The bank of 100 questions will roughly contain 25 questions of each area. If the problem set is 10 questions long, there is no guarantee that all 10 questions randomly chosen will not be from the same topic area.

Variable Question Model: MathCheck and ChemSkill Builder are examples of the variable question model that use formulas with variables to generate variations of questions. The variables can be numerical values or keywords that are dynamically chosen to allow multiple variations of a question. For example, the simple arithmetic problem 4+5, now becomes x + y where x and y may be any integer between 0 and 20. The old question was static, the answer is always 9. The new question, being dynamic, has over 400 possible answers. Since a computer has capabilities of computing all algebraic possibilities efficiently, computing the answers can be done automatically.

Another alternative uses a keyword as a variable. For example, when the keyword is randomly chosen from Alice Walker, Mark Twain, Toni Morrison or Joseph Conrad, a question could read:

The well-known author <keyword> wrote which of the following novels?

A. *The Color Purple* B. *Huckleberry Finn*
C. *Beloved* D. *The Heart of Darkness*

The question can also be inverted so that novel and author are exchanged. From a single question, now 8 different questions can be generated. By filling a database with dynamic questions, unique question sets can be generated thus providing each student with questions of the same concept with comparable difficulty.

Chemistry Alternatives

Computer based learning tools that exist for chemistry are rapidly improving. Among the available state of the art systems are ChemSkill Builder and OWL.

ChemSkill Builder is a CD-ROM based system which uses a 3.5" floppy diskette to record student scores. Questions are based on either the variable or fixed question models. With few exceptions, most of the questions are based on textual and numerical information rather than graphical or conceptual information. The student may repeat the exercises any number of times. The highest score is retained on the recording diskette which needs to be turned into the instructor to compile class scores.

OWL is an On-line, Web-based learning system which primarily utilizes the framework model. It has a tutorial mode which allows students to master a subject area and a quiz mode for evaluation. Instructors can choose from different types of questions such as: short answer, numerical answer, matching, multiple choice, multiple-multiple choice, and parameterized. Parameterized questions allow the use of variables in questions. These variables may be a numerical value which is used in a calculation or text. While parameterization is a step forward to increase the number of possible questions, the system does not include the possibility of providing parameterization of graphical information.

Web-based Homework Design Features

An idealized on-line homework system would incorporate the following features: 1) Conceptually Based (using diagrams and graphs); 2) Individually Generated (each student receives a unique set of questions based on the same concepts and at the same level of difficulty); 3) Misconceptions Identified to guide Instruction (to discover

what misconceptions the students are experiencing and to give focussed student feedback in the form of tutorials and class wide data to help guide the instructor's teaching); 4) On-line, Web-based (to take advantage of the web for broad distribution, easy accessibility, and ease of collecting and analyzing results); 5) Computer Graded (to provide direct and immediate feedback to students as to their progress and to reduce the instructor time commitment as much as possible).

The CSB/SJU model is different than the other programs discussed. It combines the originality of the framework model, the database of the fixed question model, and the variation of the variable question model. We refer to our system as being a dynamic question model. Starting from a root concept such as calorimetry or chemical concentrations, key issues involved with the concept are isolated, likely misconceptions are identified, data, charts, graphs, conceptual images that are needed are defined, question variations are determined, and key parameters are identified along with a range of acceptable values. All of this is stored in a database along with rules for the generation of the question, the correct answer, and distracters based on the misconceptions. Instead of only using variables x and y to create variation, a whole underlying structure is established. This multi-layer structure or template is then used to generate a unique set of comparable questions for each student. By using the graphical components as well as the textual and numeric variables, conceptual as well as formulaic questions can be generated.

1) Conceptually based: Chemistry exercises often tend to be of two types: algorithmic or conceptual. Algorithmic exercises (calculations based on equations and formulas) often can be done successfully without students really grasping the underlying principles behind the equations and formulas. For this reason, they are sometimes referred to as "plug and chug" exercises. Algorithmic exercises have the advantage that they are often easy to formulate. While equation based exercises are widely used and certainly have their value, there is currently a major effort in the teaching of general chemistry to include more conceptual and hybrid approaches (Nakhleb et al. 1993, Lloyd et al. 1994, Ward et al. 1993). Conceptual exercises require students to analyze and interpret diagrams, graphs, and verbal explanations and to construct mental "pictures" to explain the observed phenomena, are often more difficult to generate. Hybrid exercises, which require students to apply their own conceptual understanding to generate the desired equations and formulas, can provide powerful learning opportunities.

Take for example, the question: If a solution with a volume (V1) of 200 ml has a concentration (C1) of 0.3 and it is combined with a solution that has a volume (V2) of 100 ml and has a concentration (C2) of 1.10, what is the concentration (C) of the resulting solution? The answer [C = (C1*V1 + C2*V2)/(V1+V2)]can be easily calculated by the "plug and chug" method without really understanding the underlying concepts. However, by formulating the question in a conceptual manner, the student can be guided into dealing with the underlying concepts. For example: If Beaker A, from figure 1, contains a solution with a concentration of 0.3 and it is added to the contents of Beaker B, from figure1, what would be the concentration of the resulting solution?

In order to answer this question, the student must understand that it is the total amount of solute (S) and the total volume (V) of solution that are important. The amount of solute (S) in each beaker is related to its concentration(C) and its volume (V) [S = C * V]. From the given concentration for Beaker A and its volume, the student is able to calculate the value of each representative solute particle ("dot")[Concentration * volume/number of "dots", 0.3*200/6=10]. The student can then calculate the amount of solute in each original beaker and add them together to get the total amount of solute[10*6+10*11=170]. The two original volumes can then be added together to get the total volume[200+100], and the final concentration can be calculated[170/300=0.57]. Thus, in order to get the correct answer to the question presented in a conceptual manner, the student must understand the underlying concepts and know how to use them.

2) Individually Generated: An individually generated set of problems for each student can be established by implementing the template system. Building a template for each root question is the basis of our model. The advantages of creating a template of a root question over creating just the root question is that numerous variations can be generated from the template whereas the one root question is just one question. A template is a form, or structure and a root question is a specific question generated from a main idea in a given subject area. Thus, building a template of a root question can be thought of as getting to the root of the question by taking it apart, changing static numbers to ranges of variables, thus creating a base from which numerous questions can be generated.

A structure can then be built by creating ranges for each of the elements represented in the question. For example, by carefully choosing two volumes, V1 and V2(V2=V1*2) and 5 different amounts of solute, we can generated 10 possible concentrations.

	S_1 (3)	S_2 (4)	S_3 (6)	S_4 (8)	S_5 (12)
V_1 (100)	C_{11} (3)	C_{12} (4)	C_{13} (6)	C_{14} (8)	C_{15} (12)
V_2 (200)	C_{21} (1.5)	C_{22} (2)	C_{23} (3)	C_{24} (4)	C_{25} (6)

Table 1: Shows how the concentration of a solution can be generated from the volume and the amount of solute

From these 10 concentrations, 6 beakers will be randomly selected to represent the solutions for the questions (for example, see figure 1).

Volume = 100 Beaker A   Volume = 100 Beaker B   Volume = 200 Beaker C   Volume = 100 Beaker D   Volume = 200 Beaker E   Volume = 200 Beaker F

Figure 1: 6 Beakers as a student taking a quiz would see. From these 6, numerous questions will be asked of one or more of them

There are 210 permutation of 6 beakers chosen from 10 possible concentrations. Clearly, increasing the number of volumes or solutes allowed, would greatly increase the number of possibilities. After the "root" template is established, then questions (of the variable question model) can be generated. In turn, each of these questions can have a number of variables, greatly increasing the possible number of individually generated questions. For example: If the molar concentration of Solution [B] is [0.52], and it is combined with Solution [D], what is the concentration of the resulting solution?

In this question, Solution B, Solution D and 0.52 are all variables. The two different solutions are selected randomly from the six "root" beakers (15 possible combinations). This provides 75 versions of the question and when taken with the large number of beaker combinations, means that it is very unlikely that two students will receive exactly the same question. However, because of the structure of the process, all questions are based on the same concepts and are comparable in difficulty.

3) Misconceptions Identified a to Guide to Instruction: Identifying that an answer is right or wrong is useful but limited feedback. In addition, it would be useful to know the cause of a wrong answer -- what misconception led to the incorrect answer? Identifying the misconception that resulted in a wrong answer enables both the student and the instructor to take corrective action.

Rather than randomly generate the wrong answers for a question and inserting the correct answer among them, we have devised the concept of "distracters." Distracters are answers that are likely to be given if a student holds a particular misconception. In addition to having rules built into the question generator to generate the correct answer as one of the options, rules are also built in to generate likely wrong answers based on common misconceptions. These rules are based on likely misconceptions defined by the chemistry professor. (the subject expert). By carefully constructing the possible answers, incorrect answers can be tied to the misconceptions and action taken accordingly.

For students, this concept can be used to generate tutorials that are targeted to correct the misconception that caused the error. Instead of triggering a general tutorial on a topic area, a carefully constructed tutorial can be broken into parts where the student can be directed to the component of the tutorial that addresses that particular misconception. We see this being used when students use the system in a "practice mode."

For instructors, the performance of the entire class can be evaluated not just on whether the students understood and did well on a particular topic area or not, but also what common misconception caused problems when a class has difficulty with a topic area. By knowing the specific misconception the students have because of the distracter they chose, the instructor can address the problem directly. Specific remedies to the curriculum, special tutorial sessions or review sessions can be used to focus on the areas that cause the most problems. This comes into play when the system is used in an "evaluation mode."

Selecting distracters opens a window of opportunity, but also opens a window of problems. Problems occur when a distracter gives an answer that is equal to the correct answer or when two distracters give the same answers. This type of thing frequently occurs especially when distracters are created by using powers of two (multiplying by 2 and dividing by 2) and variables were also chosen according to powers of two. These problems however can be avoided if enough care is taken in choosing both the range of variables from which the root question is generated and in choosing the distracters. Specifically all possible cases must be considered and if a problem occurs, it must be handled by adjusting the range of variables or distracters. A computer program can be written to detect any lingering problems and handle them accordingly.

Practice Mode: Some programs have been developed for the purpose of testing and others for teaching. Testing programs do as we have discussed thus far. They take information in the form of questions, record the students response, tallies the students score, records the score, and presents the results. On the other hand, programs that teach present questions and then, step by step, go through the question and the process to get the answer, explaining as it goes, thus teaching how it is done. This we call an electronic tutor. ChemSkill Builder is a good example of how this works.

A key feature of this prototype is that is generates thousands of unique, but comparable, questions in each concept area (currently calorimetry and solution concentrations) and the multiple choice "distracters" are keyed to likely student misconceptions. When the system is complete, the "distracters" will be used to provide students tutorials that are directly related to their misconceptions, and to help the instructor uncover the misconceptions commonly held by the whole class.

Evaluation Mode: The CSB/SJU model will also contain an analysis and feedback mode for the instructor. Since all of the questions are planned, it is important for the instructor to not only know if the student answered it correctly or incorrectly but which answer was chosen and why. This information can be given to the instructor in a chart that will appear something like this:

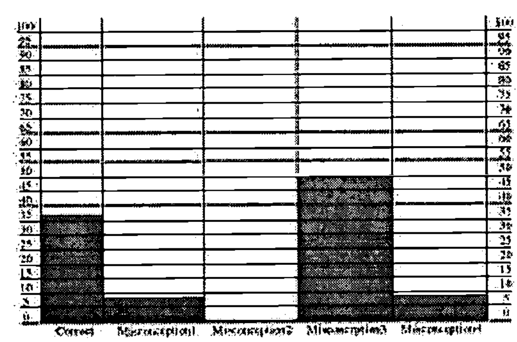

Figure 2: A sample graph showing which answer students chose on one question of a quiz.

From this chart the instructor can see that 62% of the students got this question wrong, therefore it is a problem area. Also, 50% chose the third distracter , which means many people made the same mistake.. The instructor now knows where the students are going wrong, so he or she can better help them.

The CSB/SJU model will also have a database so when a professor makes the provisions for a template from a root question, it can be kept and accessed a number of times. Also a database can serve as the warehouse that stores all scores and analysis of the students' work. Finally the CSB/SJU model will develop as an "expert system" for question development. There will be a set of rules and types so that templates can be more readily generated from a root question. This will include a number of testing algorithms that check to make sure that the range of variables does not cause any conflict. With this established our on-line homework system will be applicable to many disciplines in addition to Chemistry.

4) Web-based: Basing the application on the Web facilitates the distribution of both the application and the student responses. It provides a vehicle for easy distribution of the homework system and updates to the question base can be automatically incorporated. Students can access the application with ease from any location and Web-based programs allows the application to run on multiple platforms. Students can submit results directly to the instructor via the Internet without the need to save the scores on a diskette and manually turn them in to the instructor. At the same time, it is possible to limit access to only the students in the class. In addition, through the use of Java, it is possible to include the dynamic graphics that allow the conceptual aspect of the question to be presented to the

students. By connecting the application to a database, the results of student exercises can be automatically recorded and stored for grading and analysis.

5) Grading: It is known that the most effective teaching involves immediate feedback The most attractive functions of these programs may be that a computer can deal with the information faster than a professor can. With a computer based system, students can be told their score as they answer the questions or immediately following the set of questions, where it would take hours for the instructor to correct each set of questions and perhaps days before the students would get them back. In addition to immediate grading, the computer can compile the scores from all the students and build a graph to show how everyone preformed in relation to each other. The computer can also detect where the problem areas are so the instructor can address them specifically and immediately. The professor can review the results prepare his or her next lecture clarifying the common misconceptions of the covered material. All of these features can be computed in seconds by the computer where it would take hours of menial work and hours of analysis by the instructor. In addition to helping the student get feedback quickly, it frees up some of the instructor's time so that more effort can be put into preparing for lectures, creating better exams and giving individual help to students.

Conclusion

Our program is just the beginning of what will improve learning in the future. In addition to the unique generation of questions. Our system will include a tutorial section which will assist students having trouble grasping the concepts presented as well as a more in depth explanation or review of the material. Our tutorial segment will also have an emphasis on concepts with the use of dynamic graphics to show comparisons and relationships.

Our system is superior to the Chemistry systems that exist today. This is due to a few significant differences. The most obvious and important difference is that the CSB/SJU system utilized dynamic images and graphics and asks students to draw conclusions based on knowledge of underlying concepts. This is a more complex way of testing, of learning and of thinking.

The CSB/SJU system also presents a level of randomness among the questions that exceed the other systems. Although ChemSkill Builder has many questions in their database and they utilized the variable question model, duplication can be obtained if the process is repeated multiple times. The example in the CSB/SJU system of concentration has hundreds of possible combinations which are effective in producing individual yet equally difficult sets of questions for each student.

We do not see this approach being limited to just chemistry, and the long-term goal of this project is to develop a versatile on-line homework system that can be used easily and effectively to enhance student learning in many disciplines.

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The Use of a Computer in a Teaching Strategy in Science Education

Leticia Gallegos-Cázares
Centro de Investigación en Computación Educativa
Universidad Anáhuac
México
gallegos@aleph.cinstrum.unam.mx

Fernando Flores-Camacho
Centro de Investigación en Computación Educativa
Universidad Anáhuac
México
floresf@aleph.cinstrum.unam.mx

Claudia Limón-Luna
Centro de Investigación en Computación Educativa
Universidad Anáhuac,

Ma. Elena Hernández-Jáuregui
Centro de Investigación en Computación Educativa
Universidad Anáhuac
México

Abstract. The object of this works consist of analyze the role of the computer in a teaching strategy. To do this we establish a comparison between two groups of 6 students that attend the sixth grade of high school, in both groups the majors are physics and mathematics. Before and after the application of a didactic strategy that integrates experimentation and theory through the use of a simulator as an aid in the construction of concept schemes. We used an optics simulator to show concepts about rays and light reflection. The results showed that the amount of support given by the use of software on the construction of schemes depends on the didactic strategy. The aid is limited if this strategy does not help to develop the involved concepts.

Introduction

In science education, research on previous ideas has shown the trouble students have on conceptualization and representation of scientific models. In an attempt for solving those problems, computers have been used as an aid through several teaching strategies. The results of these studies show that students that have the aid of a computer improve on representing scientific concepts. However, the sole use of a computer does not, by itself, solve the comprehension and concept construction problems, if they are not located in the proper boundaries within the educational proposal.

The object of this works consist of analyze the role of the computer in a teaching strategy. To do this we establish a comparison between a group of 6 students that attend the sixth grade of high school at the Irish Institute, whose major is physics and mathematics, before and after the application of a didactic strategy that integrates experimentation and theory through the use of a simulator as an aid in the construction of concept schemes. We used an optics simulator to show concepts about rays and light reflection. The specific theme was Images within flat, round and convex mirrors. There is also a control group of 8 students that attend the sixth grade of high school at the Del Bosque School, whose major is also physics and mathematics. This group doesn't follow a previously established strategy, but also uses the same simulator practices that the experimental group does.

Experimental group strategy

The strategy starts with the investigation of the previous concepts students have, through the application of a pre-test. This test is designed based on Galili Igal's research (1996), as well as the teacher's findings during the first work session.

The strategy was developed on three levels, considering phenomenon situations that would lead the students to ask themselves about the way an image is formed within flat and curved mirrors, involving computer usage with a simulator that allows variable handling related to the experiments performed at the laboratory. Specific practices were developed focusing on the conceptual problems for each level and linked with the experiments performed in the classroom by the teacher. These levels are:

- *First Level*: Recognizing that reflection occurs on one plane and that the angles are measured with respect to the normal of the reflecting surface on a given point.
- *Second Level*: The representation of the images. Characteristics of a virtual image in flat mirrors. This implies that the subject must understand that he is the one that constructs an image based on the light beams reflected on the surface.
- *Third Level*: The importance of the shape of the reflecting image. Identification of the reflecting points and formation of real and virtual images as the main conceptual problems on the students.

Application on the control group

The teacher established the sequence and timing of the simulator usage as well as the experimentation.

Method

In order to analyze the conceptual change, two parallel tests were designed. These tests contained the central concepts for each level. The pre-test was given to the students during the first work session and the post-test on the last one. There were also registers as well as a report given to us by the teacher. The strategy was applied through eight work sessions, one hour long each, for both groups.

Instruments

The pre-test and the post-test are parallel tests that include the same contents. On both tests we can find:

- Two problems on which a ray model and the reflection law must be used in order to obtain the image that can be seen on a flat, as well as on a concave mirror. To answer these problems, the student must have reached the three levels described before
- A question about the Reflection Law. This question is related to level 1.
- A question related to the characteristics of real and virtual images. This question refers to level 2.
- A question about the characteristics of observed images in flat as well as concave mirrors. This question relates to level 3.

Results

The results of both, the pre-test and the post-test, applied to the 6 students on the test group compared to the results of the control group are shown in the table 1.

Group	Pre-test	Post-test
Experimental	1. The image formed on a flat mirror consists on drawing parallel rays, without using the reflection law. 2. No one used the Reflection Law. 3. The reflection Law is referred to as a bouncing of rays. 4. For concave mirrors, students cross rays in different directions, including the mirror. 5. The virtual image is positioned behind the mirror and the real image is identified as the mirror itself.	1. They cannot draw the image on a flat mirror (Level 1) 2. They can explain what happens with two mirrors at 180 and 0 degrees, but not at 45 degrees. (Levels 1 and 2). 3. They draw a proper image in a concave mirror (Levels 1 and 3). 4. They use the focal point for drawing and positioning the image correctly. (Levels 1,2 and 3). 5. They can explain the image flip in a concave mirror but not in a flat one. 6. They state the reflection law as angle equality, without specifying the angle measuring with respect to something. (Level 1). 7. They can tell a real image from a virtual one only because of their position with respect to the mirror: real images in front of it and virtual images behind it. (Level 2).
Control	1. They cross rays on the flat mirror. 2. They don't know what the focus is for. 3. They cross rays on a concave mirror, but cannot draw the image. 4. The reflection law is referred to as angle equality, but cannot apply it in any case. 5. There is no representation of the image inversion.	1. They improve the tracing for a concave mirror, but no student could draw it correctly. 2. The reflection law is not applied in any case. (Level 1). 3. There is no change on their statement of the Reflection Law. (Level 1). 4. They are confused about the focus, which they also locate in the mirror. (Level 3). 5. They explain the image flip relating it to the focus position, disregarding the mirror's shape. 6. They can tell a real image from a virtual one only because of their position with respect to the mirror: real images in front of it and virtual images behind it. (Level 2).

Table 1. A comparison between the student's ideas of control and experimental groups and pre-test and post-test.

Conclusions

In the beginning, the experimental group could not identify the reflection law. In the end, the students could construct it beyond a beam bounce and could apply it in the construction of images on curved mirrors. They have a clear concept about the importance of the focus, curvature of the mirror's surface as well as the position of the images in mirrors.

About flat mirrors, there is still confusion about how to apply the reflection law to obtain an extended image.

The control group showed little improvement on concepts and even though they advanced on the way they obtain images on concave mirrors, the lack of support on concepts to construct schemes does not favor an equal

advance to that observed on the experimental group.

The amount of support given by the use of software on the construction of schemes depends on the didactic strategy. The aid is limited if this strategy does not help to develop the involved concepts. Therefore, the graphic results of the pre-test and the post-test, regarding drawing, are meaningless and, hence do not contribute to a conceptual change.

These results confirm our initial position about the importance of the computer in a teaching strategy as a part of a hole strategy.

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Digital Mentoring in Virtual Environments: A Case Study in Coastal Science Education

Jeff Hill
hillj@uncwil.edu
Dept. of Health, Physical Education and Recreation

Robert Buerger
Environmental Studies Program

Rudi Kiefer
College of Arts and Sciences

Jim Herstine
Dept. of Health, Physical Education and Recreation

University of North Carolina at Wilmington
Wilmington, NC USA 28403-3297

Abstract: Research has consistently shown that learners in hypermedia environments may not achieve maximal results unless provided with some form of guidance, either on-line or face-to-face. To resolve this problem, coastal science educators at the University of North Carolina at Wilmington integrated a "digital mentor" into a virtual reality database of hurricane-induced changes to coastal natural resources. A prototype of this system has been used in an undergraduate coastal resources course.

Introduction

Computers have long played a role in environmental and science education. With the advent of inexpensive, easy to use computers in the 1970s, use began to permeate the classroom, as well as the field. From preschool to university, students now use computers to understand the natural world, and the interactions and issues inherent within it. A relatively new form of computing has emerged which promises to take students far beyond traditional educational boundaries. It is not a technological modification, but rather an evolution in the educational paradigms underlying the manner in which computers are used: hypermedia.

Hypermedia allows one to freely navigate among diverse media formats, including text, graphics, photographs, and virtual reality environments. However, the distinguishing feature of hypermedia is that it allows the user to create linkages and cross references within this information which may expedite the development and assimilation of a "personal understanding" of it. The advantage of educational hypermedia is that it does not predispose the user to learn from a prescribed perspective (Marchionini, 1988). In essence, hypermedia can shift responsibility for instruction from a traditional "teacher-centric" to a more student-directed mode of learning (Barell, 1991). Although potentially powerful and empowering, this too may be a potent limitation.

The Dilemma of Self-direction

We cannot assume that the self-directed nature of a hypermedia environment equates with increased learning (Borsook & Higginbotham-Wheat, 1991). Consistently, research has shown that students may not always be capable of determining their own learning styles and adapting their educational processes to this end (Dunn,

1986). This may be especially problematic when the focus of the learning methodology is self-direction, as it is in a hypermedia learning environment. Hatcher (1997) suggests that self-directed learning requires fundamentally different skills than traditional classroom learning. Yet, as Skillicorn (1996) notes, the use of hypermedia without the benefits of a directing instructor compromises the learning potential of the technology. Nonetheless, given certain caveats, it seems that computers do have the ability to facilitate self-directed learning in students ("Helping students develop self-directed learning", 1991). Further, contemporary thought in both K-12 and post-secondary education recognizes the necessity of critically integrating computer-based learning into the curriculum (e.g. Heflich, 1995; "Technology in Learning", 1995), and with good cause. Meta-analyses of computer-based instruction have revealed that positive learning gains are made at all educational levels, from elementary to adult education (Coley, et al., 1997; Kulik, 1994), although with varying degrees of success.

It should then be apparent that within computer-based educational settings "there is a compelling need for a mediating instance such as a personal teacher" (Schöch, et al., 1998, p. 1242). Yet such face-to-face interactions with instructors are not always available, adequate, or feasible. Further, specific limitations of many hypermedia systems can be attributed to a lack of such direction, not only in providing needed guidance to individual learners in acquiring and assimilating content, but also in appropriate use of the system itself (Roselli, 1995; Schöch, et al., 1998). In an effort to resolve, or at least mitigate these problems, hypermedia authors are frequently beginning to incorporate some form of student guidance into their systems. Such advisement can be either active or passive, and typically serves as an on-line facilitator of the educational process through various methodologies and modalities. To this end, a "digital mentor" was integrated into a virtual reality hypermedia system used in coastal science coursework within the natural resources recreation management curriculum at the University of North Carolina at Wilmington.

Transitioning Research into Teaching

Since 1992, coastal scientists at the University of North Carolina at Wilmington have been engaged in a longitudinal study of the impacts of natural forces upon the physical properties of undeveloped barrier islands. The resultant data have been integrated into a hypermedia system which includes such linked multimedia elements as photographs, digital video, text, sound, and graphics.

Wilmington is ideal for such a study due to its coastal location in southeastern North Carolina, and its resultant proximity to a diversity of relevant coastal resources. Most notable are several relatively pristine barrier islands managed by the National Estuarine Research Reserve. However, at the same time, its geographical location makes Wilmington vulnerable to a wide range of weather events, many of which are extremely intense. For example, two hurricanes made landfall in Wilmington in 1996: Bertha (Category 2) and Fran (Category 3). Then in 1998, Hurricane Bonnie (Category 2) made landfall in the same area, as well (see Fig. 1).

***Figure 1:** GOES images of Hurricanes Bertha (1996), Fran (1996), and Bonnie (1998)*

approaching landfall in Wilmington, NC (from left to right) – courtesy of NOAA

Although a statistical anomaly (typically one hurricane should make landfall in the Cape Fear region every 26 years), this unexpected frequency of hurricanes within a time frame of only two years created an ideal natural laboratory for documenting the processes which occur on coastal resources under such weather regimes. However, the resultant hypermedia database has also given the researchers an excellent tool for teaching students in the natural resources recreation management curriculum about these coastal processes, as well.

The "Digital Mentor"

Perhaps the most engaging and interactive components of the hypermedia database are the virtual reality scenes of hurricane impact sites on the barrier islands. In combining these virtual reality images with on-the-ground photographs, satellite imagery, and textual documentation, this hypermedia database creates a powerful learning tool for potential coastal resource managers in the curriculum. The system offers the users the ability to freely examine the three dimensional world of pre- and post-hurricane barrier islands from within the relative safety and comfort of the classroom. A primary educational advantage of this integrated hypermedia database is that the learners are now free to examine the hurricane impact data from their own perspectives, rather than from within the predetermined constraints of the researchers.

However, it was quickly realized in initial prototyping of the system (Hill & Buerger, 1996) that students were frequently unable to use the hypermedia database effectively. Typically, students were unsure of salient and critical attributes of the data in which they were immersed, and needed guidance in directing their investigations. Further, the sheer volume of the data created "virtual overload" among the learners. In essence, the students had no existing scientific cognitive schema upon which to base their analyses. To this end, a "digital mentor" was integrated into the system (see Fig. 2).

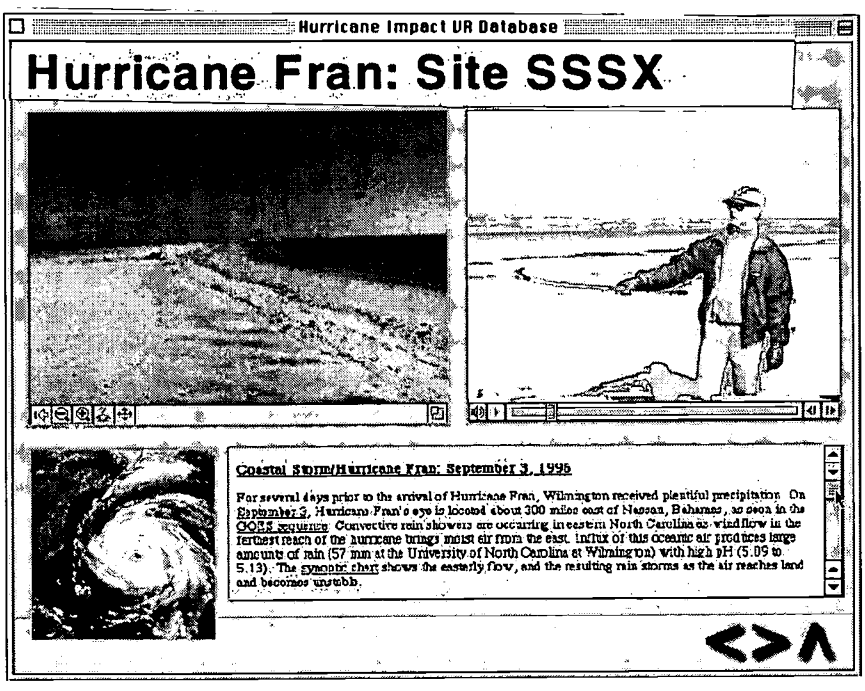

Figure 2: *The Hurricane Virtual Reality Database with "Digital Mentor"*

The "digital mentor" feature is provided through a linked digital video track of a relevant content expert who

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can be summoned at will to provide the student with guidance concerning what to look at in the virtual environment, what the meaning of relevant elements are, and how they relate to course topics. As the student navigates the virtual reality environment, s/he can merely click upon "hotspots" embedded within the scene to gain access to the necessary guidance and advisement from the digital mentor.

Much of the system is made possible through the use of Apple Computer's QuickTime technology. The virtual reality scenes were developed using QuickTime VR, and the digital mentor track is implemented as QuickTime digital video, which provides several advantages. As a cross-platform system, QuickTime allows users to view the virtual reality images and view digital video, regardless of PC or Macintosh platform. Further, the QuickTime system is widely disseminated and accepted by users and developers alike, again regardless of platform. Finally, the power, maturity, and cross-platform nature of QuickTime lends itself quite well to migration of the proprietary hypermedia system to a World Wide Web-based system.

Conclusions

It is believed that the simple integration of the digital mentor will have a profound effect upon improving the educational efficacy of the hypermedia hurricane database. Students should be more focused, directed, and effective in their interaction with the system. The next step will, then, be the integration of the modified virtual reality database into classroom settings. However, additional research will be needed in order to determine the impacts of this mode of advisement. Nonetheless, hypermedia holds great promise in the future of science education, particularly in the integration of virtual environments. Due to its focus upon self-directed exploration and personal organization of information, hypermedia can play a vital role. However, as access to information expands, as does the volume and complexity of this information, the need to provide guidance to learners becomes more salient if both efficiency and effectiveness of learning are to be considered.

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TEACHING MATHEMATICS TO STUDENTS WITH PHYSICAL DISABILITIES USING THE WORLD WIDE WEB: THE PLANEMATH PROGRAM.

Lewis E. Kraus
InfoUse
kraus@infouse.com

Abstract: Adapted materials on math and aeronautics will improve education and career options for children with physical disabilities in fourth through seventh grade. This project developed a specialized program, drawing from existing curricula, available materials and assistive technology, and used the Internet to support an interactive education experience. National math standards and aeronautics standards were used to develop the materials. National distribution has been achieved through the Internet. This project can serve as a model for development of materials and curricula for the World Wide Web that can be accessible for students with physical disabilities.

Introduction

InfoUse has conducted a three year project entitled "An Internet-Based Curriculum on Math and Aeronautics for 4th - 7th Grade Children with Physical Disabilities" with funding through a cooperative agreement with the National Aeronautics and Space Administration (NASA). NASA's award, which is administered through the High Performance Computing and Communications (HPCC) Office as part of NASA's Learning Technologies Program (LTP) program and NASA-Ames Research Facility at Moffett Field, was given as one of eight such awards for developing new ways of teaching science, mathematics, engineering, and aeronautics through developing new Internet-based information technologies.

This project has created on-line lessons and activities on math and aeronautics aimed at improving education and career options for children with physical disabilities. This project has developed a specialized program, drawing from existing curricula, available materials and assistive technology, and using the Internet to support an interactive education experience. The project targeted schools nationally. The on-line lessons and activities have been useful to students in mainstream, general education, and special education settings.

The genesis of this project was based around two issues. The first issue came from awareness that, around the 4th grade, current mathematics curricula are highly reliant on students' ability to use manipulables such as paper and pencil, calculators, or three-dimensional geometric models. Children with disabilities that affect their ability to manipulate objects (cerebral palsy, muscular dystrophy, specific hand/arm conditions, etc.) are clearly at an academic disadvantage. The second issue came from the realization that physically disabled children may not consider or be prepared for career possibilities in aeronautics or the importance of mathematics in pursuing these careers. The Internet, with its multimedia and communication capabilities, holds great potential for allowing these issues to be addressed.

Project Mission And Goals

The stated mission of this project was "To stimulate and motivate students with physical disabilities in grades 4-7 to pursue aeronautics-related careers via the development and delivery of accessible math education materials on the Internet." From this mission, we developed four goals: Improve access to mathematics and aeronautics curricula materials for 4th-7th graders with physical disabilities (Accessibility); Improve mathematics proficiency outcomes among 4th-7th grade students with physical disabilities (Math Proficiency); Inspire and motivate students with physical disabilities to pursue aeronautics-related careers (Aeronautics Careers); and Increase access to, and use of, digital communication and multimedia technology among children with physical disabilities (Innovative Use of Technology).

Product

The World Wide Web site at www.planemath.com contains lessons and provides mathematical exercises using examples from aeronautics that are maximally accessible by children with physical disabilities. The activities are based on national mathematics standards and aeronautic content guidelines. The Web site also contains "help" information, information for teachers/parents, opportunities for users to find out more about aeronautics from experts/role models, and links to other related Web sites in mathematics, disabilities, and aeronautics. The target age level for year 1 was 4th grade, for year 2 was 5th grade and for year 3 was 6th and 7th grades.

Timeframe

In the first year, the project established Internet access at school sites while designing and installing fourth grade level World Wide Web-based and instructional lessons. The lessons, written in HTML, are competency-based, with learning goals in math, aeronautics, and in the use of the Internet as a learning resource. The second year expanded the curriculum to 5th grade level mathematics, delivering additional lessons to the user site through Shockwave movies for interactive, real-time learning on the Internet. The third year created curriculum-based materials for 6th and 7th grade level mathematics, stressed exploration in science and math, accommodated advances in assistive technology, and evaluated the interest level of students using the website.

Project Resources

While the project draws on the proven multimedia, accessibility, and education skills of staff at InfoUse, the project has a variety of resources. The Center for Accessible Technology, an Alliance for Technology Access (ATA) site in Berkeley, California participated in curriculum research, accessibility issues and activity design. California State Polytechnic University, Pomona provided Internet server access, demonstrations and presentations, and hosted teacher groups. Kinko's and Sprint have donated the use of their 300 nationwide videoconference sites for wide spread teacher training. More than a dozen software vendors and publishers have donated software for participating schools. An expert advisory panel of teachers, administrators, and individuals with specific expertise in math, aeronautics, disability, and Internet provided feedback to the project at various stages during the project.

Curriculum Design

Research into classical and non-classical approaches to teaching math and interviews with teachers, administrators and experts in math curricula revealed the following educational approaches and content needs for students to be served in this project:

- Outcome-based education;
- An active role for students in their learning;
- Use of careers and role models as goals to learning;
- Cooperative work/Team or Peer Teaching (e.g., semester-long group investigation and group problem solving);
- Use real-world experiences to teach math (e.g., exploration, discussion and activities that mirror the mathematical problems encountered by pilots);
- Multi-cultural math treatments;
- Appropriate presentations of persons with disabilities, females and males, and people of various ethnicities and races; and
- The program should augment existing learning materials, not be a comprehensive mathematics curriculum.

Content

We selected topics for inclusion into the program that are consistent with current educational practices and standards (Dye, undated; National Council of Teachers of Mathematics, 1989; California Department of Education, 1996) . These topics are presented in ways that are meaningful to a range of learners in today's classrooms. The National Council of Teachers of Mathematics (NCTM) Standards and state mathematics frameworks provided the mathematics content which needed to be covered; national aeronautics curricula were reviewed for age-appropriate content that could be taught with mathematical concepts.

Math content covered includes: estimation; measurement; number sense and numeration; whole number computation; whole number operations; geometry; statistics and probability; patterns and relationships; and fractions and decimals. Aeronautics content covered includes: history of aerospace; kinds and uses of aircraft; parts of an airplane; why airplanes fly; weather; instruments and navigation; and airports.

Using the NCTM standards, the following list of ways to teach the content was assembled.

- Data collection: students develop and implement plans for collecting and analyzing data to answer questions, including concepts of mean, median, mode, and range.
- Shapes: students identify shapes, manipulate them in spatial relationships, and develop visualization skills, including understanding of perspective.
- Patterns: students discover patterns in their data, and then make predictions and form hypotheses for other variables.
- Multiplication and Division: students practice these math facts in the context of solving questions within activities.
- Area and Perimeter: students learn the relationship between area and perimeter and experiment with links to multiplication and division, and two-dimensional shapes.
- Fractions and Decimals: students practice working with fractions and decimals through pattern and shape.
- Grids and Graphs: students display their data, hypotheses, and results in a variety of ways using grids and graphs. Patterns and relationships will become obvious through these displays.
- Careers: teaching aeronautics for 4^{th} grade children included the coordination of career information with the aeronautical concepts. For 5^{th} grade children, children learn aviation history and piloting careers in specific. In 6^{th} and 7^{th} grade, students learn about on-the-job training and development as "employees" of a fictional airplane design firm.

Accessibility

The project established criteria for, and is a model for, the design of World Wide Web pages with accessibility issues, needs, and equipment in mind. Of particular emphasis are consistent placement of hot links, parallel pages of text only (no graphics), and non-scrolling pages. Browser preferences allow accessibility through font, color, and page size adjustment.

The project also established a design by which more interactive capabilities provided by the plug-in Shockwave can be accessible. Single keystroke access was established for activities designed in Shockwave.

Participation

For two and one half years of the project, registrations were captured at the PlaneMath website. As of December 1998, almost 600 teachers had registered their classes, representing over 23,000 students. Of these, 760 students were described as having a disability. The registrants came from every state in the United States as well as several countries internationally.

As a measure of its success, PlaneMath received the following recognition:

- selected by Classroom Connect, a highly respected publishing company specializing in K-12 curriculum material designed to help teachers integrate the Internet into their classrooms, to be included on their CD-ROM on outstanding web sites

- selected to the Blue Web'n Learning Applications Library by a Pacific Bell Education First Fellow, "an honor reserved for the best instructional lessons, activities, projects, resources, references, and tools on the Web."
- deemed an "Exemplary Existing Resource" by the California Technology Assistance Project
- selected to be featured in an issue of www.4kids.org, a Universal Press Syndicate (UPS) syndicated feature published by over 150 newspapers in the US and Canada. Each issue is printed with either a Sunday or a daily edition each week.
- deemed an outstanding Web Site by the WebCrawler Select Editorial team
- selected to be listed at California Department of Education's SCORE web site for recommended curriculum
- selected as one of the Eisenhower National Clearinghouse Digital Dozen web sites, November 1996
- identified as an exemplary site by the North Carolina Department of Public Instruction

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Cooperative Development of Visually-Oriented, Problem-Solving Science Courseware

Phil E. McClean, Plant Science, mcclean@plains.nodak.edu
Don P. Schwert, Geosciences, schwert@plains.nodak.edu
Paul Juell, Computer Science, juell@plains.nodak.edu
Bernhardt Saini-Eidukat, Geosciences, sainieid@badlands.nodak.edu
Brian M. Slator, Computer Science, slator@badlands.nodak.edu
Alan R. White. Botany/Biology, alwhite@plains.nodak.edu
North Dakota State University, Fargo, ND 58105

Abstract: The NDSU World Wide Web Instructional Committee (WWWIC) is a group of faculty who have a strong and active interest in applying information technology for instructional purposes. A World Wide Web (WWW) site, http: //www.ndsu.nodak.edu/wwwic/, provides many of the details of the history and the accomplishments of this group.

Introduction

The WWWIC has identified three discrete but related approaches for innovative design which are both highly technical and highly promising in terms of broad applicability for the development of courseware. These areas are: Visualizing Course Content, Simulating Course Concepts, and Interfacing with Course Content. Each of the WWWIC courseware projects emphasizes one of these approaches, and all feature active student interaction with course materials. Because each courseware application depends upon some form of simulation, students modify parameters or choose their own route to learning. This active engagement with the course materials promotes the learning experience. The direct outcome of these design and development efforts includes: the Virtual Cell (http://www.ndsu.nodak.edu/instruct/mcclean/vc) the Geology Explorer (http://www.cs.ndsu.nodak.edu/~slator/html/PLANET/), and the Visual Computer Program (http://www.ndsu.nodak.edu/instruct/juell/vp/), all of which are hosted and supported by our Java/MOO for Virtual Worlds client-server architecture.

Visualizing Course Content - Background.

To facilitate learning and understanding in a uniquely accessible way, many concepts can be presented both spatially and graphically. This is possible for abstract, theoretical, as well as physical objects. This approach to system development has positive advantages and presents profound technical and conceptual difficulties. VRML, the Virtual Reality Modeling Language (Hartman and Wernecke, 1996), has emerged as a highly plausible standard for creating visualizations, but specific problems are associated with its use. In particular, VRML and client-server applications employing VRML place prohibitive processing requirements on computing environments. Still, there are many advantages to this approach, and manageable methods of implementation can be developed. For example, the need is for state-of-the-art computers to host these applications.

Visualizing Course Content - Courseware: The 3D Virtual Cell.

Active learning involves students interacting with course materials (Reid 1994). From a computer technology perspective, this involves interfacing with the materials in a computer environment, visualizing the

subject matter in a 2D, or better yet, a 3D environment (which VRML supports), and modeling the material so that the student can learn concepts by manipulating parameters related to the subject matter.

In today's classroom, simply presenting that knowledge in a two-dimensional manner does not compel the student to understand the various relationships of that knowledge. The 3D world is much better suited for that type of knowledge. If the student has access to a 3D world that ties the knowledge base together, improved student learning may result. Therefore, a 3D dimensional graphical image of a eukaryotic cell will be developed. This cell will be navigable via a VRML plugin for WWW browsers. The image will contain all of the different cellular structures such as mitochondria and chloroplasts, the nucleus and unique topological features such as the cytoskeleton. Because 3D rendering and interactivity is a relatively new field, we will provide prototyping efforts necessary for future development. Answers are not yet known to questions such as how best to use computer and network resources to deliver this type of 3D content. Other unknowns include the dynamics of traveling through such a display and updating the module. Students are often confronted with information that is dynamic and has a deep interrelationship.

Figure 1: The Virtual Cell

All of these structures will be based upon the latest knowledge about these cellular structures. Because new discoveries are being made in the field of molecular genetics and biochemistry at a relatively rapid pace, we design 3D worlds that are easy to modify so new developments can be easily incorporated.

Simply having an attractive 3D graphic itself will provide students a perspective of cellular organization. But VRML also permits navigation to deeper concepts. The 3D cell will be linked to content. For example, traveling to and clicking upon the nucleus, the student will enter the nucleus. Once within the nucleus, they will be able to activate such processes as DNA replication. Each step of the replication process will be navigable to obtain more detailed information about the process. Within the nucleus, other processes such as transcription will be modeled. These models will include 3D visualizations of protein/DNA interactions necessary for correct gene expression. The 3D Virtual Cell can also serve as a model for any 3D world. The solutions that we seek will have applications to other fields in which dynamic, interrelated information is the foundation of knowledge. Therefore the research solutions that we devise will pave the way for these applications elsewhere on campus.

Visualizing Course Content - Courseware: The Visual Computer Program.

It is difficult to show effectively the execution of a computer program. This is particularly true for rule-based programs used in expert systems. This project (Juell 1999) develops the 3D models of program execution. The models are distributed in VRML form, allowing the student to "fly" through the steps of

execution of the program. In addition, there are a number of special Java-driven Hot Buttons to allow variations in the presentation. This supports stepping through the program, putting the program into a play loop, and hiding various parts of the information.

Simulating Course Concepts - Background.

Research in active learning environments includes implementing "live" simulations for exploration and discovery that engage learners while treating them to a plausible synthetic experience. Simulated environments are valuable teaching tools because they can take a learner to places they would never ordinarily experience either because they are too dangerous, or because they are a physical impossibility. Unfortunately, simulations are complex and difficult to build. The need is for research into the construction of such systems, so that appropriate tools can be developed to facilitate later constructions. In addition, multi-user simulations require high-speed computing resources to support the "plausible" interactions required to maintain the integrity of the virtual environment.

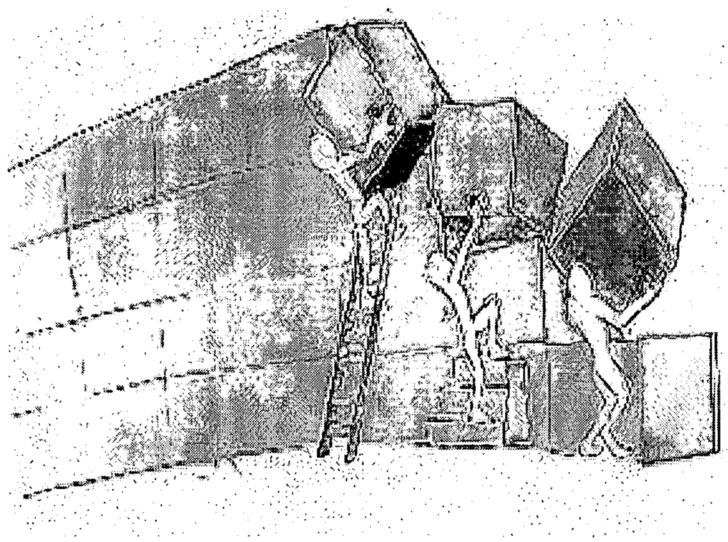

Figure 2: The Visual Computer Program

Simulating Course Concepts - Courseware: The Geology Explorer

The Geology Explorer (Slator et al, 1998; Saini-Eidukat, Schwert, and Slator, 1998; Schwert, Slator, and Saini-Eidukat, 1999) is a synthetic environment implemented as a graphical MUD/MOO, described later. This project is intended to teach college level geology students how to act like geologists. We have developed an Earth-like planet in a synthetic environment and can dispatch teams of geology students to the surface in search of evidence that the planet will support colonization. The first module involves mineral exploration, where students are expected to plan an expedition, locate and assess potential mineral and ore deposits, and survive the somewhat hostile environment in order to report on it.

Physical Geology (NDSU Geology 120) is a large-enrollment (>400 students/section), three semester hour lecture course offered in a large auditorium. Aside from lecture, the course content is augmented by slides, by a set of course lecture templates, by a textbook, and by a web resource site ("http://www.ndsu.nodak.edu/instruct/schwert/geosci/g120/g120_idx.htm"), which includes self-quizzes, photographs, course news, and links to related resources. Testing is by multiple choice exams, with students submitting their results on optical scan sheets. Nearly 100% of the students enroll in the course to complete either general education requirements or specific course requirements within their majors. Of the 424 students enrolled at the beginning of Fall, 1998, none were Geology majors.

The challenge for the instructor is to try to make these non-science oriented students think like a scientist: proposing and testing hypothesis, making appropriate decisions utilizing the basic tools of a geologist, working with the language of geology as a science, etc. It is obviously impractical for an instructor to take 434 students into the field and have them individually experience how a geologist makes on-site decisions. However, the student can experiences these in a synthetic environment, in which each student acts as a geologist and is expected to address a series of highly realistic geologic situations. Within this environment, the student makes decisions similar to those of a "real" geologist using the tools and techniques of a geologist.

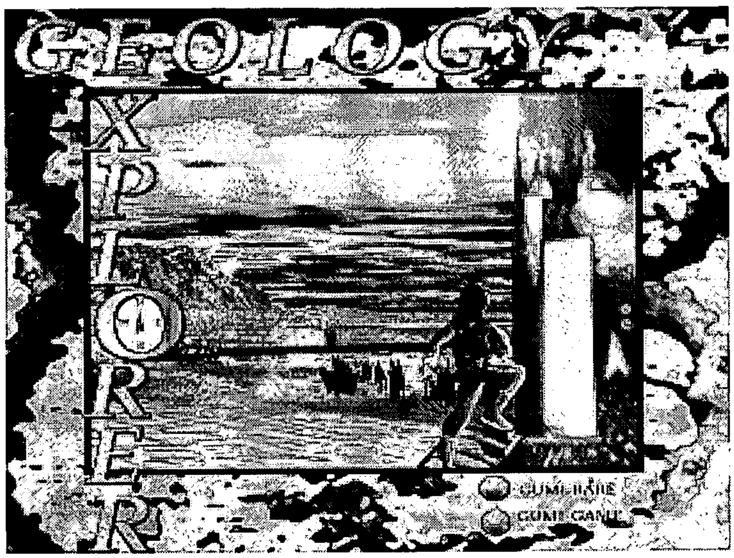

Figure 3: The Geology Explorer

In addition, because it is tied to an Earth-like planet, the course has a geographic base upon which to establish this synthetic environment. The base is not limited to just the Earth's surface but to the relationship of this surface to processes and energy sources deep within the planet. Synthetic environments could then be established at any position on, above or within the Earth sphere, and the student can evaluate diverse and often counteracting forces and processes.

Interfacing with Course Content - Background.

Research in the area of end-user interaction includes discovering better and more efficient ways of presenting information, supporting navigation, and delivering content. Client programs and browsing interfaces have moved through several generations within just the last few years, and there appears to be no end in sight. It is clear, for example, that Java development, for all the many recent strides, is still in its infancy. It appears likely that Java will be the WWW language of choice for the immediate future, although the shape of that future is only now becoming clear.

Interfacing with Course Content : Java/MOO for Virtual Worlds.

Ongoing WWWIC research involves the construction of educational technology applications for tutoring and training. These applications are of a particular type: synthetic, multi-user environments spatially oriented and designed on a model that promotes learning-by-doing, collaboration, exploration, and positive role-playing. Systems of this sort capitalize on the advantages inherent in game-like educational media.

These synthetic environments are implemented as a graphical MUD/MOO (Curtis, 1992; MUDs, or Multi-User Domains are typically text-based electronic meeting places where players build societies and

fantasy environments, and interact with each other; MOOs are object-oriented MUDs.) The participants in a role-based environment are immersed in a sustained problem-solving simulation. To succeed in their virtual world and effectively play the game, the learner must necessarily master the concepts and skills required to play their part. To "win", they need to learn the domain, and they need to learn their role in it.

Virtual role-playing environments can be a powerful mechanism of instruction, provided they are constructed such that learning how to play and win the game contributes to a player's understanding of real-world concepts and procedures. We believe the value of play in learning can hardly be over-stressed. Students quickly tire of rigid tutorial systems designed to teach at any cost and at some predetermined pace. However, since simulations can be adaptive and responsive, playing a role in a simulation can be fun. Players will throw themselves terrier-like into an environment if it feels like a game. Insofar as possible, educational software should be engaging, entertaining, attractive, interactive, and flexible: in short, game-like.

The MUD/MOO technology supporting these educational environments is in many ways similar to a Web server. The server runs a game simulation constantly, and players connect using client software whenever, and from wherever they like. However, the server is an active simulation implemented on an object-oriented database, and the database supports messaging and scripting so that the virtual world can be both inhabited and implemented at the same time. Many players and many implementers can be resident at the same time, and they can interact with each as they choose. In periods of intense involvement, i.e. supporting dozens or hundreds of simultaneous users, the server must be capable of sufficient processing speeds to preserve the integrity of the interactive simulation. The need is for a delivery mechanism that spans the user community and yet delivers acceptable enough performance that remote users will be satisfied with their learning experience.

Assessment of Learning.

A primary goal of the WWWIC team is to develop courseware tools that teach basic scientific principles and intellectual approaches. The basic principles and approaches with which we are concerned are those which are common among several scientific disciplines. Because many of the tools that we are designing will contain basic content that is necessary for the student to complete subsequent courses in their major, it is also important that the student learn discipline-based content. Therefore, some assessment tools will be generic to determine if the courseware tools are effectively teaching the student basic principles, whereas others will be more specific to measure the acquisition of discipline-based content.

As it is important to understand our target audiences, students will be asked to complete a profile form where they describe their educational background relevant to the course, the availability of computers to them, their perceived skills in using the computer, and any course-related hobbies. In an attempt to measure the actual effectiveness of the courseware tools, the student answers will be weighed against what the student learned. For example, if a student has little access to or comfort with a computer, that would be a significant factor when determining how their experience with the courseware tool affected their achieving a specific learning objective. Likewise, if a student is an expert at computer games, that should be considered a factor when assessing the effect of a module upon learning.

Formative evaluation tools will be completed by students as they use a specific courseware module. The goal of the evaluation is to find out from the student if they are learning a specific principle (generic assessment) or discipline-related content (content assessment). For example, a student might be required to complete a "one-minute paper" that summarizes their educational experience with a module. This assessment tool would be a simple narrative that describes what was learned, what concept was clear and what concept was unclear. Another assessment method that will be tested is the "dialogic journal". The journal could be collection of "one minute papers" that the student uses to characterize a longer term education experience with the courseware tool.

We are interested in measuring transferability of the knowledge from one content setting to another. For example, a student may learn basic course knowledge. That knowledge could be tested in a summative manner by using quizzes or tests. In a subsequent class, the student will be required to use that knowledge to learn a broader principle. To determine if that principle is learned, the student may be asked to develop a "concept map". This concept map would require the student to recall the basic content learned earlier and show how that content is interrelated to some broader principle taught in the current course. If the student can demonstrate in the "concept map" the relationship of the content to a basic principle, then transferability of

knowledge will have occurred. The advantage of working as a team to develop courseware modules is that we can assess if common approaches to delivering a basic principle will lead to improved student learning in multiple courses. Furthermore, by sharing an assessment technique among different classes, we can test the suitability of the different approaches.

Conclusion

As a broad field of inquiry, science has many basic principles and intellectual approaches. One of the goals of science education is to teach students a framework based on these principles and approaches that can later be used to solve science-based problems. In addition, a specific scientific field is content based. To have a successful career in science, students must master the content of a discipline. The challenge for science educators is to develop educational tools and methods that deliver the principles but at the same time teach the important content material in a meaningful way.

The development of computer-based courseware tools can significantly affect how and to what depth principles and content are delivered to the student. For example, it was not that long ago that engineering students would be given the overnight assignment of measuring the load on a beam. With the development of sophisticated CAD software, the overnight assignment can now be to design an entire room in which all of the load bearing walls meet a specific code requirement. The impact of the software is two-fold. First, the principle of load is taught in relation to the real-world realm of a room or even a building. In addition, content can be delivered at a faster rate because the rate of student learning is not limited by the tools used to solve course-related problems. Over an extended period of time, what were once advanced topics will be taught earlier in the student's education. This evolution will lead to a richer education experience that better prepares students for science careers.

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Acknowledgments

These development efforts are funded by the National Science Foundation under grants DUE-9752548 and EAR-9809761. For further information on virtual worlds software development at North Dakota State University, visit the (http://www.ndsu.nodak.edu/wwwic) NDSU WWWIC site. The authors acknowledge the large team of dedicated undergraduate and graduate students who have made these projects so successful. Special thanks to Rebecca Potter and Mark Rose for the graphic images provided for the projects and included in this paper.

Teaching Scientific Inquiry Skills with an Intelligent Tutoring System

Thomas N. Meyer
Mei Technology
MeyerN@grover.brooks.af.mil

Kurt Steuck
Air Force Research Laboratory
Steuck@alhrt.brooks.af.mil

Todd M. Miller
Mei Technology
todd@grover.brooks.af.mil

Carolyn Pesthy
MacArthur High School

Monika Kretschmer
Mei Technology
Monika@meitx.com

Abstract: Since 1990, the Air Force has been engaged in a long-term research effort, Fundamental Skills Training project (FST), to bring state-of-the-art intelligent tutoring technology to bear on growing literacy skills problem in areas such as mathematics, writing, and science. The primary goal of the project is to design, develop, evaluate and transfer prototype intelligent tutoring systems (ITSs) to public schools, and, when appropriate, to industry.

This paper discusses the science tutor, Instruction in Scientific Inquiry Skills (ISIS). ISIS is a simulation-based cognitive tutoring system constructed to teach high school students scientific inquiry skills and substantive knowledge in ecology. The primary goal of the science tutor, consistent with major science initiatives and standards, is to increase the level of scientific functioning. This paper describes the goals of the tutor, its instructional approach, and the implementation and evaluation of ISIS in a series of large-scale field studies.

Project Goal

Since 1990, the Air Force Research Lab (formerly known as Armstrong Laboratory) and the University of Texas at San Antonio, has been engaged in a long-term research project to bring state-of-the-art intelligent tutoring technology to bear on our nation's growing literacy skills problem in areas such as mathematics, writing and science. The primary goals of the Fundamental Skills Training (FST) project are to design, develop, evaluate and transfer prototype intelligent tutoring systems (ITSs) to public schools, and, when appropriate, to industry under federal technology transfer guidelines.

One of three tutors developed to help teachers and school children in basic scientific inquiry skills is the science tutor, Instruction in Scientific Inquiry Skills (ISIS). This intelligent tutor is a simulation-based cognitive tutoring system designed to teach junior and senior high school students scientific inquiry skills in the context of biology and ecology.

Tutor Goal

A goal of science education is to produce students who are competent in science. By "competent in science," the project team means that each student will be literate, functional, and critical in the domain of science. To be literate denotes the abilities to obtain, comprehend, and communicate scientific material. To be functional

refers to the ability to utilize the methods, principles, and technologies that pertain to science. To be critical indicates the abilities to assess the soundness of scientific approaches and outcomes and to judge the significance of science and technology in society.

The over-arching goal of the science tutor, ISIS, is to increase the level of scientific functioning of high school students enrolled in Introductory Biology. Because this level of functioning is too broad to address in the initial design of ISIS, the tutor focuses on skills underlying scientific inquiry. Some of the activities required in applying scientific methods are automated within ISIS; other skills constitute what the students will learn by interacting with the computer. The following are the specific, measurable objectives of ISIS. Specifically, students will be able to complete the six steps of scientific inquiry: generate a research question, state a testable hypothesis, design a controlled experiment to test that hypothesis, conduct the experiment in a simulated environment, state a conclusion from the experiment and accept or reject hypothesis.

In order to prepare students for scientific inquiry activities, ISIS first presents modeling of inquiry skill performance through several computer-based instructional modules. Once students have completed an instructional module, they are transported to a medieval castle setting, (see Figure 1) an adaptive and supportive environment where students practice using scientific inquiry skills. As students work through the assignments, they receive adaptive feedback from the castle's occupants, Igor and the Wizard. As students progress, ISIS begins to fade the support it provides by offering less directive feedback and advice.

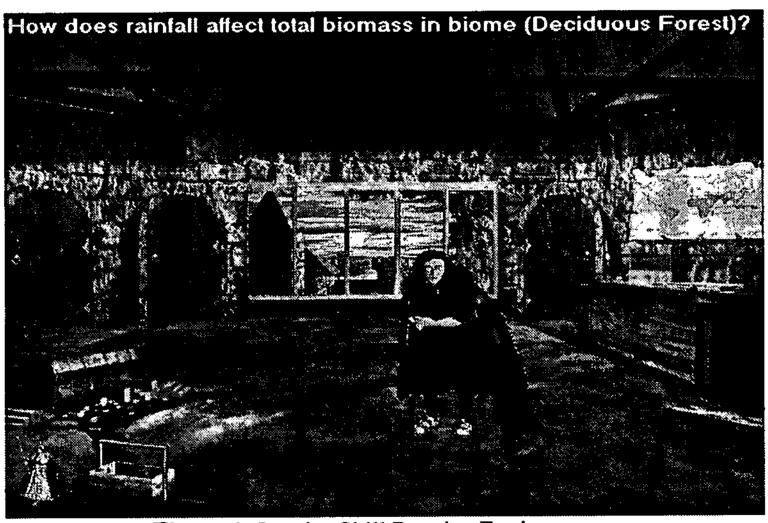

Figure 1: Inquiry Skill Practice Environment.

Tutor Content and Target Audience

The content of ISIS in which inquiry skills are taught is environmental science. The software is primarily geared toward middle, junior high, and high school populations. The test and evaluation has involved seventh, ninth, and tenth grade students.

Recently, the Department of Defense (DoD) and the Department of Labor (DoL) have entered a cooperative agreement to transition FST products from the military to DOLETA workforce development professionals for use with program participants (Youth Fair Chance, Job Corps, and Summer Youth).

Instructional Approach

A cognitive apprenticeship approach to instruction is embedded in ISIS. Cognitive apprenticeship emphasizes two relevant issues. First, cognitive apprenticeship aims to teach cognitive and metacognitive skills used by experts when faced with complex tasks (Collins, Brown, and Newman, 1989; Collins, Hawkins, and Carver, 1991). Cognitive apprenticeship approaches focus on teaching students how to solve complex problems and tasks. This requires the tutor to teach declarative, procedural, and metacognitive knowledge in the context in which it is used.

The second issue addressed by cognitive apprenticeship is the actual method of teaching students. Cognitive apprenticeship relies on students learning through guided experiences (Collins, Brown, and Newman, 1989) in which tutor and pupil interact to facilitate knowledge construction in the ways which are most relevant to the learner. Initially, an instructor models the external behaviors while describing the cognitive aspects underlying the performance of the task-related skills. Following the modeling of the skills, the student performs those skills under the direction of the instructor. The instructor guides the student through the task providing lots of structure or guidance to the student. If the student does not display mastery in performing certain skills or demonstrates content mastery in certain tasks, the teacher resorts to describing and modeling the appropriate responses. As the student becomes more proficient in performing the task, the instructor "fades" or reduces the amount of structure. Throughout the teaching-learning episode, the student is required to reflect upon his/her performance relative to that of experts. This reflection develops self-correction and self-monitoring skills. The methods underlying a cognitive apprenticeship approach to instruction (Collins, Brown, and Newman, 1989) include; 1) modeling of the cognitive skills and processes underlying task performance, 2) coaching the student during his/her performance of the skills, 3) structuring of lesson content and subsequent fading of the structure, 4) requiring the student to reflect upon his/her performance and articulate his/her knowledge, and 5) allowing students to explore how to apply newly learned information in accomplishing complex tasks.

In order for ISIS to accomplish the methods underlying the cognitive apprenticeship approach, the tutor must be able to perform several instructional activities. The set of activities chosen to implement the cognitive apprenticeship approach is described by Hsieh, Miller, Hicks, and Lorenz (1993). The tutor must be able to 1) present detailed domain knowledge and inquiry skills and multiple examples of each, 2) elicit performance from the student, 3) diagnose the student's performance, and 4) give appropriate feedback.

Simulated Ecosystems

One component of instruction in the cognitive apprenticeship approach is to allow the students to explore how to apply their knowledge in accomplishing complex tasks (Collins, Brown, and Newman, 1989). In addition, Project 2061 states that "students need time for exploring, for making observations, for taking wrong turns, for testing ideas, for doing things over again..." (Rutherford & Ahlgren, 1990, p193). Allowing students to "play" in a computer-based simulation of the domain concepts is one way to achieve these recommendations. ISIS contains a simulation of simple ecosystems, such as a grassland and a coniferous forest, so that students can conduct experiments testing their hypotheses (see Figure 2).

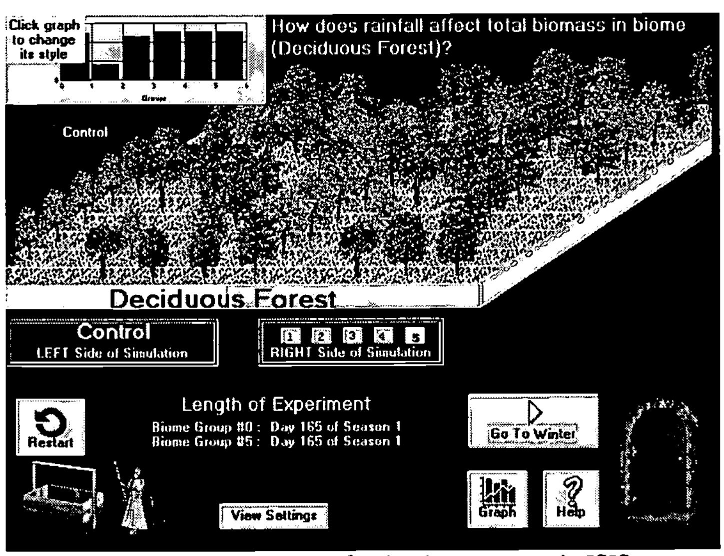

Figure 2: A simulation of a simple ecosystem in ISIS.

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Student Model

The role of a student model is to provide information to the instructional module to make instructional decisions (Self, 1990; Van Lehn, 1988). The student model is a repository of the interpretations made by the instructional module during the diagnosis of the student's behavior. The student model needs to record information for immediate, on-line, instructional and long-term, deferred, curricular decision making. The immediate decisions tend to revolve around the instructional action the tutor must take given a student's behavior. The tutor diagnoses the student's performance and then must determine whether to give any feedback and what kind. The long-term, deferred decision-making primarily involves decisions at a curricular level. Once a student has completed an assignment, the tutor needs to determine whether to advance a student to another unit of instruction or to assign a task within the same instructional unit.

The types of data recorded in a student model includes data about a student's progress through the curriculum, the student's knowledge of the biology concepts, and the student's ability to perform the skills underlying the scientific method. The curricular information includes the list of assignments completed, the current assignment, and status on the current assignment. Data on the biology concepts include whether a student has received instruction on each concept, the number of errors a student has made on the current assignment, the number of errors the student has made on previous assignments involving the concept, and a belief about the student's proficiency based on these and other data.

Results

The sample size, spanning over the past two years, has included 3,057 students located in 13 different schools in five states across the nation. Results over the past two years have indicated a positive linear relationship between students' skills and domain knowledge and experience with the tutoring system. Simply stated, students using ISIS greatly improved over the traditional classroom control group, with the size of the effect becoming more pronounced as students spent more time with ISIS (controlling for science achievement).

Observing the overall gains for the 1995-1996 term, the treatment group improved by 8%, while the control group improved by only 4%. Specifically, the skill level obtained by the students directly influenced the amount gain. Students using ISIS (having met a threshold of assignments completed) outperformed control group students on scientific inquiry skills as measures of domain knowledge. Similarly, results for the 1996-1997 term yielded an 11% increase for the treatment group, while the control group experienced only a 6% improvement.

Future Direction

Subsequent efforts with regards to the ISIS tutor include an experimental design that incorporates a within-sample design that evaluates the role of student control (guided vs. exploratory research) in performance.

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Contextualizing Web-based Interactive Learning in Science

Mary Jo Parker, Ed.D., Baylor University;
Science Department Chair-Caney Creek High School in Conroe ISD, Texas, USA
Email: Parker83@earthlink.net maparker@conroe.isd.tenet.edu

Abstract: As technology continues to make its way into daily classroom use throughout all disciplines and across all grade levels, the question of its impact and effectiveness is heard in rising crescendo. This study investigated the effects of a web-based interactive science learning environment on the academic behaviors through built-in database tracking capabilities. Results indicate that some learning behaviors within contextualized science web-based environments can be tracked as a way of examining the effectiveness of contextualized web-based learning.

1. Introduction and Rationale

As the Intranet/Internet is introduced into the learning environment of the classroom today, the effects of this technological environment must begin to be studied. Technology offers opportunity to affect and monitor academic behaviors such as problem-solving ability and metacognitive reflection. However, what evidence can be found that speaks to the effectiveness of the use of such learning places? Beyond effectiveness, can a model for visualizing any level of effectiveness be generated for such environments?

As technology creates a virtual classroom environment as it moves to a web-based space, questions arise regarding the effectiveness of such geographically unrestricted, collaborative problem-solving places (Jacobsen and Levin, 1993). Collaborative designs such as these become possible when the learning environment is placed within a web of computers, thereby facilitating and encouraging access by many to a shared Intranet/Internet webplace.

As students use the collaborative capabilities of a networked Intranet learning environment, thinking about their own thinking evolves, thereby increasing the opportunity to clarify misconceptions of knowledge, procedural or declarative. The science classroom presents one opportunity to study the effects of a shared, Intranet environment on student problem-solving ability and metacognitive reflection skills through shared contextualization. Field study data collection, posting, and discussion create a context, or anchor (Brown et.al., 1989), for this virtual learning environment based on real, concrete information.

2. Questions Researched

As part of a secondary research question, an evaluative analysis of the CourseInfo software (Blackboard, Inc., 1998) was undertaken. The tracking capabilities of the software CourseInfo were evaluated through measurement of 1) log-ons to the threaded discussions webpage, 2) number of threaded statements, 3) number of threaded dialogue statements of response to other student statements, and 4) number of threaded dialogue statements of response to teacher statements.

Analysis of tracked user movement within the shared web-based environment was investigated as one possible model of evaluating learner academic behaviors within, and as a result of, web-based environments. While further analysis remains needed, results of this study support tracking user movement as an avenue of quantifying the effectiveness of web-based learning initiatives.

3. Study Background

Subjects: Subjects for this study were first time 9th and 10th grade biology students from three public education high schools in the Conroe ISD within Conroe, Texas. The sample (n) contained 78 students of the 1400 students enrolled in Biology I courses. Two classes from each school were selected and randomly assigned to a control class and a treatment class. Selected campuses operated on an A-B, 90-minute class alternating block schedule.
Technology: Groups assigned to treatment groups received access to technology. This technology included MacIntosh platform computers. Scanners, digital cameras, and Internet-connected computers, and laser printers

rounded out the technology utilized by the treatment groups. Software access included Apple QuickTake PhotoNow software, HP scanning software, MS Office, Netscape Navigator Gold 3.0, and Inspiration 4.0.
Ecology Curriculum: Teachers at selected campuses received an Adopt-a-Ditch ecology curriculum (Stone and Myers, 1994). This modified curriculum provided the context for the web-based learning environment. Training for all curriculum lessons, use of the LaMotte Freshwater Testing Kits, web-based database was provided. Spontaneously generated forum topics were noted as the researcher analyzes collected data within the web-based learning environment.
Teacher Training: Technology training consisted of instruction and practice in the use of the CourseInfo Intranet simulation software (Blackboard, Inc., 1998) Inspiration uploading and downloading files via the Internet, digital camera use and downloading of images, use EXCEL spreadsheet/graphical capabilities, and use of the Discussion Forum environment.

4. Software Background

A secondary intent of this study was to provide evaluative discussion of the software product used to create the shared learning environment. As this newly developed distance education software product was in the process of being piloted by a variety of institutions and research programs, permission for its use as part of this study was obtained (Blackboard, Inc., 1998). Agreements between the author and software developers included evaluative information resulting from use of the product, taking into consideration the constraints of its application within the nature of the study. Results addressing the secondary research question focused on an examination of tracked user movement findings, discussion forum findings, and difficulties experienced during use of the software product.

One caveat exists as a part of answering this secondary research question. It is imperative to remember that this section's evaluative basis remains the by-product of this particular study. As many other piloted uses of this product have occurred, or are presently on-going, this author suggests that additional review of other evaluative efforts be examined should any future use of the product be initiated.

Further, it must be noted that use of the product within this study represents a model whereby security access was granted to all subjects within the study. This type of widespread access normally is not the mode of access suggested by the developers. However, this approach was utilized to create a more constructivist (Jonassen, 1996), shared environment given the nature of the software product. Therefore, review of the secondary research question findings should occur with forethought of these caveats. Future users of this software product should consider the type of learning environment they envision, as well as the learning philosophy underpinning that environment, as this study's findings of the software are taken into account.

5. Software Capabilities Within the Model of Study

Tracked User Movement

CourseInfo software provides a database of user movement patterns once entry into the website occurs. Analysis of recorded user movement can be obtained for a variety of statistical views of user movement. These statistical views were made available through the CourseSite Stats option accessible with security password through the control panel. Views (analyses) available include: 1) a statistical traffic analysis of hits for the entire course site, 2) traffic hits may be viewed by each page within the course site, 3) analysis of hits by date can be obtained, 4) a view of hits by time and by links can be accessed, 5) traffic hits by countries, visitors, and browsers can be analyzed and 6) the above information can also be filtered by server domain.

As a part of the study, tracked user movement generated information related to several aspects of user movement. Repeated visits (interpreted as level of traffic) can be connected to user preferences related to webpage function, design, or information. Total number of hits can indicate to some degree user time within the shared learning environment in general. Evaluating which pages were accessed during the study could indicate depth and type of use of the shared environment. Use of help pages within the shared environment could imply use in a self-sufficient way. Finally, tracked use of the discussion board provided information as to the development of the entire study group, the collaborative extent of the group, and student-initiated discussion. Tracked user movement, identified movement by page title and number of traffic hits as well as percentages, was summarized.

Analysis of user movement by page indicated entrance into the shared environment through the main page. The Course Documents page was used with the most frequency (13.3%) after entering the shared environment. This page provided the storage location for uploaded files (graphs, images, and documents) for all participants. All files accessed through this page by any participant were viewed or downloaded. Use of the Assignments page incurred

9.8% of the hits. This page held sample files and user instructions for the various activity demands of the ecology curriculum. The limited use of this page simulated the nature of FAQs pages in other websites, that is, they remained relatively unused. The third most frequented page within the website was the student tools page at 11.9% indicating that help pages entitled Tools seem to be more frequently accessed by novice users than pages titled in other ways.

An analysis of user movement by date was undertaken as an indicator of the overall use of the shared environment. Table 1 contains a use-by-date display of user movement within the website. Examination of use-by-date hits, filtered through server domain, provides evidence of the site's extension of interactivity between time and the users. At first glance an appearance of minimal use might be seen due to the small number of hits and the low percentages. However, closer examination indicates the fact that in an A-B block schedule hits were recorded for each day of the school week. This looms important as it suggests evidence indicating that in some way students gained access to the shared web-based environment during days when no science class was scheduled.

Discussion Forum Findings

Analysis of the use of the shared environment's discussion board revealed much about the amount of time spent using a shared, discussion place as well as about other previous discussion forum experiences within the classroom. Extrapolation of the number of hits associated with accessing the discussion board provided evidence of minimal use of this type of environment and technology, suggested a lack of previous exposure to the electronic sharing of ideas and information, and detected technical issues as the most pressing and reported discussion topics. The following sections address these extrapolations.

Table 1. Analysis of User Movement by Date of Use for the Duration of Study.

Date of Use	Day of the Month	Scheduled Study Dates	Hits	Percent of Hits (%)
5-4-98	Monday	+	4	1.4
5-5-98	Tuesday		7	2.5
5-6-98	Wednesday	+	7	2.5
5-7-98	Thursday		8	2.8
5-8-98	Friday	+	103	39.2
5-11-98	Monday		70	24.7
5-12-98	Tuesday	+	16	5.7
5-13-98	Wednesday		27	9.5
5-14-98	Thursday	+	25	8.8
5-15-98	Friday		16	5.7
Total			283*	100.0

Note. *Denotes the number of hits remaining after discounting the number of hits recorded by the dissertation's author while monitoring site.

Use of the shared discussion board. Originally, a total count of discussion threads posted by the author of the study was determined. Sixteen threads were initially established as "starters" for each of the activities in the ecology curriculum guide. The use of starter threads potentially enabled moderation and enumeration of topics by the author or by each campus teacher. A count of the number of discussion responses indicated very little activity within the shared discussion board. Minimal new discussion threads were originated through the duration of the study. The lack of discussion threads or responses seemed surprisingly low considering that each curriculum activity included responses to the discussion board topics as indicated in each activity directions. Analysis of discussion threads and responses suggested little time of use within the forum opportunity of the site. Only five new discussion threads were recorded over the duration of the study. Of the new threads recorded only one came from a student. Efforts to understand this lack of activity brought focus to the nature of the discussion threads or response messages actually recorded within the discussion forum.

Nature of the discussion forum threads & responses. A review of the content of the discussion threads created by teachers and students indicated their experiences with technical difficulties associated with some aspect

of the various technologies involved in the study. Primarily, use of the uploading and downloading capabilities presented time-consuming difficulties as apparent in the number of discussion threads and responses made by teachers and the one student discussion response dealing with this aspect of the study. Additionally, qualitative analysis of the dissertation author's discussion responses suggest frustrations and needed help on the part of the writers of the responses. In some instances the discussion thread titles indicated the degree of technical problems being experienced "Feeling frustrated-Punch Here", "Need Directions", or "Need Directions too".

An analysis of the dates of the forum threads and responses provides additional evidence of the minimal use of the discussion forum as well as potential reasons for this lack of use. The dates of teacher and student discussion threads and responses seemed to indicate initial use occurred late into the study and did not follow the curriculum guide of activities. Table 2 summarizes discussion threads and responses by date.

Table 2 seems to suggest that the teachers, at least, were beginning to try the use of the forum as a place to share difficulties as well as a place for seeking help. When dissertation author discussion threads and responses were analyzed, all appear to address technical issues inherent in the software or in the computer platform providing technology capabilities.

Table 2. Summary of Discussion Threads & Responses by Date.

Discussion Thread Titles	Date	By
Test Discussion	May 1	Teacher
Test Run	May 1	Teacher
Feeling Frustrated-Punch Here	May 8	Teacher
Need Directions	May 11	Student
Need Directions too	May 11	Teacher
Discussion Response Titles		
Re: Ditch Site Locations	May 5	Teacher

Difficulties Experienced Using CourseInfo Software

Examination of uploaded files and discussion forum transcripts provided evidence of a variety of difficulties experienced with the piloted software. These difficulties seemed to cluster around novice user levels of the participants, computer platform inconsistencies, and software security issues of the software.

When an initial survey of all uploads into the CourseInfo ditch ecology site was performed, upload attempts provided evidence of use of the site by students was high. However, this same information suggested that the on-site help pages and on-hand training documents had not been accessed during initial uploads as many attempts to upload were to incorrect locations. Once user uploads were found attempts to open and view each was made. This was initially undertaken by the dissertation author to insure the viewability of the data. Computer platform issues came into evidence during this phase for all campus users. All campus users operated MacIntosh platforms that automatically upload files with no pre-assigned file extension added to the filename. PC platforms and software automatically pre-assign the filetype extension to a filename, thereby enabling identification of the filetype. This became critical within the CourseInfo environment as each uploaded file, when opened, launched a copy of the application needed for readability. The lack of automatic assignment of filetype extensions as a result of MacIntosh platform use caused initial uploads by each campus to be unreadable. This issue created multiple upload attempts of the same data and high frustration levels among the users uploading.

6. Summary

The secondary research question attempts to identify academic behaviors that can be tracked within a shared, web-based learning environment such as that offered by the piloted CourseInfo software. Identifying user movement patterns in web-based environments and discussion forum patterns as well as attempting to ascribe meaning to these movement patterns by connecting these movements to academic problem-solving and metacognitive reflection offers much potential to these new learning environments. Connecting meaning to these

movement trends within the context of the shared, web-based environment may be the most interesting, potentially, meaningful aspect of this study.

As the use of shared, web-based learning environments within secondary classrooms experience rising use, models focused on understanding the critical elements of effectiveness of these environments seem necessary, rather than novel. Tracking user movement and discussion forum patterns offers a potential way of documenting and quantifying learner critical thinking and metacognitive reflection within a web-based learning environment. Tracking movements and discussion forum patterns provides one method of assessment within the web-based environment that can be maintained behind the scenes without interference to the learner and without overt, game-like feedback. This type of assessment informs instruction, the instructor, and the learning environment. The potential exists for measuring the effect of the environment through the learner's movement patterns, thereby offering the possibility of creating an optimum learning environment for each and every type of learner.

The richness of shared data, data examination, and learner insights follows from the natural extension of user movement pattern analyses. Moving learner metacognitive reflection capabilities to a web-based learning environment presents the academic accountability often missing from current models of web-based learning. Not only can depth of knowledge, but also critical thinking levels, begin to be warehoused for constructive use by each learner/user.

Contextualizing web-based learning environments with science real-time data collection and evaluative activities appears to favorably support the improvement of academic behaviors. Given the strong emergence of distance education initiatives, evaluating and assessing these behaviors within the web-based learning environment becomes ever more important. Add to this the constructivist nature associated with this study's model, and the power and empowerment of this type of web-based learning place becomes awesome, and needed.

7. Future Implications

The results of this study present one practical model for infusing technology into the classroom setting, for improving problem-solving ability and metacognitive reflection over a short duration, for creating a collaborative, cooperative learning space, and for maintaining a science space for learning where no gender differences arise.

The power an Intranet offers within the constraints of a school district, or geographic locale, have not yet been tapped. This study proposes one mechanism for doing just that given the infrastructure present or absent through the use of a web-based Intranet. This model offers a "get your feet wet" method of networked connectivity for classrooms and teachers who have not yet jumped into the world-wide web.

This research provides a study in contextualizing connectivity with end goals of improved problem-solving and metacognitive reflection. Both of these elements are often lost when initial attempts to jump into networked learning occur or are contemplated. Further, this study provides an avenue of documenting the nature of learning during the use of web browsing or other networked connections. Tracking learner movements within a browsed website has metacognitive as well as problem-solving implications for each and every learner.

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The Effect of a Shared, Intranet Science Learning Environment on Academic Behaviors

Mary Jo Parker, Ed.D., Baylor University;
Science Department Chair-Caney Creek High School in Conroe ISD, Texas, USA
Email: Parker83@earthlink.net maparker@conroe.isd.tenet.edu

Abstract: As technology continues to make its way into daily classroom use throughout all disciplines and across all grade levels, the question of its impact and effectiveness is heard in rising crescendo. This study investigated the effects of a shared, Intranet science interactive learning environment on the academic behaviors of problem-solving and metacognitive reflection. Results indicate that learning behaviors within science web-based environments provide support for this learning environment model.

1. Introduction and Rationale

As the Intranet is introduced into the learning environment comprising the classroom today, the effects of this technology must be investigated. Technology offers opportunity to affect academic behaviors such as problem-solving ability and metacognitive reflection.

As technology creates a virtual classroom environment as it moves to a web-based space, research must be conducted to determine the effectiveness of geographically unrestricted, collaborative problem-solving (Jacobsen and Levin, 1993). This type of collaboration becomes possible when the learning environment is placed on a web of computers, thereby facilitating access by many to the same place on the Intranet.

As students use the collaborative capabilities of a networked Intranet learning environment, thinking about their own thinking evolves, thereby increasing the opportunity to clarify misconceptions of knowledge, procedural or declarative. The science classroom presents one opportunity to study the effects of a shared, Intranet environment on student problem-solving ability and metacognitive reflection skills.

The purpose of this study was to investigate the effectiveness of a shared, Intranet learning environment on problem-solving ability and reflective metacognition on 9th-10th grade biology students. Should any gender differences emerge within this shared, Intranet environment arise, they were studied.

2. Research Questions

1. Will the use of a shared, Intranet environment improve learner problem-solving ability in science as measured by pre- and posttesting?
2. Will the use of a shared, Intranet environment increase learner metacognitive reflection as measured by use of pre- and posttest visual learning software (Inspiration) as measured by a) number of concepts used, 2) number of concept links used, and 3) number of concept nodes used to determine changes in learner thinking patterns, and by web-based Course Info software tracking capabilities within a threaded discussion site and?

3. Will gender differences emerge with the use of a shared, Intranet environment in the science area as determined from pre- and posttest scores measuring problem-solving ability and metacognitive reflection?

3. Methodology

Subjects: Subjects for this study were first time 9th and 10th grade biology students from three public education high schools in the Conroe ISD within Conroe, Texas. The sample (n) contained 78 students of the 1400 students enrolled in Biology I courses. Two classes from each school were selected and randomly assigned to a control class and a treatment class. Selected campuses operated on an A-B, 90-minute class alternating block schedule. Classes operating on this type of schedule met certain classes three (3) days per week and two (2) days per week alternating every other week. The sample population included male and female subjects.
Technology: Groups assigned to treatment groups received access to technology. This technology included MacIntosh platform computer labs or classroom computers. All treatment groups accessed minimally 6 computers and maximally 10.

Scanners, digital cameras, and Internet-connected computers, and laser printers rounded out the technology utilized by the treatment groups. Software access included Apple QuickTake PhotoNow software, HP scanning software, MS Office, Netscape Navigator Gold 3.0, and Inspiration 4.0.
Ecology Curriculum: To limit any physical risk each teacher at selected campuses will receive an Adopt-a-Ditch ecology curriculum (Stone and Myers, 1994). The researcher provided training for all curriculum lessons, use of the LaMotte Freshwater Testing Kits, web-based database, and administration of all pre and posttesting instruments. Intentional Intranet discussion forum topics were generated by teachers and the researcher during the training sessions. Spontaneously generated forum topics were noted as the researcher analyzes collected data within the web-based learning environment.
Teacher Training: Training occurred over a three day time period for 2 hours each day. An additional 1.5 hrs. of on-site training session ended the teacher training sessions. All training occurred prior to research initiation. Each teacher received complimentary computer diskettes upon completion of each training session.

Technology training consisted of instruction and practice in the use of the CourseInfo Intranet simulation software (Blackboard, Inc., 1998) Inspiration (Inspiration Software, Inc., 1994) uploading and downloading files via the Internet, digital camera use and downloading of images, use EXCEL spreadsheet/graphical capabilities, and use of the Discussion Forum environment.

All teacher training sessions involving the La Motte Freshwater Testing Kit focused on MSDS safety sheets, general safety practices, disposal of used testing solutions, disinfecting procedures following field work, understanding each freshwater test, and practicing testing techniques (LaMotte, Inc). All teachers received a pail of kitty litter for use during the study. This training insured the highest standard of safety would be established by each teacher in the study and maintained for all class sessions where necessitated by the curriculum content.

Training involving discussion and overview of the ecology curriculum document was incorporated into each training day. Both treatment and control version curriculum documents were used in this training.

Instruments: Treatment and Control groups were randomly assigned at each campus by the principal investigator. Both treatment and control groups on each campus were taught by the same teacher. Several instruments were used to discern problem-solving ability and metacognitive reflection both in the treatment and control groups of this study.

Problem-Solving Ability

The Watson-Glasser Critical Thinking Appraisal was used to measure student's problem-solving ability (Psychological Corp., 1990). The Watson-Glasser was selected due to its design to measure certain aspects of critical thinking including 1) the abilities to recognize problems, 2) evaluate evidence cited to support claims for truth, 3) reason inferentially, and 4) apply the preceding to problems. The test included norms for high students that were developed systematically for this grade level. Its reading level was ninth grade and the mental skills it demands were probably above that. The test could be administered in a group setting, and was timed at 40 minutes which "fit" the campus classroom schedule of the treatment and control groups. Validity of the test was more than acceptable when assessing instructional programs. Evidence supports several aspects of the construct validity of the Watson-Glasser instrument. This instrument was used for assessing problem-solving for both the treatment and control groups.

Metacognitive Reflection

Metacognitive reflection was measured through use of student-generated concept maps developed with the visual learning software program Inspiration (Inspiration Software, Inc., 1994). Concept maps were reduced by 1) the number of concept used, 2) the number of concept links used, and 3) the number of concept nodes used. As part of a secondary research question, an evaluative analysis of the CourseInfo software was undertaken. The tracking capabilities of the software CourseInfo were evaluated through measurement of 1) log-ons to the threaded discussions webpage, 2) number of threaded statements, 3) number of threaded dialogue statements of response to other student statements, and 4) number of threaded dialogue statements of response to teacher statements. Analysis of tracking user movement within the shared web-based environment gave some indication of problem-solving and metacognitive reflection abilities within the environment.

4. Findings

In answering the first question [Will the use of a shared, Intranet environment improve learner problem-solving ability in science?], group means indicated no support for problem-solving improvement. While groups did not differ significantly in terms of problem-solving ability, results from t-Test analysis suggested slight movement toward improvement as a result of exposure to the shared Intranet environment. Significant support for increases in problem-solving ability were seen when individual differences, as measured by paired analysis, were employed. When consideration was given to the individual nature of problem-solving ability, these findings indicated even clearer support for the use of collaborative, constructive, and connected technologies in the potential increasing problem-solving abilities. Use of these technologies within the framework of the science classroom because of the problem-based opportunities appears productive and naturalistic. By providing the contextualization for meaningful inquiry meaning-making thrives and re-application of that meaning to new, problematic situations increases. Problem-solving, or critical thinking, within the context of

web-based shared, learning environments strongly indicates additional research be undertaken to further address the learning behavior.

The scrutiny of length of exposure to this environment becomes an important one. Much research supports lengthy time periods of exposure to shared learning environments as methods connected to increased problem-solving ability (CSILE, 1989; Ryser, Beeler & McKenzie, 1995). Yet, exceptionally small numbers of studies have been undertaken to discern the effect of compacted time periods focused on increasing problem-solving abilities (Abeygunawardena, 1997). A limitation of this study would appear initially as the short timeframe allotted to the study. However, the timeframe utilized represents the reality of many science approaches currently in use. The findings of this study become more relevant given the design methodology mirroring classroom realities. The significant findings for paired differences should continue to be studied, but should also be taken as potential methods for increasing problem-solving ability. While this study does not address all possible questions of what increases problem-solving ability, it does examine one particular model, that of a shared, Intranet science learning environment. Through this examination results indicate the possibility this environment has as one method for potentially impacting problem-solving ability. As the length of time of the study is considered in concert with problem-solving ability, one continues to ask if something else was at work contributing to this increase in problem-solving ability over this short duration. This query leads to the discussion of research question two.

Data analysis of research question two [Will the use of a shared, Intranet environment increase learner metacognitive reflection as measured by use of pre- and posttest visual learning software as measured by a) number of concepts used, 2) number of concept links used, and 3) number of concept nodes?] indicated significant support for improved metacognitive reflection when measured by number of concepts, number of concept links, but not number of concept nodes used. Use of the visual learning tool accessing the concept maps within the shared, Intranet learning environment improved the amount of reflective thinking in which learners engaged at significant levels. Both group means and paired analyses supported changes in metacognitive reflection at significant levels.

The power of metacognitive reflection has been well-documented (Jonassen, 1996). The construction of individual representations allows learners to monitor and facilitate their own problem-solving (Gordon, 1996). The process of metacognitive reflection appears to become inextricably connected to problem-solving ability. Add to this process the multiplicative power afforded by a shared, Intranet learning environment and the element of time, as linked to improvement at individual levels of problem-solving, appear to become compacted. The results of this study robustly support the use of visual learning software (concept mapping tools) within a shared, Intranet learning environment to improve not only metacognitive reflection, and thusly problem-solving ability in a less direct way.

The robust results of improvement of metacognitive reflection within the shared, Intranet learning environment and the interwoven connection to problem-solving ability seem to suggest a model for the improvement of problem-solving ability within shorter timeframe constraints. Further research seems warranted, as well as worthwhile.

In addressing research question three [Will gender differences emerge with the use of a shared, Intranet environment in science for the academic behaviors of problem-solving ability and metacognitive reflection?] Analysis of gender differences in problem-solving ability and metacognitive reflection indicated no levels of significant differences. Group means and paired analyses for problem-solving ability and metacognitive reflection showed no differences with the

shared, technology-supported science setting. At first glance these findings shape themselves as contradictory to landmark gender studies (Bailey et.al., 1992). However, when the shared, Intranet environment is scrutinized, a cooperative and collaborative nature reveals itself. Environments of this type seem to appeal, and rank high, with the feminine gender(Miller, Chaika & Groppe, 1996). The lack of significant gender differences in problem-solving and metacognitive reflection resulting from the shared, Intranet learning environment strongly suggests an equalizing effect (Loyd and Gressard, 1989). This shared technology-supported learning environment may pose one model which science classrooms can use to create equal opportunity in scientific endeavor for both genders. At the very least the lack of any significant differences as a result of the environment presents potential for a model of improvement of problem-solving ability and metacognitive reflection which crosses all boundaries of gender.

5. Future Implications

The results of this study present one practical model for infusing technology into the classroom setting, for improving problem-solving ability and metacognitive reflection over a short duration, for creating a collaborative, cooperative learning space, and for maintaining a science space for learning where no gender differences arise.

The power an Intranet offers within the constraints of a school district, or geographic locale, have not yet been tapped. This study proposes one mechanism for doing just that given the infrastructure present or absent through the use of a web-based Intranet. This model offers a "get your feet wet" method of networked connectivity for classrooms and teachers who have not yet jumped into the world-wide web.

This research provides a study in contextualizing connectivity with end goals of improved problem-solving and metacognitive reflection. Both of these elements are often lost when initial attempts to jump into networked learning occur or are contemplated. Further, this study provides an avenue of documenting the nature of learning during the use of web browsing or other networked connections. Tracking learner movements within a browsed website has metacognitive as well as problem-solving implications for each and every learner.

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Making It Work For You - Problem Based Learning Approaches In Undergraduate Science Courses

Dr. Preetha Ram,
pram@emory.edu, Chemistry Department, Emory University, Atlanta, GA.

Abstract: Problem-based learning (PBL) is a pedagogical approach based on recent advances in cognitive science research on human learning. This paper describes the application of PBL in undergraduate courses and discusses the specific needs of this environment: the process, the role of the facilitator, the role of the problem, evaluation of the course, specific information about our implementation at Emory in an undergraduate science course, and guidelines for educators to design a problem for their own curriculum. This paper also describes the pivotal role played by LearnLink, university wide computer network system used extensively by our students.

Introduction

Problem based and project based approaches have always been popular themes in education and especially relevant to science education (Dods, 1996, Hughes, 1996) Recently, there has been a resurgence of interest in these pedagogies for the emphasis they place on scientific inquiry, problem solving and collaborative learning. *Shaping the Future*, a recent NSF document stresses the importance of these three principles in education by stating in the vision statement, *" It is important to assist them (students) to learn not only science facts but, just as important, the methods and processes of research, what scientists and engineers do, how to make informed judgments about technical matters, and how to communicate and work in teams to solve complex problems. "* (NSF, 1996) Project and problem based learning courses aim to achieve just that.

Problem-based learning (PBL) is a pedagogical approach based on recent advances in cognitive science research on human learning (Brown et al, 1989, Hmelo et al, 1994, Williams, 1993,Savery & Duffy, 1995). PBL has been used in medical schools for many years and is recently gaining ground in K-12 and undergraduate curricula (Barrows, 1988, Bras, et al, 1995). This pedagogy offers the promise of increasing student motivation and student interest and provides an opportunity for students to develop an in-depth knowledge of a subject, while acquiring valuable problem solving skills. Many educators are tempted, but are either wary of the time demands or by their lack of experience in the area. Most educators who are inclined to try PBL must also do so by themselves, as loners, since few institutions have system wide PBL initiatives such as at the University of Delaware (http://www.udel.edu/pbl/). We will discuss survival strategies for such isolated educators.

The PBL classroom

In a PBL classroom, students learn in the context of a problem to be solved. The responsibility of learning is with the students not with the facilitator. There are five well-defined stages in the PBL process- Introduction, Inquiry, Self Directed Study, Revisiting the Hypotheses and Self Evaluation (Barrows, 1988).

In the *Introduction Stage*, students are presented with a problem that gives them a well-defined role to adopt. In the *Inquiry Stage,* the facilitator guides the inquiry process so that students elicit data about the problem, look for additional information in the materials provided (the *Inquiry Materials*), and write down the topics that they need to look up (the *Learning Issues*). The facilitator demonstrates how to organize the problem-solving process into distinct steps. The information generated in the discussion is entered in one of four categories *Facts*, *Hypotheses (Ideas)*, *Learning Issues* and *Action Plan*. At the end of the first session, students commit to one of the many hypotheses and select Learning Issues that they will pursue independently. Having committed to a hypothesis and chosen learning issues, students look up information from different sources - with some initial guidance, in the *Self Directed Study Stage*. After their self-directed study, students evaluate the resources they used and share information with their colleagues during the *Revisiting the Hypotheses Stage*. They reconsider their hypotheses with the benefit of the new information they have gathered as they try to solve the problem. Finally, during the *Self*

Evaluation Stage, students are asked to evaluate their efforts and their groupmates' efforts as - problem solvers, as self directed learners and as members of a group and discuss these evaluations with the group. The instructor acts as a facilitator of the process, listening to the discussion, probing their understanding, interceding appropriately when they proceed to apply their science knowledge and modeling the problem-solving process.

PBL and Curriculum Design

It is important to ensure that the problem satisfies the curricular goals of the course and that the course fits within the curricular framework of the undergraduate program. Courses in an undergraduate curriculum build on strengths achieved in previous years and need to advance student's knowledge so that they can advance to higher level courses. PBL courses have to fit into this continuum and accomplish the required coverage of material expected of the course. We have found it useful to adopt a technique used by Barrows *et al* where we start by compiling a detailed listing of the topics of the syllabus (Barrows, 1985). In a table format, we then list the components of the problem(s) we have tentatively chosen and examine these components to see if they would involve coverage of the syllabus topics. This matrix or table, then indicates the efficiency of our problem, which topics in the curriculum can be covered by using this problem, which topics are repeated, which topics are not covered etc. The instructor would design or choose a problem, in which most topics of the syllabus would be encountered by the students. For example, our problem on water quality analysis provides our students with opportunities to learn about many different aspects of analytical chemistry. A problem about a patient in a diabetic coma provides rich material for a physiology course. During the semester, we periodically revisit the matrix to keep track of the coverage of the syllabus topics. This matrix can also be an effective tool to convince others of the coverage of curricular topics in the course.

Designing a PBL problem

In PBL classrooms, the choice of problem determines the probability of success of this pedagogy. The premise of PBL is this: if we give students a challenging task that engages them, they will learn to solve problems and they will learn the associated knowledge in order to solve the particular problem at hand. Their learning will be deeper and more meaningful and will last longer since it is knowledge that they have constructed themselves within a context, and in response to a need (Schank *et al*, 1993, Bransford *et al* 1986; Brown *et al*, 1989). However, this presupposes designing a task or a problem that will engage the entire class and also satisfy the curricular needs. Barrows and others have developed a strategy for ensuring the success of the PBL process (Barrows, 1996). The design of a problem involves choosing an authentic, real-world situation that the students are able to see as a genuine problem. PBL problems must (1) be based in compelling, real-world situations (2) generate multiple hypotheses (3) exercise problem-solving skills and require creative thinking (4) require knowledge and skills that satisfy curricular objectives (5) be integrated and contain components of more than one discipline.

A central issue in problem design is the question of authenticity. What appears authentic to the instructor may not always be authentic for the students (Brown *et al*, 1989, Ng, & Bereiter, 1991). There is undoubtedly some risk in this venture - some of our problems have fallen flat - with very little student enthusiasm. Some insight into student's backgrounds and interests is highly recommended. There is a growing body or literature regarding the importance of student's backgrounds in their perceptions of authenticity and the resultant interest in the course. We recommend choosing some issue or topic that is of local interest, or is newsworthy. In our PBL workshops we always start with a brainstorming session, with colleagues or students, to generate ideas for problems (Ram, 1996).

Once a suitably compelling problem has been chosen, it is important to bring the problem home to the students, to engage and excite them, through the use of simulations, videos, newspaper or popular magazine articles, dramatization, and so on. It is also important that the students identify with the problem. This issue relates to the earlier discussion of authenticity. The problem also has to have a clearly defined role for the students to adopt. Our forensics problem puts them in the role of a criminal investigator. The problem statement should also specify the deliverables. This is what they are expected to turn in at the end of the course. These project outcomes should be chosen with the class or curricular need in mind and should also appear to be a natural outcome of the problem itself. For example, if writing skills are one of the goals of the course, written reports would be very appropriate. Lab demonstrations, presenting a case to the mock jury, staging a play, writing a handbook, designing an experiment - are all examples of different deliverables.

Implementation at Emory University

At Emory, we have used PBL effectively in chemistry courses, both lecture and labs. Student enrollment has been as high as 60 in a lecture course. Instructors in other departments at Emory are also involved in the use of PBL in their courses. Here we describe our implementation in the chemistry department. In one lab course, students worked with a voluntary environmental advocacy group, the Upper Chattahoochee RiverKeeper, to monitor the quality of water in the Chattahoochee river watershed. Students learned experimental analytical chemistry techniques and problem solving skills in order to help the organization monitor pollutants (Ram, 1999). In another version of the course, students worked as mentors for elementary, middle school and high school children involved in water quality monitoring. They accompanied school children on their water sampling trips, trained them to use the test kits and helped them gain an understanding of the science behind the tests. They would perform water quality tests using advanced instrumentation and EPA techniques in the lab and would provide some feedback to the school children about their data. A different implementation of PBL has involved forensics - students work as forensic chemists to unravel a murder mystery. They are presented with a simulation of the murder, clues to analyze and characters to interview.

In general, students meet for one hour sessions per week for the PBL discussions. They explore the problem, define the facts, decide on the learning issues and in subsequent sessions discuss the experiments and their results as the semester progresses. Depending on the problem they are working on, the nature of these discussions and the tasks they perform varies. They may have a deadline for a report that they have to give the RiverKeeper or a demonstration to arrange for their school. They may be trying to solve the case with the evidence they have collected or may be interviewing "suspects" that they have identified. They also meet for three additional hours to perform the lab. They are expected to spend at least two to three hours a week on self study, posting messages on LearnLink or writing lab reports.

We provide students with three different kinds of logs or worksheets. One is the PBL worksheet where they keep track of facts, ideas and learning issues. At each session, one student is assigned to put this information on the board and one student records it on paper which is then copied and distributed to all. Another sheet is an individual log of their self study – it keeps track of the their assigned learning issues, the topics they researched, the sources they used, their rating of the sources they used. If students used the net to research a topic, they were required to rate their satisfaction with it and to provide evidence that it was a reliable source. The third log is a self evaluation log – where each student is asked to rate themselves as a problem solver, as a member of a group and as a self directed learner. They are also asked to evaluate the other members in the group. We have found that initially students are very reluctant to perform this kind of evaluation. However, as the semester progresses, with the facilitator modeling the self evaluation process, students learn that there is a place for honesty and critical evaluation and they struggle with learning how to critique someone diplomatically. These evaluation logs are then rich sources for the instructor seeking evidences of progress and development.

Ensuring Success

(a) The problem. Most critical to the success of the process is the problem. If the problem is challenging, authentic and involves students naturally in the learning knowledge, then the course is half way to being a successful course. Without engaged, interested and motivated learners, the PBl process deteriorates very rapidly. **(b) The facilitator and the facilitation process.** The PBL process requires the facilitator to model the problem solving process through carefully chosen comments and statements. Students should be encouraged to think for themselves and not to look to the facilitator for answers. This often means that the facilitator has to allow students to voice their misconceptions or identify inadequacies in their knowledge themselves. They should be given an opportunity to learn through the self directed study stage, or by talking to other students or experts. It is highly recommended that educators interested in this pedagogy be trained to facilitate the PBL process by expert facilitators. This style of interaction requires a paradigm shift for both the instructor of the course and the students – both are used to the "sage on the stage" model for the instructor. **(c) Student participation.** When PBL courses are isolated in a nonPBL curriculum, students start out by feeling disoriented and lost. They need a lot of support in the initial stages where they are shown the kind of behavior they are expected to display. The facilitator has to build a safe environment for students to ask questions, to accept inadequacies in their knowledge so they can go to the next step an correct these inadequacies. Students typically are not very good at working in groups. It is therefore essential to start the process with a discussion of group behavior, responsibilities and ethics. Once the facilitator has set up such an environment,

then students will be able to take full advantage of the PBL process. **(d) Evaluation tools and protocols**: There are two levels of evaluation and assessment involved. The instructor of the course needs to evaluate students' learning, growth and development and also to evaluate the success of the PBL problem. Students will of course respond to the style of evaluation being used. So in the early stages of the problem it is important to explain the benchmarks for performance expected of students. We tell our students we expect to see a clear demonstration of growth in problem solving skills, participation in group problem solving, and self study skills through out the semester as well as demonstration of domain knowledge. We assess the first through regular evaluation sessions and logs and the latter by written tests or lab exercises. Our electronic tools have helped us considerably to evaluate the first set of parameters. **(e)PBL support group**. We maintain an online discussion space for educators using PBL – both experts and novices are welcome to post messages, share experiences and ask for help and give help (www.chem.emory.edu/~ram/pbl).

How Can Technology Help This Faculty Intensive Pedagogy?

We have used technology at different stages of the course to aid the PBL process. In the early stages where the problem is presented to the students, additional information about the problem is made available through websites designed for the specific problem. These sites point to reliable sources of information and can provide guidance that is very valuable in the initial stages. This initial guidance, often termed scaffolding, orients the students in the problem domain (Wood *et al*, 1976, Guzdial *et al*, 1996). We can provide information, in our course, about experimental techniques, instrument procedures etc. Links to reliable sites with useful information, the government EPA sites, newspaper articles etc. can also help increase the authenticity of the problem.

In the next stage, through electronic bulletin boards or interactive web sites, students in large classes can conduct online discussions to augment their classroom interactions. Students quickly adapt to this method of communication and use their online discussion groups to share information and post the results of their literary searches. We require students to share the results of their self study and literary searches with the class through these postings. We encourage students to respond to postings, ask for explanations and reply to questions, critically and scientifically. Students are therefore given an opportunity to put their thoughts in writing and also to interact with their colleagues in a professional manner. The bulletin board finally becomes the online notes for the class - a compendium of material unearthed by the class during the problem solving process. During this, the role of the facilitator is to read the messages, assess the extent of coverage of a particular topic, record instances of transfer of information etc and guide the discussion in a fruitful way. For example, if a student has provided only a superficial summary of their topic, less than expected by the syllabus of the course, then the facilitator could post a follow-up question- if other students have not already done so. It is again important for the facilitator to not take control of the on-line discussion - just as in class, but to encourage students to express themselves and to respond to posts - in a timely and responsible manner.

In the final and evaluative stage, electronic discussion boards are invaluable because they document progress in student development, learning and problem solving skills. In our experience, students used these discussion groups not only to communicate information, but also to talk to one another in an informal manner. These student exchanges are difficult to capture -without taping all the discussion sessions. We were able to gather much material through these online discussions. We noticed that our students were frank and honest and many of them preferred this medium of communication over talking in class! We have always encountered students who were quiet in class but who posted well researched, well written messages. We would then use these messages to draw out these students in class by asking them to read from their posting.

We list a few other examples of how our electronic bulletin board helped the PBL process and helped us evaluate the students and the course itself.

(a) Development of responsibility: Students took on the responsibility of the problem and the accountability that was involved. They would post messages to organize meetings on weekends and during the Thanksgiving break so they could spend time working on the problem. They contacted the teaching assistants to organize the supplies for the labs and training sessions on the equipment.

(b) Development of scientific approach and organizational skills: Students posted questions asking demonstrating curiosity about the scientific principles of the problem. They emailed other faculty in related fields (physics and geology) to get further information. They searched internet sites to obtain useful and up-to-date information. This information was shared with everyone in the group and easily accessible.

(c) Development of a group feeling: Students learned to work as a part of a collaborative group. They developed a feeling of responsibility to the group and learned to work out interpersonal dynamics. We saw

postings where students would apologize for failing to show up for meetings with their group mates or for inadequate literature searches. We noted postings where students offered to help some one out in the lab and where some one asked for help. Students showed a willingness to collaborate and share knowledge with group and learned to deal with group problems in a constructive way. For example, one student, realized that they were not working quite as much as their groupmates on the project and expressed this in an online message apologizing to the group.

(d) Transfer of knowledge: We were able to document instances where students made connections to previous courses and made connections outside the project to real world issues. They would make comments like, " I know this because I just studied it in my Physics course..." or " I didn't know this, but if you were a child and you drank water with so much nitrates in it, you would be pretty sick ..." Some times, students emailed Instructors of other courses, and involve them in the discussion by referring to course material that they had encountered in that course.

Finally, with new interactive web technology, it has become possible to offer the problem on-line. Students are given information about a problem in stages. They are expected to learn more about the problem and are given a few topics to narrow their searches. At the end of their learning period they submit information they have learned to the web-site, so others in the class can view their results. Only then are they allowed to access further information about the problem. This approach, using interactive web technology, allows the instructor to offer PBL units to a much larger class.

Conclusion

Problem based learning is a powerful technique to teach problem solving skills to undergraduates while keeping them motivated to learn. PBL courses in science disciplines can also help students learn to think about underlying scientific principles and help students see science from an integrated perspective through the use of integrated, authentic problems. Typically, PBL has not been very easy to implement in undergraduate curricula for many reasons. Use of technology, multimedia, electronic bulletin boards, web-sites and web based discussion groups can help educators interested in developing PBL courses in many ways - in the delivery of the problem, in assisting students in the early stages by providing them with helpful information, in promoting collaborations, in larger enrollment courses and finally by helping instructors evaluate students and the effectiveness of the course.

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Semi-Quantitative Computer Modelling and Classroom Science

F. F. Sampaio
Nucleo de Computação Eletronica da Universidade Federal do Rio de Janeiro - Brazil (ffs@nce.ufrj.br)
A. C. Kurtz dos Santos
Depto. de Física - Fundação Universidade do Rio Grande - Brazil (askurtz@ufpel.tche.br)
L. Ferracioli
Depto. de Física - Universidade Federal do Espirito Santo - Brazil (laercio@npd.ufes.br)

Abstract: This paper discusses some ideas about the importance of using computer modelling in Science classes from a perspective of System Dynamics and presents two different semi-quantitative computer modelling systems (called WLinkIt and VISQ) and some work with students in Brazil using VISQ.

Introduction

A model is a "new" world that someone constructs to represent things from our world (or an imaginary one). Normally these models represent a simplification of the modelled world and we can interact with them to explore and understand how things work both in the model world and, perhaps, also in the modelled world. In this way models (and computer modelling) have an important role in the process of understanding Science, not only giving students the opportunity to develop some cognitive abilities such as formulating and testing hypothesis, idealisiation and abstraction, but also recognizing the structural and functional similarities between different dynamic structures and processes such as the water cycle and homeostatic system, a leaky tank and radioactive decay among others.

However, our teachers almost never use this tool in the process of teaching-learning science. Some factors can contribute to this situation: Tearchers are not well prepared to use this idea; lack of adequate tools for school; students do not have the necessary mathematical background to work with these ideas.

A possible way to start using these ideas in schools is to combine more user-friendly computer modelling systems which do not demand too much formal mathematical knowledge from the students, together with an educational approach where students can work with "real" problems (which make sense for them) and a methodology that facilitates the introduction of concepts and ideas about modelling.

From our perspective this can be made possible by combining semi-quantitative computer modelling tools, work with real problems that are part of the daily lives of our students and the System Dynamics approach (Forrester, 1968) including causal-loop diagrams (Roberts, 1983) as a methodology to construct, simulate and reason about models and the modelling process.

The System Dynamics Approach

The System Dynamics approach (SD) can be seen as a new way of understanding dynamical phenomena (natural, phisical, biological, etc) that occur in our daily lives taking into consideration not only single pairs of cause-effect variables, but the functionning of the system as a whole (Forrester, 92b; Mandinach & Cline, 94; Kurtz dos Santos, 95; Sampaio, 98).

From an educational perspective, the undersdtanding and application of these concepts give to the students the possiblity of understanding complex dynamic systems developing ideas about <u>*how*</u> and <u>*why*</u> these systems evolve with time (Roberts, 83; CC-STADUS,98)

WLinkIt - A Semi-Quantitative Computer Modelling Tool

WLinkIt is representative of a category of computer based modelling systems called *semi-quantitative* systems (Mellar et al. , 94). The system can be used to represent causal relationships between objects and/or events of a certain domain. The vocabulary used in its environment tries to correspond well to intuitive or common-sense ways of talking about systems.

The construction of a model with WLinkIt is made through the use of a direct-manipulation interface using a graph metaphor to define the objects and relationship of a certain model. In most cases these objects can be used by the modeller to represent some aspects of the world to be modelled such as the level of pollution of a city, its main causes and its consequence on the health of the population of that city (See Figure 1).

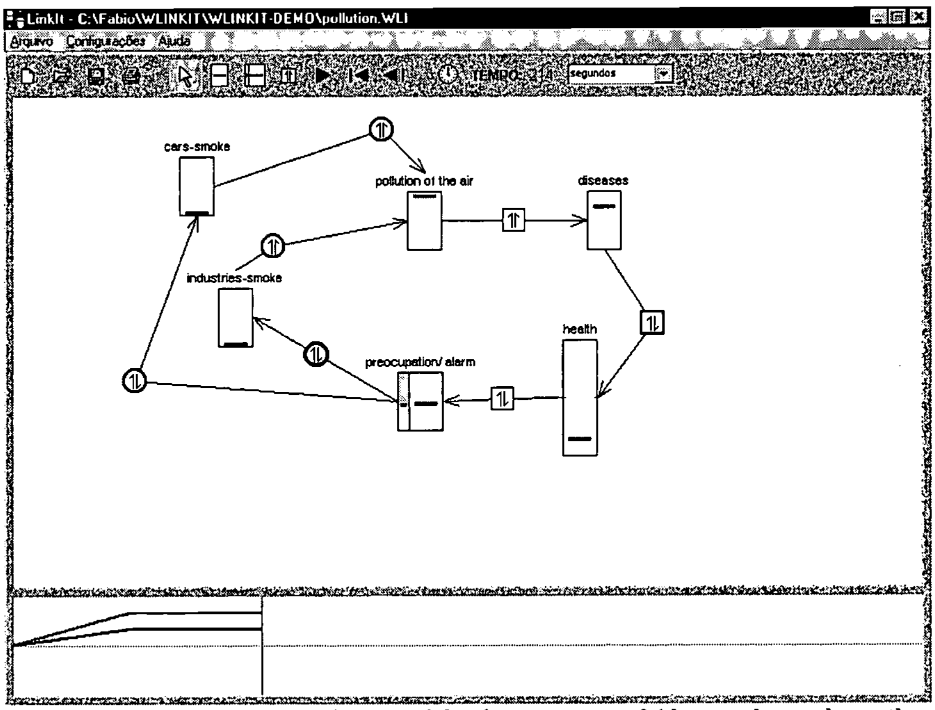


Figure 1: LinkIt's window with a model being constructed (the graph are shows the variables *pollution of the air* and *diseases*)

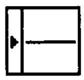
The central idea with this style of interface is to try to focus the attention of the user on the objects and actions of interest, replacing, for instance, a command-based interface where the operations are made through a more artificial and indirect process (Shneiderman, 1992).

To create a model with WLinkIt, the user has to define the variables and relationships and attach to them some characteristics that reflect the functional aspects of the objects and events being modelled. The system, in its turn, is responsible for running the model. In order to do so, it executes two steps: First it has to choose a set of mathematical equations (always hidden from the user) - based on the characteristics of the variables and relationships already created - that will control the behaviour of the model. Second, it makes the model evolve over time through the calculation and iteration of these equations. During this process of running the model, the user receives visual feedback from the system, seeing changes in some physical aspects of the objects on the screen.

WLinkIt Elements

LinkIt has two main system-objects: variable and link. Object-variables are presented to the user as a box (called variable-box) containing one or two level bars inside it. This type of object can be of two forms:

Smooth variables can bc used to represent any factor about a problem someone wants to model. They are shown on the screen as a rectangular box with a horizontal amount level indicator in the middle (ex: variable *pollution* in Figure 1). They can be of two different range: [0, +1] (ex . *pollution*) and [-1, +1] (ex. *health*). These two ranges combined with the visualization of the amount level on the screen, permit the representation of positive and negative values or more qualitative ideas such as above or below the "normal" level.

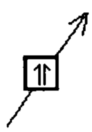


On/Off variables can be seen as a special case of Smooth variables. They serve to represent conditional factors that can control the behaviour of dependent variables. Their box is divided into two parts. The left part contains a threshold level indicator (a small triangle) used to define when the variable will trigger and the other part of the box contains the amount level indicator. Both of them can be moved by the user independently. (ex: variable *preocupation/alarm* in Figure 1).

When a variable is created its default range is set to 'positive only' values. If the user changes it to 'any value' (through the Information box of the variable), the height of the variable box doubles (ex: variable *health* in Figure 1) and all links that arrive or depart from it are redrawn to fit the new size of the box.

The resting level (internal value = 0) of an 'any value' variable is indicated by two small dots located on the left and right side of the box.

Links are used to connect variables and define a causal relationship between them. Basically the system provides two different types of links:



Go together links are used to define relationships where the value of the affected factor is immediately calculated based on the value of the causal factor. Mathematically it serves to represent relationships of the kind $y = a * x$, where a is a constant that can be modified by the user. The value of a is visually represented in the model by the sign showed inside the square box in the middle of a link (e.g. according to Figure 1 $disease = +1 * pollution$ and $health = -1 * disease$).

Gradual (or *cumulative*) links are used to define relationships where the value of the causal factor can be seen as a rate of change of the dependent factor. Mathematically it serves to represent relationships of the kind $y(t+1) = y(t) + a * x$, which is a discrete time step approximation of the linear differential equation $dy / dt = a * x$, where a is a constant that can be modified by the user. The value of a is visually represented in the model by the sign showed inside the circle box in the middle of a link (e.g. according to Figure 1 $pollution(t+1) = pollution(t) + 1 * car\text{-}smoke$ and $industries\text{-}smoke(t+1) = industries\text{-}smoke(t) -2 * preocupation\text{-}alarm$)

Also the links that arrive at a certain variable (called input combination) can be combined in one of three different forms: they can be summed up (or subtracted if an opposite link is used), multiplied (or divided if an opposite link is used) and averaged.

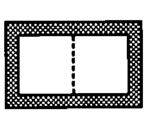
All of these different types of variables with their different input combinations and links with their different direction of effect and strength, permits the system to model, in a very accurate way, a wide range of problems that are part of the science curriculum of our schools.

VISQ - A Semi-Quantitative Computer Modelling Tool

Like WLinkIt, VISQ uses the neural networks mathematics to run causal diagrams on the computer screen, givng a systematic interpretation to any causal diagram. In a certain way this system can be seen as a simplification of WLinkIt, where only gradual (cumulative) relationships and smooth variables are possible.

VISQ allows the creation of semi-quantitative models regardless of content, both in human and natural sciences.

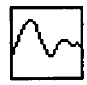
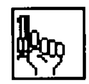
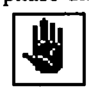
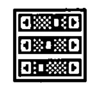
The main window of the program (see figure 2) shows the icons which are the program functions. To make a model the user has to use them, as explained below.



This icon represents a variable or a constant. It has an amount level indicator that can move in the left-right direction to represent semi-quantitative values.

 Positive and negative icons which represent the links that connect the boxes. Mathematically they serve to represent relationships of the kind $y(t+1) = y(t) + a * x$, which is a discrete time step approximation of the linear differential equation $dy / dt = a * x$, where a is a constant (weight and sign of the link) that can be modified by the user.

All other direct manipulated functions needed to construct and simulate a model are available:

 To change the name of a selected variable;  To isolate one variable to observe what happens without it;  To delete a box or a link and reset the model;  To observe graphs of temporal evolution of any variable and phase diagram of a variable against the other;  To run a model and also its associated graphical window;  To stop a simulation and a graph presentation;  To change speed, damping, time interval and scales of graphs;  To give semi-quantitative initial values of dependent and independent variables of a model.

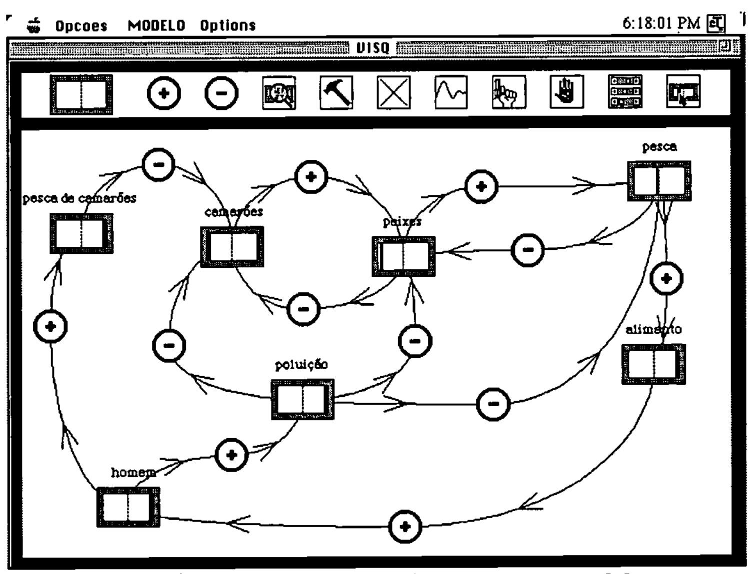


Figure 2 - VISQ main screen with the tools and a model.

Students Modelling Environmental Issues

Teachers at Fundação Universidade do Rio Grande - Rio Grande city in the southern of Brazil - are developing a project which aims to improve the standard of Science Education in primary public schools through the use of computer modelling computer. A first subject chosen was Environmental Education mainly because it is not very well discussed in our classrooms and its practice motivates an intense exercise of citizenship.

The Sample

The project worked with 16 (11 to 18 years old) students. Each student worked, once in a week, in four meetings of 3 hours each using the computer. These students have never worked with a computer before.

The tasks

An instructional material was developed and tested with primary school students in some topics. The modelling tasks were preceded by comic strips and texts strongly related to the students' reality.

The first task was presented by a comic strip of a child that should take a shower and keep clean. The second was also a comic strip of a little Indian that is trying to fish in a polluted river without fish because of a polluter monster which is a plant. This comic strip is followed by a text about "pollution in our industrial city" taken from a local newspaper. There are also two activities one presented by an "ecological poem" and the other about "bats". The final activities were presented by texts also taken from local newspapers about "recycling litter", "Rats population explosion" and "Fishing of irregular size prawn in Southern Brazil".

Analysis of the tasks

The framework for the analysis of students' work considered four dimensions: (1) the nature of the entities invoked; (2) the nature and status of the links used; (3) the final structure of the VISQ model and (4) the model's coherence and the process of model building. Some relevant results of the analysis are presented below.

- In general students developed models composed mainly of variables with very few "other" (events/processes and doubtful)[1].
- Causal links used were mainly reasonable, being followed by a low number of reasonable associations. Unreasonable causal links and unreasonable associations were rare[2].
- A further analysis showed that events/processes, objects and doubtful entities tended to make part of unreasonable causal links and associations. Chains were used mainly with reasonable causal associations and variables were used mainly with reasonable causal pairs and feedback loops.
- In general students have used at least one feedback loop in any of the tasks, which is considered a positive aspect.
- The models constructed tended to be coherent for all tasks, with more than half of the students building fully coherent models in all tasks.

Conclusion

The work presented here with VISQ and other previous studies with WLinkIt (not discussed here) using the System Dynamics approach, suggest that students were capable of engaging in system thinking.
We hypothesize that the students is able of *system thinking* when : (1) s/he uses variables in reasonable causal links, in fully coherent models with at least one feedback loop and/or (2) during the building of the model, they have to ask for simultaneous graphs of variables, using the graphical outputs to improve the model structure, reach a reasonable level of discussion of the situation studied, and relate the model to reality.

While observing the model running on the computer screen, students discussed and came to their own conclusions. Such interactions promoted a better understanding of the situations studied, as well as the critical thinking about environmental issues.

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[1] Examples of *other* (events/processes and doubtful) and *objects* are: angry, friend, beautiful, river, boot, monster, nature, sewer, cities, seas and planting.

[2] Examples of *unreasonable* causal links are: fishes increases prawn; health decreases people; trees increase pollution; litter decreases recycling; fishing decreases fisherman; population decreases litter and litter decreases rats. Examples of *reasonable associations* are: fox increases grass; leopard increases grass; sewer increase litter; recycling increases money and cleaning increases love. Examples of *unreasonable associations* are: seas decreases prawns; seas decreases fishes; man increases indian and litter increases boots.

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A Virtual World for Earth Science Education in Secondary and Post-Secondary Environments: The Geology Explorer

Donald P. Schwert[1], Brian M. Slator[2], Bernhardt Saini-Eidukat[1]
Departments of Geosciences[1] and Computer Science[2]
North Dakota State University
United States
schwert@plains.nodak.edu
slator@badlands.nodak.edu
sainieid@badlands.nodak.edu

Abstract: The Geology Explorer is an educational research project that implements a virtual world for geologic exploration. Students "land" on Planet Oit: a synthetic, multi-user space where they practice being geologists in a role-based 'learn by doing' environment. Working individually, or with each other, students learn fundamental concepts of geology and strategies for deductive problem solving through their experiences in the exploratory environment. This pedagogical approach gives students an authentic experience that includes elements of practical, field-oriented expedition planning and decision making, while introducing them to discipline content.

Introduction

By its nature, geology is perhaps the most visual of all sciences. Geologists use the sense of sight to navigate in a spatial world, exploring earth surfaces of considerable diversity and relief while viewing minerals, rocks, and other natural objects of variable color, texture, and luster. To be a geologist, one uses vision to draw maps, to navigate with a compass, to describe terrains, to interpret earth process by landform evolution, and to read instruments of all levels of sophistication.

Aside from vision, other senses are involved. Touch is used by rocks to describe the texture of rocks and minerals. Taste is used to detect the presence of specific minerals. Sound is used to detect certain properties of rocks. Smell is used to detect certain chemical components in minerals and rocks.

Thus, it can be argued that it's in the field that the primary training of geologists occurs. Here, students can synthesize the science by using all of their senses to analyze a complex, colorful, and multi-dimensional world. Students both work and compete with each other, as they learn how to think, act, and react as geologists and as they apply basic principles of the scientific method to observations and measurements of objects and processes.

At most educational institutions, whether they be secondary or post-secondary, it is impractical to regularly take students into the field and have them individually experience how a geologist makes on-site decisions. However, the student can experience these if placed within a virtual world that emulates reality. This virtual world is a synthetic, role-based environment, in which each student acts as a geologist and is expected to address a series of plausible geologic situations. Within this environment, the student makes decisions similar to those of a "real" geologist, using the senses, tools, and techniques of a geologist.

The experiences provided to the student within this virtual world can be both meaningful and authentic, although some trade-off is required to make it, as well, fun, challenging, and occasionally unpredictable. The goal is to have the student assume the role of a geologist in applying the scientific method to observations and measurements he/she makes in this virtual world. By keeping these experiences structured, albeit loosely, students are self-directed into a "learn by doing" (Dewey, 1900) process patterned on that applied in field-training. The virtual world, itself, can be designed to operate simultaneously at all levels of sophistication,

thus allowing students ranging from 7th grade through college to navigate the world simultaneously, encountering simulated situations relevant to their level of training and expertise.

The Geology Explorer

The Geology Explorer (Saini-Eidukat et al., 1998, Slator et al., 1998) is a game which teaches principles and procedures of geology within a networked, multi-player, simulation-based education environment developed under the supervision of North Dakota State University's World Wide Web Instructional Committee (McClean et al., 1999). Student players of the game undertake geologic investigations of Planet Oit, a mythical planet whose orbit is the same as that of Earth but on the opposite side of the Sun. The first version of the Geology Explorer is text-based; a graphical interface is under development.

Planet Oit is simulated on a MOO ("MUD, Object-Oriented," where MUD stands for "Multi-User Domain"). MUDS are typically text-based electronic meeting places, where players build societies and fantasy environments, and interact with them (Curtis, 1992). Technically, a MUD is a multi-user database and messaging system. The basic components are "rooms" with "exits," "containers," and "players." MUDs support the object management and inter-player messaging that is required for multi-player games, and at the same time they provide a programming language for writing the simulation and customizing the MUD. Because the Geology Explorer is intended to be a platform-independent distance education system, the client software in all cases is based on a Telnet client developed in Java.

Planet Oit is being designed to emulate the geologic features and processes of Earth. The first version is a realistic planetary design, consisting of a single, super-continent composed of roughly 50 "rooms" (Figure 1). The rooms are arranged so as to be both geologically-diverse and coherent. A variety of Earth-like environments, ranging from tropical coastlines to volcanic calderas to glaciated peaks, allow for multiple geologic terrains to be explored. A museum of rocks and minerals is available at the landing site for use as a standard reference collection. Coordination of navigation on the planet is made possible by using directions relative to Earth-like geographic poles.

Implemented, as well, are almost 40 scientific instruments and geologic tools (streak plate, acid bottle, magnet, etc.), nearly 100 different rocks and minerals, and over 200 boulders, veins, and outcrops. Students use a command language, which allows for navigation, communication, and scientific investigation while on the planet. Command verbs dictate the student's application of instruments ("streak," "scratch," "hit," etc.) and senses ("view," "taste," "touch," etc.). Students can communicate, and therefore work, with one another through verbal commands.

Once the layout and artifacts of Planet Oit were implemented, we imposed the "rules of the game" over top. Specifically, we created an environment where students are transported to the planet's surface and acquire a standard set of field instruments. Each student is automatically assigned an initial exploratory goal. The goals are intended to motivate the student into viewing his/her surroundings with a critical eye, as a geologist would. Goals are assigned from a principled set, so as to leverage the role-based elements of the game. In order for a student to achieve a goal (and therefore earn points), he/she must address a multitude of tasks identical to those faced daily by field geologists. These include the selection and use of proper field tools, navigation across the planet to the correct region, and interpretation of the tests that the student applies to the problem. As each goal is satisfactorily completed, the student is automatically assigned new goals requiring progressively higher levels of expertise and decision-making. By practical applications of the scientific method students learn how to think, act, and react as geologists.

In this first version, students are assigned to achieve a minimum of a certain number (let's say, 500) of points in order to meet the minimum expectations of the planetary exercise. Upon achieving these points, the student is "awarded" with an invitation to an end-game scenario: an advanced setting of the game, involving a fanciful integration of geologic investigations with riddle-solving.

Tutoring

A key feature of educational media is the ability to tutor students. On Planet Oit, tutoring is done through unintrusive but proactive software agents. Agents monitor student actions and "visit" a student as the need arises. Tutors give advice, but they do not mandate or insist on student actions, nor do they block or prevent student actions. There are currently two types of tutors implemented, but a third type is planned:

- The equipment tutor detects when a student has failed to acquire equipment necessary to achieving his/her goal. If the student needs certain instruments to perform necessary tests, the equipment tutor remediates on that topic.
- The exploration tutor detects when a student has overlooked a goal in his/her travels. The tutor checks whether the student is leaving a location that might satisfy a goal; i.e. if the goal is to locate kimberlite, and there is kimberlite in the "room" that the student is leaving, the tutor will so inform the student.

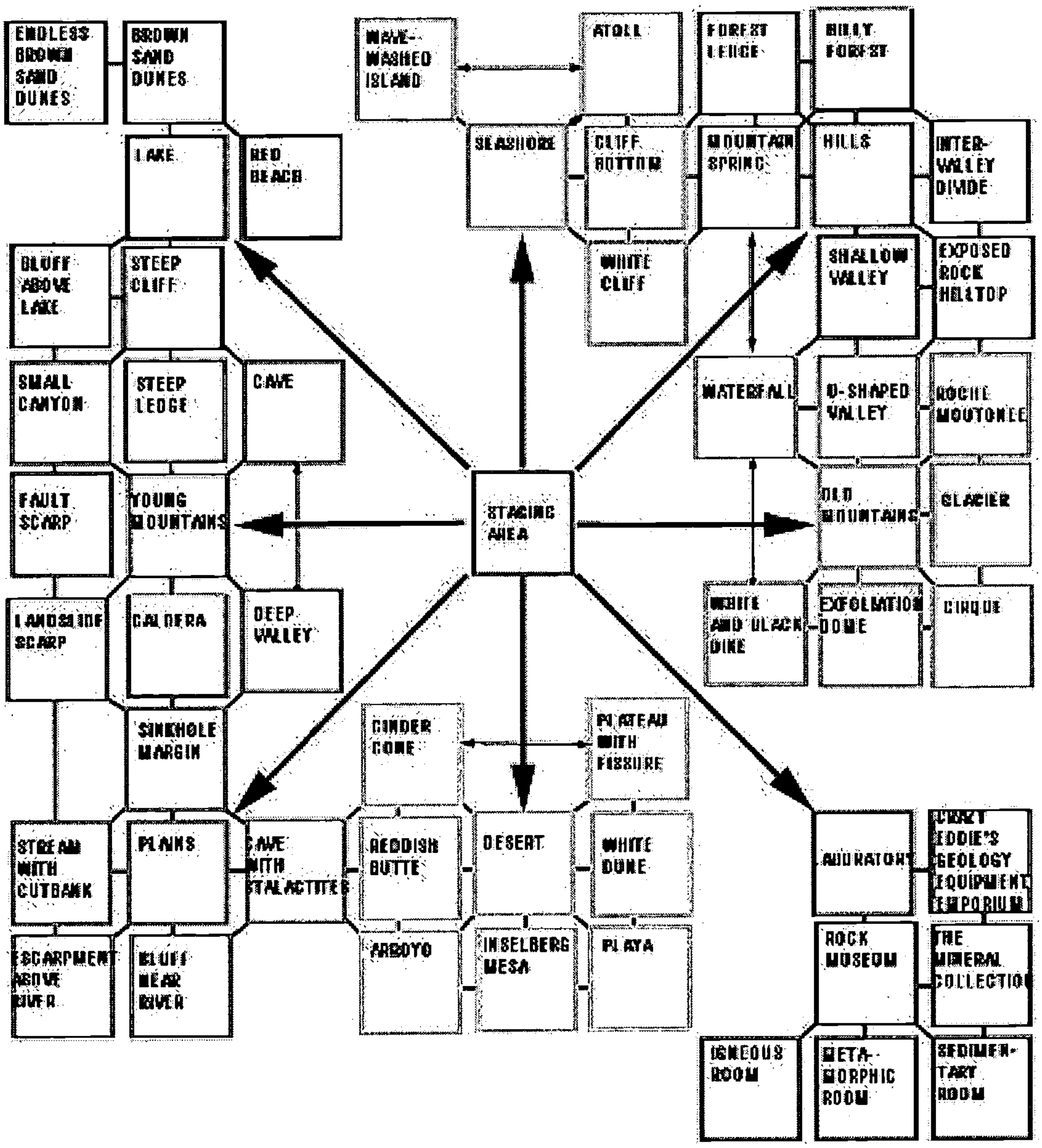

Figure 1. Map of Planet Oit implemented in the text-based version.

- The science tutor will be designed to detect when a student makes an error in his/her analyses; either when a student makes a wrong guess and why (i.e. what evidence is still lacking) or when a student makes a correct guess with insufficient evidence (i.e. a lucky guess).

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Assessment

Developing methods for the assessment of student learning are central elements of our research. The assessment goal is to determine the benefit to students derived from the "learn by doing" experience on the planet. The assessment strategy rejects the notion of standardized multiple choice tests as an adequate instrument in this pedagogical context. While there are, indeed, facts and concepts acquired in the course of exploration which are neatly packageable and testable with objective instruments, the effect on student learning in that arena will not be significant, nor would we expect it to be.

Therefore, the assessment protocol designed for the Geology Explorer is subjective in that it seeks to measure how student thinking is improved. To do this, players are given a subjective, narrative-based survey where they are presented with a short story containing a geologic problem. They are asked to record their impressions and any questions that occur to them, and then they state how they would resolve answering the problem. These surveys are analyzed for the presence of what could be considered "important" geological or problem-solving concepts or procedures.

After the players have experienced an extended exploration of Planet Oit, they are given a similar post-test survey with different but analogous problem-solving scenarios. They are again asked to record their questions and impressions. These surveys are then compared with the pre-test versions to detect any evidence of improved performance. If players now exhibit a better understanding of the problem-solving scenarios, this creates the clear implication that they have learned from the game.

In Fall, 1998, students from a large-section class (approximately 400 students) of Physical Geology at North Dakota State University were invited to participate in the assessment project. Physical Geology is the university's introductory geology course, populated largely by non-science students who enroll to complete their science requirements (in Fall, 1998, none of the course enrollees were declared geology majors). Because the class is so enormous in size, it demonstrates the obvious impracticality of field-training each student to think and behave as a geologist. Approximately half of those students enrolled for Fall, 1998, volunteered for the assessment project.

All volunteers first completed a technology assessment survey, which ranked the entire volunteer corps relative to their computer skills, plus allowed for an equal division of the corps into two groups based on both these skills and gender. Approximately 75 students in one such-ranked group completed the minimum point goal of the Geology Explorer game, plus completed the pre- and post-game scenarios. A second equally-ranked group of students, of approximately the same number, completed a parallel exercise involving interactions with a geophysical database available through the World Wide Web; this group did not participate in Planet Oit, although they likewise were asked to complete an identical set of pre- and post-game exercises. All remaining students in Physical Geology (approximately 200) neither participated in the game nor in the web-based exercise, but nonetheless completed the pre- and post-game scenarios. All of the scenarios are being evaluated to detect any changes among the three groups in relative levels of learning.

Graphical Interface Development

Because of the highly-visual nature of geology, we are implementing a highly graphical and interactive interface to the existing text-based simulation. Despite the arguments of MUD "purists" that the existing text-based game provides a suitably imaginative environment, we remain convinced that graphical visualization of space and objects will enhance both the quality, reality, and pedagogical value of geologic experiences on the planet. For example, the differentiation between hand specimens of quartz (a mineral), chert (a sedimentary rock), obisidian (an igneous rock) requires overly-lengthy descriptions in the text-based version, but becomes instantaneous with the introduction of an image of the specimen.

Thus, currently under development is a graphical user interface where players will be able to: 1) navigate the planet via maps (Figure 2); 2) see authentic landscapes containing boulders and outcrops; 3) see and manipulate tools and instruments; and 4) see themselves and each other. To accomplish this, we are implementing the "rooms" with graphically rendered backgrounds (i.e. an authentic looking drawing of a desert scene), with photographic foreground elements. This approach, called "2 1/2 D" in some circles (as in between 2D and 3D) has the advantage of separating foreground from background, which assists the player in

determining where to direct their attention. Without this separation, there is a danger of the important outcrops being "lost" against a photographic backdrop which might feature spurious outcrops and boulders.

Conclusion

The Geology Explorer is an attempt by geoscience educators to develop educational tools and methods that deliver the principles but also teach important content information in a meaningful way to earth science students.

Figure 2. Map of Planet Oit (see Figure 1), but implemented in the graphical-based version.

As the need for computer-based education and distance learning systems becomes increasingly obvious, the value of such "active" versus "passive" learning becomes increasingly clear. Virtual classrooms and virtual laboratories help solve many of the problems faced in secondary and post-secondary education: distance learning becomes a reality, learner diversity is accommodated (both in terms of learning styles and life styles), and in many cases the curriculum becomes more active, more role-based, more self-paced, and

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more “learn by doing” than “learn by listening.”

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Acknowledgements

Development of the Geology Explorer is funded by the National Science Foundation under grants DUE-9752548 and EAR-9809761. The authors thank Phillip McClean, Paul Juell, and Alan White of North Dakota State University for their constant input as our project develops. We also acknowledge the large team of dedicated undergraduate and graduate students in the computer and earth sciences who have made this project so successful. In particular, we wish to thank John Bauer for his contributions in programming and graphical user interface development and Rebecca Potter for her work on developing the graphical backgrounds for the new version.

High School Science Teachers' Perceptions of Barriers and Supporting Conditions to Telecommunications Implementation

Scott W. Slough, Department of Early Childhood Education and Reading, Georgia Southern University, Statesboro, GA 30458 USA, sslough@gasou.edu

Abstract The purpose of this study (Slough, 1998) was to examine and describe the high school science environment within an emerging telecommunications-rich setting in an effort to provide a better framework for implementation of telecommunications technology in science classrooms. This paper will focus on the perceived barriers and supporting conditions for the implementation of telecommunications in the high school science classroom by 24 high school science teachers from a single district who had been in an emerging telecommunications-rich environment for at least two and one-half years. Data was collected through open-ended ethnographic interviews with the Concerns Based Adoption Model (CBAM) providing a theoretical framework.

The popular and educational press is inundated with calls for placement of the Internet and the World Wide Web—telecommunications—in schools. If implemented properly, telecommunications and the associated information technologies have the potential to change science teaching and learning. As schools race to implement these technologies, it is important that we consider the teacher and the changes that telecommunications require of the teacher and subsequently the students. While barriers and supporting conditions to telecommunications are the focus of this paper, the data results from a broader study (Slough, 1998) involving high school science teachers' perceptions of a range of issues related to telecommunication implementation at the high school level utilizing the Concerns-Based Adoption Model (Bailey & Palsha, 1992) as a theoretical framework. Research questions for the entire study focused on teachers' and students' use of telecommunications, barriers and supporting conditions to telecommunications implementation, and the effect of telecommunications on the teaching and learning of science. Data was collected through open-ended ethnographic interviews with 24 high school science teachers who had been in an emerging telecommunications-rich environment for at least two and one-half years as of the Fall Semester, 1997. The setting for this study was carefully chosen for its early local support for implementing telecommunications and the advanced stage of infrastructure and support already in place. It is hoped that these teachers' stories about the barriers and supporting conditions for implementing telecommunications in the high school science classroom would help us understand how to help other teachers as they go through similar stages of implementation.

Concerns-Based Adoption Model (CBAM)

The Concerns Based Adoption Model (CBAM) proposed by Bailey and Palsha (1992) provided a theoretical framework for data analysis and subsequent discussion. The Bailey and Palsha model includes five stages; awareness, personal, management, impact, and collaboration. Some basic assumptions of CBAM are that the concerns are progressive, and to some extent sequential; that individuals progress slowly through the concerns regarding particular innovations; and that progress in one innovation does not necessarily transfer to new innovations (Hall & Hord, 1987). Although certain aspects of progression along stages of concerns are common, the progression is ongoing and personalized and can be mediated to the extent that training is matched to the needs and concerns of individual teachers at appropriate times. Teachers were placed at differing stages based upon their responses to all of the research questions in the study (Slough, 1998). Separate lists of barriers (Table 1) and supporting conditions (Table 2) by stages of implementation were developed, including those for users and non-users alike.

Barriers and Supporting Conditions

When paired with supporting conditions, the barriers provided a window to the teachers' knowledge of telecommunications; it is only through knowledge that the teacher can adequately reflect upon what hinders and supports action. The pairing of barriers and supporting conditions was more than just opposites. In many cases, teachers used lack of supporting conditions or removal of a supporting condition already in place to describe a barrier and removal of a barrier to describe a supporting condition. In order to preserve this duality, lack of

supporting conditions was listed as barriers and as supporting conditions. Barriers and supporting conditions also provided insight into the teachers' concerns about telecommunications, their underlying beliefs, and the values that drive decision making and action. One barrier that had been discussed in the literature and was found repeatedly in this study was support. Previous authors had used support to describe administrative support, monetary support, collegial support, and technological support among others. The teachers in this study used support almost exclusively to mean administrative support. In the rare instances that it was used in another context, that context was explicitly shared. Table 1 shows the emerging descriptors that were developed as the perceived barriers to implementing telecommunications in the high school science classroom.

Stage	Barriers
Awareness (n=4)	A long list of barriers—or almost none
Personal (n=6)	Time, training, support, and curriculum Interference with lab space and equipment No pedagogical barrier
Management (n=6)	Time, training, support, and curriculum, minor barriers Access to inappropriate materials considered major barrier Pedagogical concerns considered major barrier
Impact (n=4)	Support and curriculum, minor barriers Loss of lab space due to permanent placement of computers and peripherals Safety concerns from wires in and around sinks and gas jets Effect on student learning was a barrier that had been overcome How to refine teaching methods with telecommunications considered major barrier
Collaboration (n=4)	Recognized barriers but considered them to be more challenges than barriers Recognized that money was a long-term barrier that either solved or exacerbated other barrier

Table 1
Perceived Barriers to Telecommunications Implementation

Table 2 shows the emerging descriptors that were developed as the perceived supporting conditions to implementing telecommunications in the high school science classroom.

Stage	Supporting Conditions
Awareness (n=4)	Little recognition of supporting conditions Support from administration, knowledge
Personal (n=6)	Proof that it works Support from administration
Management (n=6)	Proof that it works Used a different single supporting condition to enable other supporting conditions Time, money, training, support from administration
Impact (n=6)	Proof that it is valuable to the student Positive results with the students "Someone to get them over the hump"
Collaboration	Get out of their way and let them do it

(n=4)	Money was the single supporting condition that enabled others

Table 2
Perceived Supporting Conditions for Telecommunications Implementation

Teachers at the awareness stage were generally unable to provide concrete examples of barriers to their access because they lacked a sufficient knowledge base. On the other hand, teachers at the personal stage were able to generate a significant list of barriers. The most important barrier to these teachers was time, specifically their time. In fact most of the rest of the barriers were related to how they infringed upon the teachers' time. Lack of sufficient training was a second barrier. Each teacher had a different vision for training but it always revolved around their convenience. These teachers also wanted support, primarily from their principal. The teachers all expressed some way that telecommunications would take away from their present curriculum. Significant in its absence was the lack of a pedagogical barrier. The teachers had not considered whether telecommunications were different from regular instruction. This is possibly due to the fact that they considered telecommunications to be "just another source of information." Teachers at the first two stages, awareness and personal, shared one critical supporting condition, support from the administration, primarily the principal. For both groups of teachers, this support was not limited to telecommunications. They felt as if they were not supported in the daily activities of teaching; they felt isolated. Teachers at the awareness stage wanted more basic knowledge about computers in general. At the personal stage, teachers had some knowledge; they wanted proof that it worked before they changed their curriculum or used their time to learn, or used their energy.

Teachers at the management stage consistently listed more barriers than any other group. Minor barriers were time, training, support, and a rigid curriculum. There were two major barriers identified by the management teachers, access to inappropriate material and pedagogical concerns. Access to inappropriate material included students just "goofing off" on the World Wide Web or more serious concerns about their liability in case of a student accessing adult material. Most of the teachers at the management stage did use computers and telecommunications personally but were openly hesitant about using it in the classroom. They did not see how telecommunications could conform to their teaching style. Both of the major barriers were consistent with the management teachers' vision of the teacher in control of the classroom. Teachers at the management stage focused on supporting conditions that would help them manage, or control, their jobs and proof that telecommunications really helped students. Each teacher listed a single supporting condition that, if in place, would create other supporting conditions. For instance, support from administration was listed by half of the teachers. If you had support from the principal, he could provide money to pay for training, to pay for more computers, and to pay for the teachers' time when they trained and practiced with telecommunications. Other single supporting conditions included time, money, and training.

Teachers at the impact level mentioned lack of support and a restrictive or full curriculum as minor barriers. Even though they were actively in the process of implementing telecommunications to the best of their abilities, they recognized that they needed help in exactly how to implement telecommunications. Each teacher had a different telecommunications approach, and each teacher repeated that approach. They simply needed more ways to integrate the technology and were obviously frustrated because they could see the potential. Teachers at the collaboration stage did not see barriers as much as they recognized challenges that teachers as professionals overcome to implement anything new and innovative.

Teachers at the impact stage were quick to point out that the major supporting condition had been proof that telecommunications were valuable to the students. That value could be motivation, a self-perceived improvement in the teacher's teaching, or a teacher-perceived improvement in student learning. On a daily basis, the driving force that kept these teachers going was positive results with the students. The one supporting condition that the impact teacher wanted, and did not necessarily have, was one telecommunications collaborator who would provide technological and more importantly pedagogical support so that they could reach the collaboration stage. Teachers at the collaboration stage recognized supporting conditions for others but by and large did not feel as if they needed any personal support. They did, however, recognize the long-term need for money to continue to provide state-of-the-art technology in their classrooms.

The literature has focused on the barriers to implementing technology in general (Becker, 1991, 1994; Hadley & Sheingold, 1993; OTA, 1988, 1995; Sheingold & Hadley, 1990), with some work—notably Honey and Henriquez

(1993)—identifying barriers to telecommunications. Barriers reported by teachers in this study generally agree with the research literature with two notable science specific exceptions, loss of laboratory space and safety concerns with wires running in and around sinks and gas supplies. Although, others have reported lack of space as a barrier for implementing computers (OTA, 1995) and telecommunications (Honey & Henriquez, 1993). High school science classrooms typically have a "classroom area" and a "lab area" with varying degrees of overlap. Science classrooms also traditionally have sinks, large faucets, and gas jets occupying a large amount of the working laboratory space. Permanently installed computers take up lab space, and computers on carts typically have wires and cables draped around and through sinks, faucets, and gas jets.

Conclusions

Studies into barriers and supporting conditions for technology implementation have traditionally focused on those teachers who were users. This study has specifically given the non-user a chance to voice concerns. Barriers and supporting conditions as a whole are supported by those found in other research (Becker, 1991, 1994; Hadley & Sheingold, 1993; Honey & Henriquez, 1993; Honey & McMillan, 1993; OTA, 1988, 1995; Sheingold & Hadley, 1990). This study contributes barriers and supporting conditions identified for teachers at different stages of innovation (see Tables 1 and 2).

Bringing telecommunications into the science classroom creates special problems dealing with loss of laboratory space and safety concerns. The science classrooms in this study, and in many other schools, typically had a lecture area and a lab area. Computers were typically placed in the laboratory area. Teachers in this study who were implementing telecommunications had done so at the expense of laboratory space and/or laboratory efficiency. Computers were either taking up permanent bench space or, where computer carts were used, they were constantly being moved for labs to occur. Neither situation is satisfactory in the long-term. Also related are the safety concerns associated with running electric wires in and around sinks and gas jets. If telecommunications are to become integral parts of the science classroom, long-term planning needs to address the potential need for lecture space, laboratory space, and computer space in a safe environment

Limitations

This study, like all others, has some limitations. Some of the limitations of this study include the restricted population, one-time interviews, and dependence upon self-reported data. A longitudinal study of the population is warranted to monitor teachers' concerns over a longer time span, especially in light of the fact that telecommunications represent a changing innovation. Additionally, teachers were not asked about specific requirements to take the next step in implementing telecommunications. They were simply asked for barriers and supporting conditions for implementing today's telecommunications technology. A long-term study would allow collection of data from participants, as they were transitioning from one stage to another. This might also identify individuals for case-studies who were transitioning from one stage to another.

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Acknowledgements

For a complete description of the study, please refer to http://www2.gasou.edu:80/facstaff/sslough/dissertation/contents.html.

Design of Interactive Multimedia Modules to Enhance Visualization in Chemistry Courses

JERRY P. SUITS
Department of Chemistry, McNeese State University, Lake Charles, LA 70609-0455 *suits@mail.mcneese.edu*

ALICIA A. COURVILLE
Department of Science, LaGrange Senior High School, Lake Charles, LA 70607

Abstract: In this paper we describe the features that are needed in a multimedia module to enhance the visualization skills of students enrolled in general chemistry courses. Visualization of chemical phenomena and abstract chemical principles can help them develop the multiple representations they need to solve chemistry problems. These representations are an essential part of a two-stage model of chemistry achievement: in stage one students can use traditional instructional methods to learn many basic algorithmic skills, whereas in stage two they can use multimedia learning modules to develop their thinking skills, e.g. visualization, and to integrate these two types of skills. Multimedia modules can help them in both stages when chemistry problems are presented within a real world context; i.e., we have found that they can solve math-type chemistry problems better and, in addition, they should be more motivated to use a deeper approach while learning chemistry.

Introduction

College students who enroll in first semester general chemistry approach learning in different ways based on their background knowledge, aptitudes, and their level of interest in the course. Many of them become "rote learners" because they prefer a surface-level approach (Schmeck, 1988) in which they can apply their memorization and computational skills. This approach minimizes their effort and reflects their lack of interest in the course. Conversely, other students whom we call "conceptualizers" adopt a deep approach (Schmeck, 1988) in which they strive to understand the underlying structure of the subject matter. They tend to use a flexible learning strategy that taps into both a conceptual and an algorithmic understanding of the subject because it is intrinsically interesting to them. A third group of students termed "algorithm memorizers" strive to make a good grade, but they are not interested in the course content per se. Rather, they prefer to minimize their effort and strategically use algorithms as a short cut to obtaining an understanding of the material. These three learning approaches tend to produce different levels of achievement in the first general chemistry course.

Students usually adapt a particular approach to learning chemistry, as described above, based upon their perception of the content and instructional methods used in the course. Traditional instructional methods tend to fragment knowledge into two distinct types: lectures tend to stimulate only passive learning of the theoretical material, whereas laboratory work often focuses exclusively on manipulatory skills in which students record their observations on a fill-in-the-blank lab report form. Consequently, very few students can integrate these two types of knowledge, and thus they have a large gap in their understanding of chemistry, which is an empirical science. In this paper we hope to show how this gap can be bridged by a multimedia learning module and to illustrate how the features of this module can help students develop their visualization skills. The module elicits these skills in concert with computational skills so that students experience a direct connection between a chemical principle and its corresponding chemical phenomenon. In addition, the module is designed to perk their interest in chemistry via presentation of real world applications and to motivate them via a "personalized" type of feedback.

Visualization and Levels of Design

The design of interactive learning modules should be most effective when three levels of design (Lavoie, 1995) are used to make instructional decisions. The primary design level focuses upon the scientific

problem and its inherent characteristics, whereas the secondary level imposes an external set of instructional guidelines in order to keep learners "on task" so they can make progress towards accomplishing the goal in an efficient manner. Finally, the tertiary level integrates the scientific problem with learner characteristics and minimal instructional intervention, i.e. guided inquiry. Thus, the instructional format should be "seamless," so that learners can use their cognitive load capacity (working memory) to search for an interrelated set of scientific facts, concepts and procedures without expending a huge cognitive load on trying to understand the instructional features of the module(s). Visualization of relevant scientific images while listening to an auditory explanations can increase intrinsic cognitive capacity, while reducing the extraneous cognitive load imposed by multiple sources of information (Mayer, 1997; Sweller et al., 1998).

The Primary Design Level

On the primary level, the goal is to help learners solve a scientific problem. Hence, the designers need to understand the structure of the scientific discipline in order to establish the primary instructional sequence (Suits & Lagowski, 1981). Chemistry is an empirical science in which empirical inquiry and theoretical principles interact and evolve together to form a multidimensional structure. The Learning Cycle (Atkin & Karplus, 1962) has been modified to include hypothetico-predictive processing (Lavoie, 1995) that interacts with all three phases of the learning cycle (i.e., exploration, concept introduction, and concept application). The goal is to help learners understand how scientific investigations are conducted by having them actively engage in all three phases of investigation. Bruner (1966) has stated that this sequence is most effective when it begins with an experience (enactive representation), then is followed by a visual image that summaries the experience (iconic representation), and then culminates with a verbal or mathematical expression (symbolic representation) that is both more generalized and more powerful. For example, in a pH-monitored titration experiment, students can titrate an acid solution with a NaOH solution while simultaneously measuring the pH (enactive). After performing the experiment, they can graph the volume of NaOH versus pH (iconic), and then generate a theoretical titration curve based upon mathematical equations (symbolic). When students can express a scientific principle with multiple representations, they can better understand the principle and its applications (Bodner & Domin, 1995). Conversely, when laboratory and lecture topics are covered at different times and in different places, very few students can integrate the knowledge and thus truly understand the underlying structure of chemistry. For a particular scientific principle, this gap can be bridged by a multimedia module that is designed to present all three modes of representation in one lesson (Russell et al., 1997).

Secondary Design Level

On the secondary level, the goal is to use instructional design principles to guide the learners and to keep them "on task" throughout the lesson. These principles as described by Gagne (1985) have been applied to computer-based instruction, computer simulations (Reigeluth & Schwartz, 1989), and interactive video (Lavoie, 1995). When learners interact with well designed lessons, they should be able to learn without additional help from their teachers. The level of challenge provided by the lesson should match the students' level of skills. Otherwise, an oversimplified lesson can result in boredom, whereas a difficult lesson can overwhelm students.

Tertiary Design Level

On the tertiary level, the students should be challenged to solve a complex scientific problem (primary level) but provided with just enough guidance to sustain their progress in solving the problem (secondary level). This type of instruction, called guided inquiry, combines instructional strategies from both behavioral and cognitive psychology. These strategies should be incorporated into an instructional module so that learners can integrate multiple sources of information without overwhelming their cognitive load capacities (Sweller et al., 1998). The multimedia learning module should contain the following features (Lavoie, 1995; Suits & Lagowski, 1981):

- presents a goal to be accomplished;
- assures that the learners have the appropriate prior knowledge and skills needed,

- supports learner control of the decision-making process by allowing them to control the pace and content (through branching options) of instruction;
- focuses attention on relevant information (cues);
- provides feedback that includes hints, correctives, or elaborations as needed;
- generates a disequilibrium when scientific principles conflict with learner beliefs;
- displays textual (auditory) and visual information simultaneously; and
- assesses the level of competency that the learners have attained at the end of the lesson through multiple-choice or open-ended questions.

Each of these features should be used to reduce the extraneous cognitive load (working memory) so learners can extend their verbal and visual cognitive capacities to internalize the intrinsic cognitive material of the module.

At this tertiary level, instructional design should be based upon the fundamental premise of constructivism (Connell, 1998; Lunenburg, 1998); i.e., that learners actively construct their own knowledge, rather than passively absorbing the presented information. More specifically, the instructional module should (Lunenburg, 1998) begin with a goal that is personally meaningful to a particular group of learners and one that is centered upon a primary concept of the discipline (i.e., the primary design level). The design should use student responses to drive the direction of the module, shift instructional strategies, and alter the content of the module. Also, the "wait time" for student responses to the more complex questions should be extended and untimed as much as possible. Also, technology should help students use sketches and mental pictures (iconic) to build a bridge between manipulatives (enactive) and abstractions (symbolic) (Connell, 1998; Presno, 1998).

Visualization and Multiple Representations

Many students enrolled in a general chemistry lecture course/section use a learning approach that emphasizes an algorithmic understanding at the expense of a conceptual understanding of the course material. They may be influenced by homework and exam problems that require the use of algorithms to set up and solve the problems in an efficient manner. Conversely, some students are able to make connections between the microscopic representations in which atoms (o is oxygen and • is carbon) and molecules (o=•=o is CO_2) and the algorithms used to solve problems at the symbolic level of representations (e.g., chemical formulas, equations,

chemical apparatus (glassware, etc.) and then measure or observe chemical properties, e.g. color changes, mass, volume, or pH. However, these activities (enactive representations) are all macroscopic representations of

(Keig & Rubba, 1993) to produce a conceptual knowledge in which all information about a chemical topic is interconnected. A multimedia learning module can be designed to help learners acquire this conceptual

Visualization and Cognitive Learning Styles

Many of the abstract chemical principles in chemistry require that learners associate the terms used to

can form these images that allow them to acquire creative insights and to restructure their perspective and hence solve complex problems (Kleinman et al., 1987). Some students possess the cognitive learning style (Pillay,

others can only process information that is based on verbalizations (the verbal-articulation loop). The imagers, the former group, can visualize these images in the absence of visual material, whereas the verbalizers, the latter

visually-based information. Thus, multimedia instruction may differentially benefit the imagers (Mayer, 1997) because they see real visual images that they can then visualize mentally and store in long-term-memory.

that a greater diversity of students (Nakhleh, 1994) can learn in ways that optimize their understanding of the material. One such design involves using task scenarios that avoid gender stereotyping (Littleton et al., 1998).

We have developed a multimedia learning module on the gas laws for a college-level first semester general chemistry course for science and engineering majors. The primary goal was to get students to visualize chemical phenomena and the principles that govern gas behavior. A chemical principle is often an abstract relationship that requires multiple representations (Keig & Rubba, 1993) in order for one to fully understand, appreciate and apply the principle to an appropriate chemical phenomenon (Ben-Zvi & Gai, 1994). The gas laws are a set of chemical principles that must be understood both individually and collectively in order to solve real-world gas behavior problems. The gas laws may be represented as a series of:

- diagrams which show molecules as dots in two different conditions (e.g. high pressure and low pressure)-- where the behavior of the dots represents the behavior of the gas molecules;
- mathematical equations that allow one to solve for the value(s) of unknown parameter(s) and hence to fully describe the condition of the gas (i.e., covers all measured and calculated parameters);
- real gases that exist in the laboratory under controlled conditions in which one or more gas parameters can be systematically manipulated and the effects on the other parameters can be measured;
- real gases that exist in real-world applications in which several gas laws operating simultaneously.

Most students tend to develop only an algorithmic understanding of the mathematical equations that are described by the gas laws, but few are able to relate their algorithms to sketches of gas molecules that are also described by these same gas laws. We illustrated these gas laws (scientific principles) with sketches that showed breathing in the lungs, a movie of an expanding air bag in an automobile based upon a student calculation (given grams of solid to unknown Liters of gas), and sketches of molecules involved in processes governed by the gas laws (Courville, 1998). Verbal information was presented in two modes-- written text and auditory narration to explain the problem in a coherent manner. Verbal and visual information was presented simultaneously as much as possible to allow learners to increase their capacity to process both modes of information and to transfer this capacity to novel problems (Mayer, 1997; Sweller et al., 1998).

Real-World Scenario

Each section of the module begins with a *scenario* that describes a real-world situation (Reigeluth & Schwartz, 1989) where the gas laws govern the behavior of gas molecules. In the diaphragm-lungs gas exchange scenario (Courville, 1998), a voice (auditory) describes how the diaphragm and lungs operate work to produce lower pressure (inhalation) and higher pressure (exhalation) and the effect on volume of the lungs. Students then proceed to work several Boyle's Law problems ($P_1V_1 = P_2 V_2$) within a context that makes the mathematical operations meaningful. Within a given scenario, both conceptual (qualitative) and algorithmic (quantitative) problems are presented for students to work. Thus the scenario provides a context in which different aspects of same chemical phenomenon can be featured. A true understanding of the chemical principle(s) involved requires looking at a phenomenon from different perspectives. For example, Boyle's law can be illustrated by drawing dots, which represent molecules. If twice as many molecules (dots) are present in the same volume, then the pressure on the gas has doubled. Likewise, if an external pressure (e.g. more bricks are stacked atop a movable piston) is doubled, then the volume of the gas is halved. On the computational level, given the values of pressure and volume under one condition, the student can solve for the value of one parameter (either pressure or volume) in a second condition. On the laboratory level, the student can manipulate the volume of an enclosed gas with a "leveling bulb" that is filled with mercury between the bulb on one side and the enclosed gas on the other. Raising the bulb thus increases the pressure on the gas and consequently decreases its volume. Lowering the bulb has the opposite effect. On the real-world level, a breathing person is using Boyle's Law to manipulate air into and out of the lungs as appropriate.

Multiple Representations of Air Bag Chemistry

The automobile air bag scenario (Courville, 1998) illustrates how several gas laws govern the behavior of the expanding gas. First, the gas inflates the bag (the desired effect), while also cooling the temperature and exerting a pressure on the bag. Second, the person (or dummy) falls forward due to the inertia of the forward-moving vehicle (Newton's first law), which increases the pressure on the bag but stops the person before they crash into the vehicle's steering wheel or windshield. This scenario can be represented in several different ways:

- as a set of *mathematical calculations* that involves gas stoichiometry-- the student calculate the amount of solid (grams of sodium azide, NaN_3) needed to properly inflate the bag first under ideal conditions, i.e., at STP (0°C and 1.0 atm), and then at room temperature and an a higher pressure (real world conditions as found in an automobile) due to the generation of gas molecules formed during the chemical reaction);
- as a *movie of an expanding air bag* which is dependent upon each student's calculation/miscalculation of the initial amount of solid needed; i.e., each student sees one of three possible movies (See Figure 1):
  (a) If they calculate a mass that is correct, then a movie shows an air bag that properly inflates; (b) If they calculate a mass that is too small, then a movie shows that the bag underinflates and an appropriate auditory message is delivered to them;
  (c) If they calculate a mass larger than is needed, then a movie shows that the bag overinflates and bursts while an appropriate auditory message is delivered.
- an *animated graphic sequence* (Burke et al., 1998) that shows the rapidly expanding gas molecules (dots) slowing down (lower velocity, hence lower temperature), diffusing (spreading out from the site of the solid-to-gas reaction), and colliding with the inside of the bag (exerting pressure which inflates the bag and then keeps it inflated).

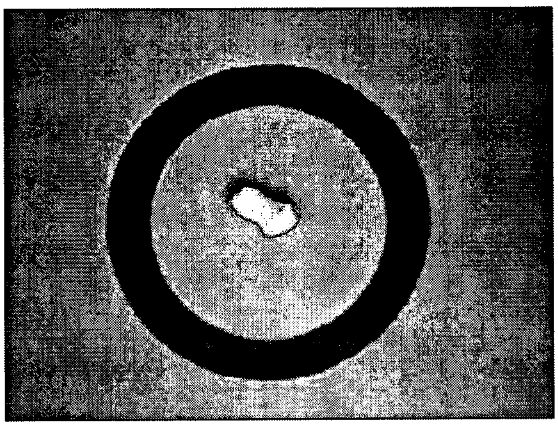

Figure 1: Initial frame for the air bag inflation movie

Conclusion

In conclusion multimedia learning modules can be designed to help students simultaneously visualize a chemical phenomenon (macroscopic representation) and its corresponding chemical principle (microscopic or symbolic representation). They can use these real images of a phenomenon to form mental images that are needed to develop mental models of a chemical principle. When math-related problems are worked within a real world scenario of a chemical phenomenon, then students can use their mental models to understand the algorithms that allow them to converge on the correct answer to the problem. Our recommendation is that a multimedia learning module be developed for each set of chemical topics (e.g. one module for each hour examination) so that students can begin to visualize the essence of these topics and build bridges among multiple representations for each chemical principle encountered. Our overall goal should be to help students develop a deep approach that allows them to understand course material and to solve real world problems.

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Acknowledgments

The authors would like to thank the Louisiana Educational Quality Support Fund (LEQSF-Graduate Fellowship) for its support of A.A.C., and the Chavanne-Miller Endowed Professorship in Science for its support of J.P.S. Both authors acknowledge the LEQSF 1996-97-ENH-TR-35 Grant for funding the computer technology described in this paper.

Providing a Weather Satellite Image to a Classroom Using the Internet and a CD-ROM

Mikinori Tsuchida
Sapporo Utsukushigaokamidori Elementary School
Japan
tsuchida@nikonet.or.jp

Hironobu Suzuki
Sapporo Yonesato Elementary School
Japan
hironobu@mb.infosnow.ne.jp

Tatsuya Hirono
Keisyo High School
Japan
hirono@spc.ritsumei.ac.jp

Tsuneya Takahashi
Center for Educational Research and Development
Hokkaido University of Education
Japan
takahasi@sap.hokkyodai.ac.jp

Abstract: A system by which data from a weather satellite can be processed, stored and accessed using the Internet and a CD-ROM was developed for use in the classroom. Four thousand images compiled from annual weather satellite data, together with the software program which works on Windows 95/98/NT systems, were stored on a CD-ROM. The software, which was developed for precollege students, allows the user to have easy access to satellite images, to display and animate the images, to show cloud top temperature, to superimpose an infrared image onto a visible image, and to select a weather topic.

Introduction

Students are familiar with weather satellite images shown on TV or in the newspaper, which have a strong visual appeal. Thus, satellite images would not only be an excellent teaching aid for the study of weather but would also provide an opportunity to introduce computer technology into the classroom.

The use of the Internet has spread remarkably in recent years. The Internet is a useful source of data, especially real-time data. However, images displayed on present Internet sites are of poor quality due to lossy data compression and animation for any desired period is impossible. Moreover, a long time is needed to download a large volume of data. In the classroom, therefore, it is better to use a software program that can provide clear images and that offers educationally beneficial functions such as animation. A large volume of data should be supplied with some storage device such as a CD-ROM.

In this paper, we describe a system and a software program that we have developed for using satellite images as teaching material in the classroom. This system can automatically process and store data from a geostationary weather satellite. The data can be provided to the classroom using the Internet and a CD-ROM. The software program offers the various functions for students to study weather and the environment.

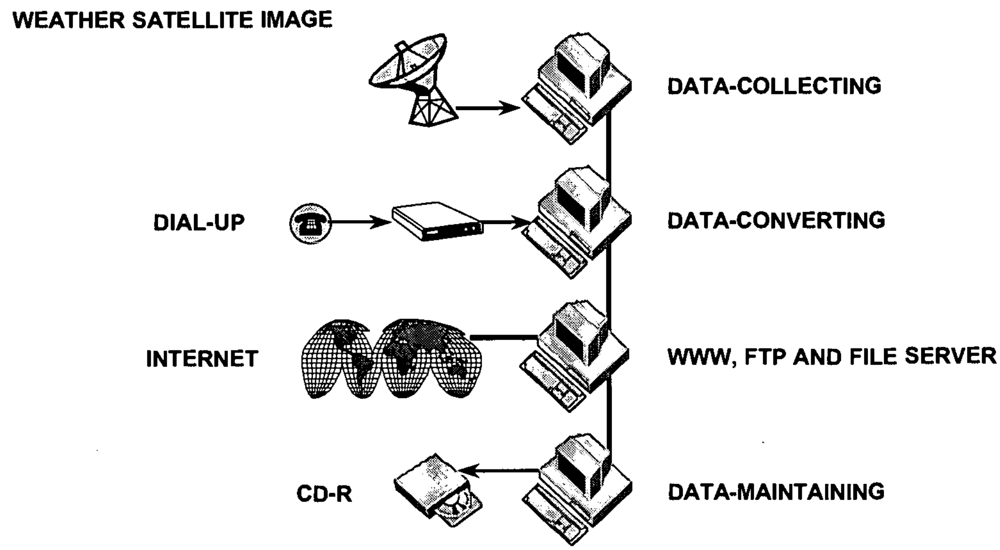

Figure 1: Schematic diagram of the system for providing satellite weather data using the Internet and a CD-ROM

Preparing Images for the Classroom

First, a network using a modem and a telephone line was constructed with NetWare Connect software (Tsuchida et al. 1996). The number of remote users, however, was restricted because the name of each new remote user must be preregistered with a server and exclusive software must be used for logging in. Online service through the Internet may provide a more convenient service in the case of many unspecified users. Hence, to provide a Web page, the system has been restructured as shown in (Fig. 1). The system consists of four computers together using TCP/IP. A computer of an Internet server and storing provided data uses Linux software. After first-hand data from the geostationary satellite is stored, the data format is converted into that of providing data in the Windows NT computer, which also functions as a server for remote access. Computers for collecting satellite image data and for data maintenance use Windows 95/98.

A commercially available system (Nippon Hakuyo Co., Yokohama, Japan) consisting of a parabolic antenna and a personal computer was used to receive images from a geostationary satellite and convert the data from analog to digital format. The antenna was set up on the roof of the Center for Educational Research and Development, Hokkaido University of Education. The meteorological satellite was positioned at longitude 140 degrees east and directly above the equator. This system is able to receive the following images: 1) infrared images from around Japan (updated hourly), 2) visible images from around Japan (updated hourly during daylight hours), 3) infrared images from the globe, divided into four zones (updated every 3 hours), and 4) water vapor images from the globe, divided into four zones (updated every 12 hours). Water vapor images were not included in our teaching system, because they are not common images and may be confusing for students.

The first-hand data (800x800 dots and 64 gray scales, i.e. 8 bits), whose file size is 626 KB, is sent to and stored in the Windows NT machine. The reduction of the size of the file is essential for compiling more data in a single CD-ROM and for providing data through the Internet. The data is automatically processed by the computer at regular time intervals, which can be changed as required. After the overlapping areas have been removed, four images, representing the four zones into which the earth is divided, are pasted together to produce a complete image of the globe. For convenience of treatment on a monitor, the size of the file is then reduced by averaging the gray scales of four adjacent dots. The 8-bit first-hand data is converted into 4 bits (16 gray scales), thereby reducing the size of the file by half. This process does not affect the quality of images in practice probably because the first-hand data is produced through the digital processing of an analog image received from the geostationary satellite. Next, the data files are compressed by Run Length Encoding (Barron and Orwig 1997) in which every bit of the original

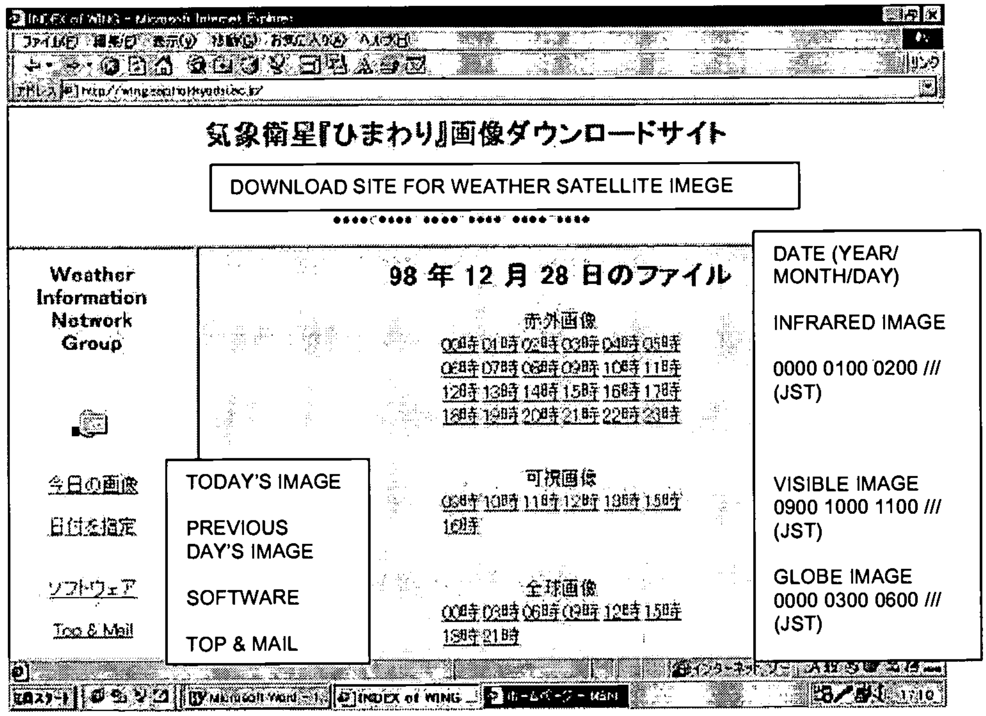

Figure 2: Web page of a list of daily images

information in the images is preserved, in order to maintain a clear image. For example, in the case of images obtained in November 1998, the file sizes were decreased by an average of 50% for infrared images from around Japan, by 34% for visible images from around Japan, and by 31% for infrared images from the globe. The average final file sizes for these images were 157 KB, 206 KB and 137 KB, respectively. The compression rates of visible images taken in the morning and evening were higher than those taken at noon because the shade area is monotone. The converted data is stored in the Linux machine, which is linked to the Windows NT machine by Samba software. The accumulated data is saved on a CD-ROM using a data-maintaining computer.

The Linux computer also functions as a WWW and FTP server to provide the data to the classroom. It is also possible to access the server through a digital or analog telephone line via the Windows NT computer. A large volume of data can be provided with a CD-ROM according to teacher's request. CD-ROMs containing satellite weather data for the years 1996 and 1997 are now commercially available. Each of these CD-ROMs contain about 4,000 images (more than 600 MB), including infrared images from around Japan obtained every 3 hours, visible images from around Japan taken at 12 a.m. (JST) everyday, and infrared images of the globe taken at 9 a.m. and 9 p.m. (JST) everyday. The CD-ROM for the year 1997 also includes everyday weather charts.

Providing Images through the Internet

Web and FTP servers have been set up on the Linux computer to provide access to the data stored in the computer, especially to the real-time data. The Web pages were produced using HTML. The user selects the desired image from a daily list of images, as shown in Fig. 2. When a user accesses the Web site, the CGI written by Perl software automatically updates the list to provide the latest information. In case of requiring an image from a previous day, the user simply enters the appropriate date and then selects the image from the list of that day's images. Although the data can be read using the software described in next section, software that is easier to use is offered on the Web. The software, however, has only the following functions: displaying an image, storing an image as a bit-mapped formula, and magnifying an image two-fold or reducing it by half.

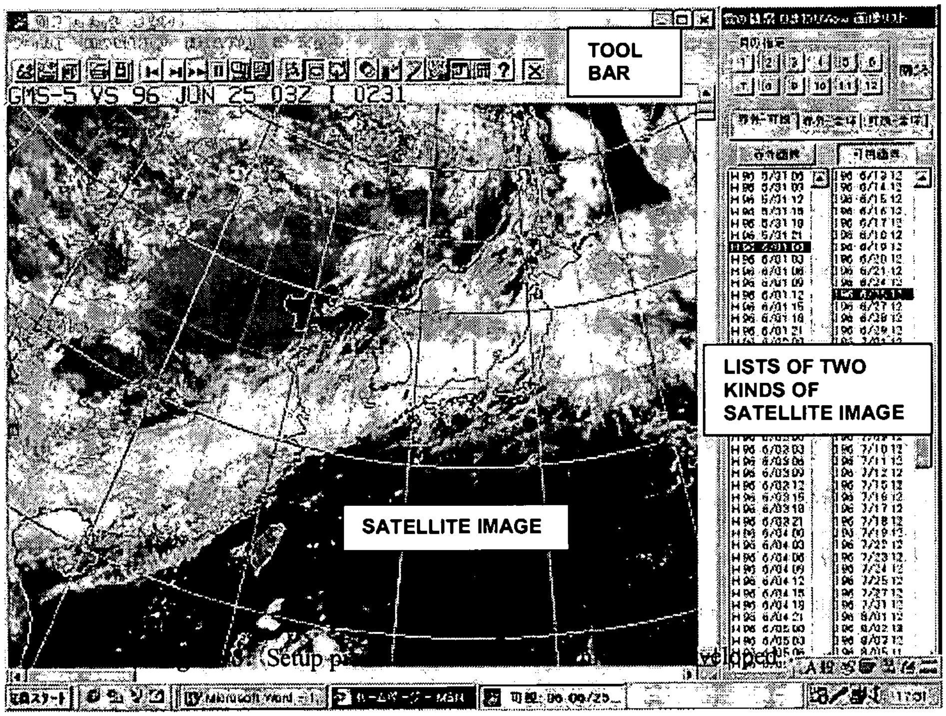

Figure 3: Screen where the software appears.

Satellite images were downloaded on remote site via an analog telephone line with a 28800 bps data modem. It took 34 seconds to download an infrared image of 149 KB and 49 seconds to download a visible image of 207 KB. Thus, the transfer rate of data was over 4 KB/second. It has been shown that this system would be of practical use even by an analog telephone line.

Software for Presenting Images

New software was developed to allow precollege students to be able to handle satellite images easily. Our previous software can only be used on MS-DOS (Suzuki et al. 1996). The new software can be used on Windows 95/98/NT systems, and it is included in the above-mentioned CD-ROM containing annual weather data. The software was developed using C++ programming language (Borland). We recommend a Pentium system with a monitor of over 800x600 pixels be used with this software.

The newly developed software has the following features:

1) Lists of each kind of satellite image can be displayed on the screen. Lists of two kinds of image are displayed simultaneously. It is possible to jump to the beginning of the month for which images are desired.

2) Infrared images from around Japan, in which areas of lower temperature appear as whiter in tone, can be viewed.

3) Visible images from around Japan, in which areas of higher reflectivity appear as whiter in tone, can be viewed.

4) Infrared images of the globe, in which areas of lower temperature appear as whiter in tone, can be viewed.

5) Each image can be enlarged twofold or reduced by half.

6) The image immediately preceding or following the image selected can be displayed.

7) Images can be animated, once or repeatedly, within any specified time period. Animation is available at three speeds: 1 image/second, 5 images/second or the maximum speed possible on the computer being used. By using animation, students can observe the movement of clouds associated with a weather system such as a cyclone or a typhoon. Animation of images of the globe also shows the

(a)

(b)

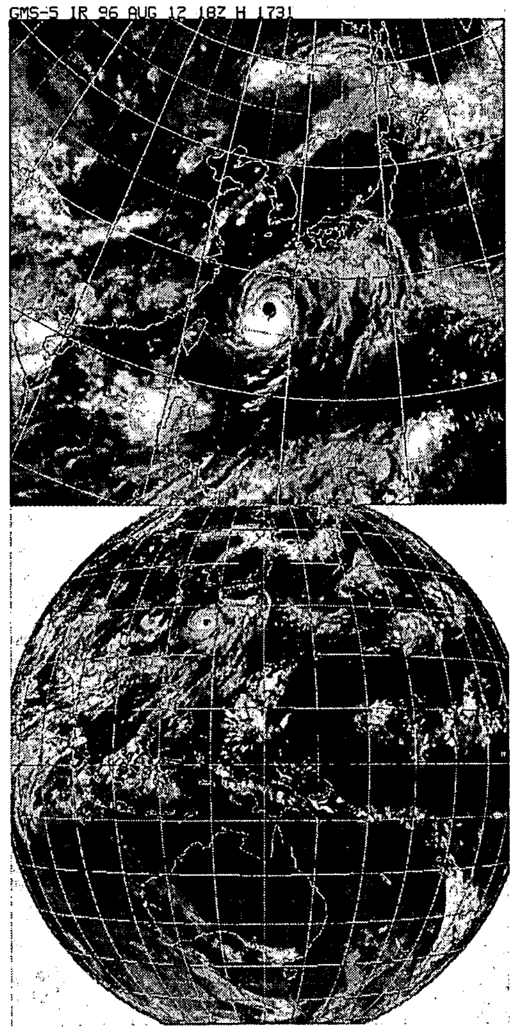

Figure 4: Examples of satellite images: (a) an infrared image of Japan, (b) an infrared image of the globe.

distribution and movement of clouds as a reflection of global air circulation.

8) An area of high, middle and/or low temperature range (infrared image) or reflectivity range (visible image), or an area of a specified temperature/reflectivity range, can be colored. The generation, development and dissipation of a cyclone, a front or a typhoon can be effectively displayed using coloring. For example, a spiral cloud street whirling into the center of a typhoon can be made easily recognized by coloring.

9) The temperature range at any specified point by using the mouse on an infrared image can be displayed. The temperature of a cloud top or of the earth's surface is shown at intervals of about 7 .

10) An infrared image can be superimposed onto a visible image obtained at the same time using 16 shades of red and 16 shades of green, respectively, in order to estimate cloud type. Red, green and yellow areas represent high clouds (such as cirrus), low clouds (such as stratus or fog), and clouds well-developed vertically (such as cumulonimbus), respectively. The yellow areas represent areas in which precipitation is most likely.

11) A list of weather topics for study, such as a severe winter snowstorm, a rainy season, a typhoon, a migratory anticyclone and a cyclone, can be displayed on the screen. The user can click on a topic of interest.

12) A daily weather summary can be displayed. This summary includes (a) the locations of cyclones, fronts, typhoons and highs; (b) high and low temperatures, amount of precipitation or wind speed at a

observation point where the extreme value was observed; and (c) seasonal phenomena such as the first and last snowfall and frost, the first flowering of cherryblossom trees, the first change in the color of ginkgo tree leaves from green to yellows, and the first appearance of butterflies.

13) Daily surface weather charts can be displayed using the CD-ROM for 1997.

14) An image can be stored as a bit-mapped formula.

15) An image can be copied to a clipboard and then into a document using word processing or graphics/painting software.

16) Images can be directly printed.

17) Help information is available on how to use the software, how to interpret terms appearing in the daily weather summary, how to use animation, how to superimpose an infrared image on a visible image, and how to access real-time data.

The above functions can be selected from the menu bar, tool bar or pop-up menu. How the software appears on the screen and examples of satellite images are shown in (Fig. 3) and (Fig. 4), respectively.

Conclusions

In order to provide weather satellite images to a classroom using the Internet and a CD-ROM, a system for automatic processing and storing of necessary data at regular time intervals was constructed. An image of the globe is produced by a combination of four regional images and then reduced in size by averaging the gray scales of four adjacent dots. The 8-bit first-hand data is converted into 4-bit data (16 gray scales). We found that this process had little effect on the quality of the images. The data files are compressed while all the information in the original file is retained for maintaining a clear image. A user accessing the Web site selects the desired image from a list of the images automatically renewed by CGI. Simple software is provided on the Web to enable the display, storage as a bit-mapped formula, magnification and reduction of an image.

CD-ROMs containing 4000 images compiled from annual satellite data, together with the software necessary to access the data, are now commercially available. The main functions of the software are as follows: 1) displaying and animating images; 2) coloring an area of high, middle and/or low temperature (infrared images) or reflectivity range (visible images), or an area of a specified range; 3) showing on an infrared image the temperature range of a cloud top or the earth's surface at a point specified using the mouse; 4) superimposing an infrared image onto a visible image to estimate cloud type; 5) indicating topics for study; 6) displaying a daily weather summary and a daily weather chart; and 7) copying an image to a clipboard.

The satellite images provided by the Internet and a CD-ROM using the system developed here are very useful for the study of weather and the environment in the classroom. Using this system, it is easy for students to learn, for example, the rules which govern weather changes, such as the west-to-east movement of weather systems and the movement of typhoons. Also, this system would allow students to understand weather from a global viewpoint.

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The Field Lessons About Science Education For Grade Schools

Naoko Takahashi
NTT Information and communication systems laboratories
Japan
naoko@isl.ntt.co.jp

Hiroaki Aiba,
Keio Gijuku Yochisha
Japan
aiba@yochisha.keio.ac.jp

Hideki Suzuki
Keio Gijuku Yochisha
Japan
cool@yochisha.keio.ac.jp

Tsugumasa Suzuki
Keio Gijuku Yochisha
Japan
deniro@yochisha.keio.ac.jp

Abstract: This paper reports two practices which used the computer network on field lessons. We experimented to use the computer network for elementary school students of Keio Yochisha on the seaside school and a science lesson. On the seaside school we connected between the school in Tokyo and the hotel in Chiba with the ISDN network so that the students on the seaside could communicate with teachers and students in Tokyo. The other experiment treated the course for the dynamics of water flow where the teacher at the upper stream of the river and students in the classroom connected via the internet over 32kbps PIAFS dial-up line. We discussed on the effectiveness of the use of the internet.

Introduction

Recently, the internet becomes widely used in earth science education. To provide and search various data of the nature environment (Stevens 97, Pender 97) is helpful to do project learning and enlighten students on the nature. As for the collaborative education we can see examples of learning through discussions on regional differences in the project learning(Pinhey 98). Utilization of the internet in the project learning are usually done using computers and networks which are fixed in schools.

Many units of science education on grade schools that requires some field lessons. However, most field lessons cannot take place due to various problems about the time limitation, the guarantee of students' safety, the lack of teachers who accompany students and whether there is any place near the school suited for teaching about the unit or not. It is able to solve the above problems by letting the students observe on the field virtually with the computer network. Also, if we use the computer network on the field lessons(out of the school), the students on the field can ask some one on the other place, and they can show their report of observations while they are on the field.

We report 2 experiments for the fourth grade of the grade school on the Keio Yochisha in Japan. One is a lesson about "the dynamics of water flow" as the example of the virtual field lesson. Another is a lesson about "the study of the shell" on the seaside school with the computer network. The purpose of this lesson about "the study of shells is studying the mysteries of the nature by noticing the existence of the great variety of the shapes in the nature. On the seaside school, the students checked the name of the shells that were collected by them. On our

experiment, the students who have shell whose name he could not find communicated with the teacher and the student in Tokyo. The purpose of the lesson "the dynamics of water flow" is recognizing the difference among the upper, the middle and the lower steam about the flowing speed, the width of the river, the size of the stones on the each place, etc. We experimented on the upper stream of Tama river. On our experiment, the teachers went to the upper river which students rarely see and answered questions which the students in the classroom asked with the video conferencing system

The experimental environments and the flow of two practices

We show the experimental environment including how we connected the computer and the network, and also show the flow of two practical lessons.

The seaside school

In this practice (Fig. 1) we selected to a temporary ISDN line for five days and connected to the indoor network to use a video conferencing system. We used a wireless LAN so that it could use the internet where the facilities of the seaside school is placed. On the seaside we set up a PC for the video conferencing system and eight notebook PCs for the BBS on the WWW. To prepare our experiment we spent one day for selecting an appropriate communication circuit and two days to establish a network for our practice. We used MS NetMeeting 3.1 for the video conferencing system.

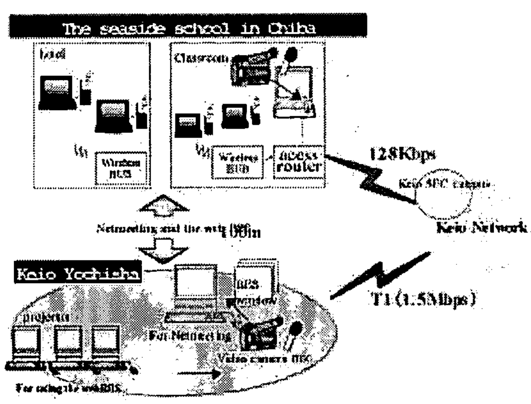

Figure 1: The network of the lesson " the study of shells"

The flow of the lesson "the study of shells" follows:

1. The students prepared to read the book and the homepage which the teacher edited about the shell on Chiba's seaside
2. They collected shells on the seaside at Chiba
3. They checked names of the shells they collected.
4. Only the students who couldn't find the name of the shell, because it was a kind of rare shells, asked the teacher on Keio Yochisha who is a specialist of shells about the rare shell.

In advance we took the shells' pictures and make them possible to be browsed on the web by the BBS on the WWW. The teacher on Keio Yochisha could see steal photos and video image clips in real time.

Students at the seaside school made reports on their seaside school with the BBS on the WWW, and students at Keio Yochisha read those articles and made replies to students on the seaside.

The class for dynamics of the water flow

We selected to use PHSs for outdoor network because it was impossible to establish an ISDN line(Fig. 2). We prepared two notebook PCs and two PHSs on the river side. We used one PC for a video conferencing system and the other PC for browsing the BBS on the WWW and capturing steal photos. At the school we used a projector to show the video window of the video conferencing system and assigned one PC per each two students to browse the BBS on the WWW. We also prepared the tent because it might rain. We spent one day to select a circuit and one day to decide the appropriate place to study the upper reaches of the river in preparation of the practice. We used MS NetMeeting 3.1 for the video conferencing system.

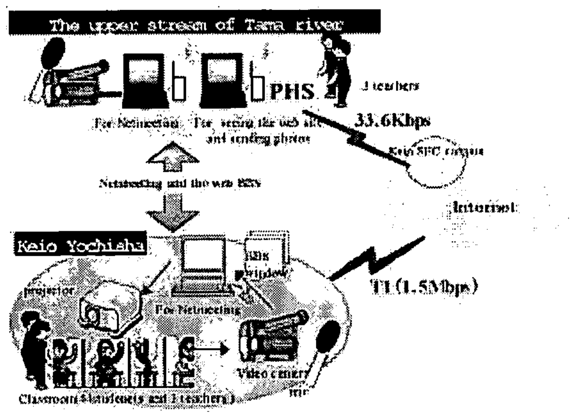

Figure 2: The network of the lesson "the dynamics of water flow.

The flow of the lesson "the dynamics of water flow" is follows:

1. The teacher taught the students about dynamics of the water flow.
2. Twenty students researched about the middle and the lower of Tama river. The teacher made homepages which report about those researches.
3. All students saw the report of the middle and the lower of river on the Web.
4. They saw the video images of which the teacher had already taken.
5. They asked the teacher on the upper stream of Tama river and the teacher answered their question by the steal photos and the video images on real time.

On the upper stream of Tama river there were one teacher of science and two assistants, in the classroom there were two teachers. One assistant on the upper stream of the river operated the video camera , took pictures, and captured the photos.

The other assistant input the teacher's answer by the chat tool of the video conferencing system.

Results

We show the results of two practices.

The seaside school

The seaside school was held from May/ 26 /1998 to May /29/1998. The number of the students who joined the seaside school was 134 and the number students who asked the teacher on Keio Yochisha about the name of the shells was 10. The number of the article submitted to the BBS was 138(86 articles out of 138 articles were submitted by the students). The topics that we found on the practice follows:

1. It is difficult to recognize correct colors and full details of shapes of the shells from the images of the video conferencing system.
2. The students on the seaside were interested in the replies of the BBS from the students at Keio Yochisha. The reason that The students on Keio Yochisha made many reply (The number of articles that were submitted from Keio Yochisha was 25.) which was written to study the usage of the BBS.

The class for dynamics of the water flow

We held 3 lessons on June/26/1998 that was a sunny day. The length of each lesson was 40 minuets. The number of the students who attended to each lesson was 40. Almost all of the students showed a hand when the teacher told them to raise a hand if they had questions. Twenty eight students asked the teacher about the upper stream of river. The contents of those questions were about the depth of the river, the temperature of the river, the size of the coarse fragments (stones), the kind of the lives, whether fish were there and whether fishermen were there. The findings on the practice follows:

1. Some students couldn't correctly recognize the width and depth of the river from the images and the still photos. It is difficult to recognize that can't be expressed by two dimensions by video images and photos .
2. It is necessary to show an appropriate object for comparison that let someone recognize the size. When the teacher taught the students about the size of the coarse fragments he put his shoe beside the fragments. He told them about the size of his shoe so that the students can recognize the size of the fragments.

Configuration of Network and Materials

Through these two experiments, our findings on the setup of the environments follows:

1. It was necessary to go to the place more than twice to configure and set up the network. The preparation of field lessons has to be begin very early because that is usually difficult to connect to the internet from places where it is suitable for field lessons. But it is difficult to go to places for field lessons because such places are usually far place.
2. It is easy to set up PIAFS networks: it always worked properly if an electric wave reaches.
3. The influence of the weather was remarkable. It was often needed to start a set up sequence of the video image's quality in the video conference system again because of the change in the weather. Also, the preparation to protect materials from rains (prepare the tent and so on) is important.

Establishing the environments of the computer network on the field lessons

How to build the environments of the computer network in the field lessons referring to the result. The establishment of the computer networks are restricted by following constraints.

1. Whether outside or inside of the school
2. The effective area of communication equipment (inside or outside the area of cellar telephones, PHS telephones, availability of ISDN public telephones)
3. Mobile area of equipment while the lesson
4. Users of mobile machines: (teachers or students)
5. Application software(video conferencing systems, web BBS, etc)
6. The period to use the network
7. The budget

Firstly, it should be decided which kind of the line to be used for connecting to the internet by dial up connections based on above conditions. We compared four kinds of lines to use dial up connections: telephone circuits(56Kbps), ISDN lines(128Kbps), PHSs (32Kbps), cellar telephones, and so on(ISDN1.5, dedicated lines and satellites are very expensive so that we can only use those lines for temporary circuit.). The characteristics of each

line are listed in the Table 1.

When you will use video conferencing systems, you want to use the ISDN lines. However the cost of the ISDN lines is expensive and the term to request from establishing a ISDN line to finishing the establishment of the ISDN line is too long(2 or 3 weeks). If you may lose the video quality, even the PIAFS network can be used in a class fully by the experiment "The dynamics of water flow".

If you use the network for outdoor use, serviceable area is one of the most important factor in deciding communication circuits. The serviceable area of an ISDN line is limited to the area where the cable for ISDN line can be reached. But this range can be extended by combining the ISDN line with the wireless LAN.

If you have only a short time to prepare the environments, you have better to check to use the PIAFS networks because it is difficult for teachers to construct temporary LANs with dialup routers and wireless hubs and the PIAFS networks works properly with the condition set up in advance if an electric wave reaches.

	Telephone	ISDN lines	Cellular	PHS(the PIAFS network)
speed	56Kbps	128Kbps(Balk connection)	9600bps	32Kbps
Cost	low	high (The public telephone: lower)	low	low
Communication use range	The range that a cable can be reached.	The range that a cable can be reached. (The range spreads out by combining it with the wireless LAN.)	The Japanese domestic whole area	The range of the PHS use that it was smelled around the city
set up	easily	more difficult	easily	easily
a term of establishing	2 or 3 days	2 or 3 weeks	no wait	no wait

Table 1: Characteristics of communication lines for dial up use

Conclusion

1. The network for field lessons
   The ISDN network provides a stable and higher speed communication link. However, establishing temporary ISDN lines are expensive and spend long time for preparation. If a field lesson is open for the long term, it is good to construct the stable network with the ISDN network. The dial-up network with notebook computers equipped with a PIAFS card is suitable for field lessons in the short time.
2. The effectiveness of computer networks on the field lessons
   It is effective to use the computer networks on the field lessons at the inconvenience place because the students can connect with a lot of web sights that provides various information by the network and the motivations of the students are raised due to communicating with someone in distant places. Also it is effective to use the computer networks
3. The video conferencing system
   It is difficult to recognize the details of things as shapes and size of shells with the video images sent by the video conferencing system. So we recommend to use steal photos too.
4. The limit of steal photos and video images
   It is difficult to make students recognize that can't be expressed by two dimensions by photos and video images. It is necessary to explain by the word under the present condition.

Acknowledgements

This research was advised by a grant from Mr. Takanashi of Keio Yochisha.
This research was supported from Hana Tsuchiya, Yasuhisa Kato, Hideyuki Hoshide.

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On-line Science Activities from the Network Montana Project and the NASA Ceres Project

David A. Thomas dave@math.montana.edu
Cynthia S. Thomas cynthia@math.montana.edu
Brian D. Beaudrie beaudrie@math.montana.edu
Montana State University
United States

Abstract: The Network Montana Project and the NASA CERES Project at Montana State University have created extensive on-line educational resources for K-12 science education on the themes *Earth System Science* and *Astronomy and Planetary Sciences*. In addition to classroom-ready activities, these projects have also developed graduate level distance learning courses for K-12 teachers interested in using project materials in their classrooms.Ê This paper presents an overview of the Network Montana and CERES project materials and summarizes lessons learned during their development, testing, and delivery.

Introduction

The Network Montana Project (NMP) was funded in 1995 by a three year 2.5 million dollar National Science Foundation Network Infrastructure for Education grant. The project involves a statewide collaborative effort with industry support to construct a scalable, sustainable network for Montana's educational needs. One aspect of the project focused on the development of WWW-based curricular materials for K-12 science education. In 1995, on-line scientific data began to appear on the WWW. The best developed of these WWW sites dealt with the earth sciences. Recognizing the potential value of such resources in K-12 education, NMP researchers set out to create prototype curricular materials that integrated mathematics, science, and technology in the context of contemporary scientific investigations on the theme Earth System Sciences (ESS).

The CERES Project was funded in 1996 by a one million dollar grant from NASA. The grant established a NASA Classroom of the Future in the Burns Telecommunications Center at Montana State University and supported the development of an extensive library of on-line and interactive K-12 science education materials for teaching astronomy. Closely aligned with the NRC National Science Education Standards, these next-generation, web based lessons make maximum use of exciting on-line NASA resources, data, and images. The development strategy sought to assemble classroom teachers, university professors, and NASA scientists to develop, field-test, and distribute innovative classroom ready lessons that would help students carry out inquiry based learning activities using genuine NASA data.

Both projects have developed on-line, graduate level, distance learning courses for K-12 teachers interested in formal instruction in the use of project materials. These courses are formal components in Montana State University's Master of Science Degree in Science Education by distance education program.

The Network Montana Project http://www.math.montana.edu/~nmp/

In 1995, there was little in the literature that offered a research basis for the development of WWW-based curricular materials. Borrowing from related literature and leaning heavily on experience, we proceeded on the basis of certain assumptions. The assumptions and what we learned follow:

1. *Assumption*: Using email and other telecommunications tools, writing teams consisting of (1) experienced K-12 teachers with high level computer and networking skills, (2) university mathematics and science educators, (3) university research scientists and mathematicians, and (4) graduate research assistants with extensive computer and networking skills could synthesize and sustain a shared vision encompassing content, format, and pedagogy, then implement that vision without the necessity for face-to-face meetings;

Lesson Learned: Over a period of months, it became painfully clear that *Assumption 1* was naïve at best. We all struggled to synthesize a common vision encompassing both the content and the format of the Earth System Science classroom activities. When it became clear that we were not making satisfactory progress toward that goal, a week-long, face-to-face meeting was scheduled for all participants. That meeting produced the breakthroughs we were seeking and taught us an important lesson. Begin every project with face-to-face meetings. These meetings must achieve several results before the participants are prepared to relate to one another as a team. Most importantly, participants must develop a shared vision of collaboration in which the team creates a valuable educational product in a context of trust and mutual respect. This can only happen in an authentic manner as the participants develop an appreciation for one another's strengths and weaknesses. This takes time and opportunity.

2. *Assumption*: Although there were only a few on-line databases at the beginning of our project to motivate the development of curricular materials, additional on-line resources would become available throughout our project, and we would use the new resources to create new curricular materials.

   Lesson Learned: Assumption 2 turned out to be true. What we did not anticipate was the publication of new on-line scientific databases almost on a monthly basis. Keeping up became a problem. While we all had experience using WWW browsers, none of us had ever attempted a systematic survey of WWW scientific or educational resources. We had only engaged in rambling, recreational meanders through cyberspace. Explorations of this sort typically take little effort, involve hardly any skill, and create the impression that finding information on the WWW is easy. This impression often leads to the false expectation that, perhaps with some clever insider knowledge, one may quickly and conveniently locate and retrieve specific sorts of on-line resources for educational and/or professional purposes. Systematic information mining is a difficult, time-consuming task involving high level skills and critical judgments. Considering the hundreds of hours we spent identifying, retrieving, reviewing, sorting, and selecting on-line resources, it is clear that this sort of activity ought to be thought of as a group responsibility rather than a task for an individual.

3. *Assumption*: We would all learn the necessary technologies and new science as necessity required;

   Lesson Learned: Assumption 3 was true by necessity, and we were all eager learners.

4. *Assumption*: The work would become easier and we would become more productive as we gained experience;

   Lesson Learned: In spite of our best efforts, staying abreast of new resources and technologies became progressively more complex and demanding. During development of the ESS materials, the discovery of unanticipated resources frequently reshaped our goals and expectations. Furthermore, as new scientific databases appeared during the year, changes and additions were made in activities previously considered complete and ready for field testing. This practice became an issue among the project personnel. Some individuals voiced concerns that the materials would never be completed and therefore never ready for dissemination. Others embraced the notion of a continuously evolving "product" that could be shared immediately. Eventually, the issue was forced by the appearance of new on-line scientific and educational resources that could not be ignored. We all came to accept the fact that efforts such as ours were inherently "works in progress" and should be published as such. Just as on-line data resources may under go periodic changes in content and format, on-line curricular materials may evolve (as time and resources permit) to take advantage of new and better information resources and changing pedagogical expectations.

5. *Assumption:* Classroom materials should demonstrate the value of on-line data, information, and computational resources in authentic scientific investigations, connect to and extend the existing curriculum, and implement national mathematics and science standards.

   Lesson Learned: Assumption 5 shaped the content and format of the ESS materials. Classroom activities are organized both by theme (See Table 1) and by grade level (Novice K-3 Intermediate 4-6, Advanced 7-9, Expert 10-12). To emphasize the global nature of scientific investigation and its cultural aspects, some of these materials have been translated into Russian in anticipation of collaborative, interactive educational

projects in which teachers and students in Russia and the United States will jointly investigate themes presented in the ESS materials. Teachers interested in participating in this project are invited to contact the authors.

Theme	Level	Activity Titles
Atmosphere	Novice	Exploration, Local Weather Data Collection, Analyzing Weather Data, Weather Journals and Predictions, Creating a Temperature Map, Cross-Curricular Connections
	Intermediate	Tracking a Winter Storm Across the USA, Tracking a Hurricane, Extensions and Long Term Project Ideas
	Advanced	Storm Chasing, Focus on Hurricane Andrew, Moving Air Masses
	Expert	Coriolis Effect, Global Circulation and Weather Maps, Weather Tracking and Interpretation
	Assessment	Items and activities for all levels
Geosphere	Novice	On Shaking Ground, Exploding Mountains, The Layered Earth
	Intermediate	Plate Tectonic Puzzle, The Moving Plates and The Plate Motion Calculator, Peanut Butter and Jelly Earth Layers
	Advanced	Mountain Building, Investigation of Hot Spots
	Expert	Measuring Volcanoes, Investigating Earthquakes, Plate Tectonics
	Assessment	Items and activities for all levels
Hydrosphere	Novice	Stream Ecosystems, The Water Cycle
	Intermediate	Observing Ocean Colors From Space, Measuring Global Sea Surface Temperatures, Strategic Sailboat Racing
	Advanced	Dynamic Sea Temperature Studies, Graphing Ocean Surface Temperatures, El Nino
	Expert	Running Water, Exploring Phytoplankton Pigment Concentrations, The Red River of the North: the flood of 1997
	Assessment	Items and activities for all levels
Mountain Environments	Novice	School Biome Detectives: Classroom Mountain Biome, Creating a Contour Map of Your School Playground, Where are Da Bears Now?, Fire in Yellowstone National Park
	Intermediate	Life Cycle of a Mountain, Ground Water - The Hidden Resource, Water Quality Monitoring and Streambed Sediments, Fire in Yellowstone National Park
	Advanced	Rocks and Topography, Advanced Mountain Topography, Bird Habitats, Measuring Earth's Vegetation from Space, Cryosphere
	Expert	Bighorn Sheep, In Search of Mountain Lions, Visualization Investigations
	Assessment	Items and activities for all levels
Maps, Models & Remote Sensing	Understanding and Using Maps	Old Maps, Contemporary WWW-based Mapping Services, Cartography: History, Issues, & Problems
	Understanding and Using Models	Making a Model of Your Classroom, Making a Paper Model of a Mountain, Making a Computer Model of a Mountain
	Understanding and Using Remote Sensing Data	What Is Remote Sensing?, Seeing With New Eyes, Applications of Remote Sensing, On-line Data & Information
	Montana Is My Home	Maps, Visual and Infrared Photography, Radar
	Moscow Is My Home	Maps, Visual and Infrared Photography, Radar
	On-line Resources	On-line Educational Resources

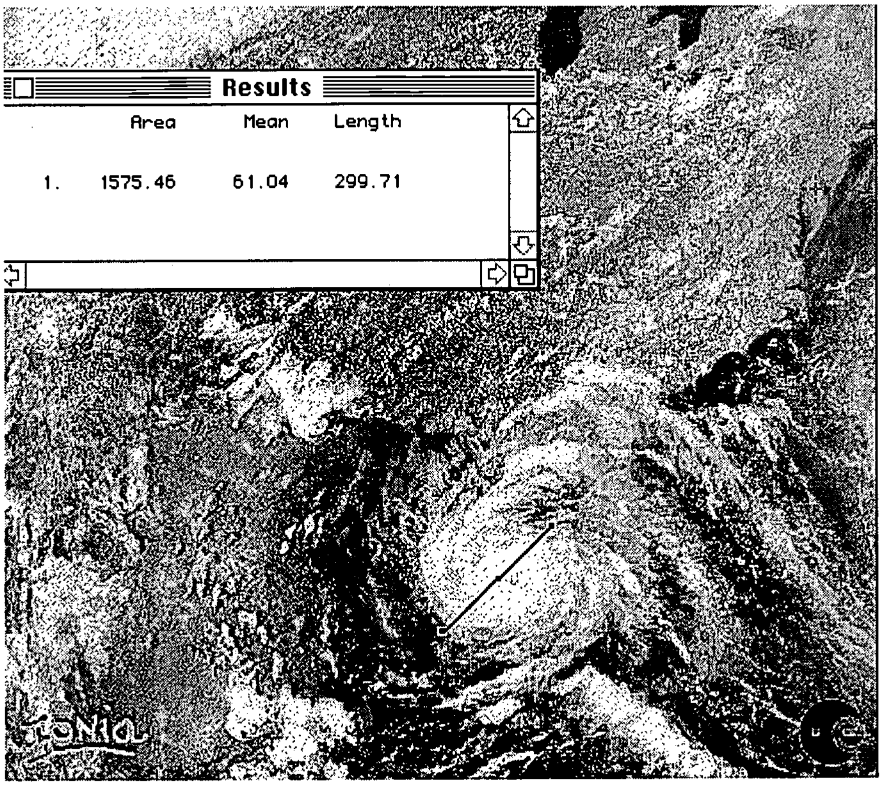
Table 1: Network Montana Project Earth System Science On-line Classroom Activities

6. *Assumption*: Most K-12 teachers encountering our curricular materials would do so at conferences, in local staff development workshops, while browsing the WWW, or as students in our distance learning courses;

   Lesson Learned: Teachers frequently share our materials with their colleagues and students.

The activity *Focus on Hurricane Andrew* illustrates our approach (See Figure 1). In the activity, students

- Learn how hurricanes change over time;
- Use on-line databases to obtain critical information necessary in calibrating the image processing tool NIH Image for measuring features on satellite images of Hurricane Andrew;
- Measure the diameter of Hurricane Andrew using NIH Image.



A two credit, graduate level, distance education course *Internet-based Earth System Science Instruction* based on the NMP ESS materials is offered through MSU's Master of Science Degree in Science Education program (http://btc.montana.edu/nten/sciedmasters.shtml). The instructor for the course is NMP Expert Level team leader Prof. Jerry Nelson of Casper College, Casper, WY. Schools interested in arranging special training and related professional development courses are invited to contact the authors for details.

The NASA CERES Project http://btc.montana.edu/ceres/

Most WWW users interested in space know that NASA has made vast databases and image libraries available on the Internet.Ê For example,ÊNASA has more than 750,000 individual images of the planet Jupiter located on the Jet Propulsion Laboratory (JPL) web site alone.Ê Although NASA categorizes these resources through Space Link (http://spacelink.nasa.gov/index.html), the sheer volume of available information and data makes the identification and acquisition of potential teaching resources a complex and time-consuming task. Most K-12 teachers lack the time and expertise to develop extensive educational resources based on NASA data.

The NASA CERES Project was charged specifically with the development and dissemination of WWW-based K-12 science education materials focused on NASA Office of Space Science themes: The Sun-Earth Connections, the Search for Origins, the Structure and Evolution of the Universe, and the Exploration of the Solar System. Based on a review of available data and images, the CERES Project selected Astronomy and Planetary Sciences as its theme and created classroom materials at grade levels K-4, 5-8, and 9-12.

Currently, there are twenty classroom-ready activities are available at the CERES web site (See Table 2).Ê These activities make use of some of the most relevant, recent, and exciting findings in contemporary space science.Ê Data from NASA's missions, both manned and unmanned, are used to create activities that motivate, engage, and challenge students.Ê

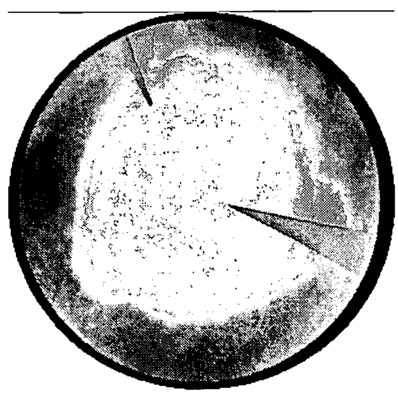
Resource	Grade Level	Activity Titles
Student Inquiries and Extension Lessons	K-4	Sky Paths, Learning Planet Sizes, Birthday Moons, Every Picture Tells a Story
	5-8	Every Picture Tells a Story, Investigating the Changing Polar Ice Caps, Planet Paths, Polar Caps: Image Processing Tutorial, Changing Faces, Analyzing Meteorological Data From Mars, How Much Do You Weigh on Distant Planets?, Digital Images: From Satellites to the Internet
	9-12	Sun's Impact on Earth's Temperature, Searching for Protoplanetary Systems, The Expanding Universe, Galactic Inquiry, Life Cycle of Stars
SpaceQuests	K-4	MoonQuest
	5-8	MarsQuest
	9-12	MountainQuest

Table 2: NASA CERES Project On-line Classroom Activities

CERES activities are structured investigations in which students explore NASA data in order to construct first-hand knowledge about the astronomical universe. These WWW-based activities are tied to the NRC National Science Education Standards astronomy objectives. Typically requiring 1 - 4 class periods, the activities can be used as an introduction to astronomy topics, as an intermediate activity, or as an extension requiring active participation by students.Ê These activities can be presented and taught under a variety of different strategies and settings, but having the students work in small groups and using a constructivist methodology maximizes the discovery potential.

The activity entitled *Investigating the Dynamic Martian Polar Caps* illustrates our approach. In this activity, students download NASA Hubble Space Telescope (HST) images of the Martian polar ice caps in summer and winter. Using image processing techniques, students measure and compare various images of the changing Martian and Earth polar ice caps (See Figure 2). In completing this activity, students

- Learn that
  - The size of the polar ice caps on Earth and Mars depend on the length of the planetary seasons;
  - Planetary seasons depend on the tilt of the axis of rotation;
  - The length of the season on each planet depends on the time for one orbit of the planet around the sun.
- Measure the sizes of the polar ice caps on Earth and Mars using image processing techniques.
- Compare the changing sizes of ice caps on Earth and Mars using the tilt of the axis of rotation, the time to complete an orbit (one year), and the time for one rotation about the axis (one day).



In 1995, San Diego State University education professor Bernie Dodge, together with Tom March, developed an innovative way to use the Internet to teach students at all levels.Ê He termed his idea a WebQuest (Dodge, 1995).Ê CERES WebQuests are small group, inquiry-based activities that ask students to use WWW-based

resources to gather and process information needed to complete an assignment. The class is divided into focus groups, each group working on a different aspect of the activity.Ê As each group completes its task, it reports its findings to the entire class.Ê These collaborative group projects require roughly 4 to 10 class hours and integrate a variety of science, mathematics, technology, and communication skills. CERES adopted the WebQuest format because it gives each student a clearly defined task with several entry points, it is flexible to the needs of both groups and individual students, it enables students to work at their own pace, and it provides a structured environment for introducing students to current information from NASA and other WWW sources.

The MoonQuest, written for grades K-4, contrasts myths written about the moon with scientific data provided by NASA and other sources.Ê The MarsQuest, written for students in grades 5 - 8, takes a futuristic look at interplanetary space travel and asks students to ponder the best vacation spot on the Red Planet. The MountainQuest is a more Earthly adventure.Ê Designed for high school students, this quest select the most suitable location on Earth for a new observatory.

CERES has also created WWW-based, graduate level, science education courses. The two courses currently offered are

1) Physics 580 *Studying the Universe with Space Observatories*
   Recent NASA missions have rapidly increased our ability to explore and understand the structure, dynamics and evolution of our universe. Mysteries from the inner workings of stars to the formation of galaxies and the beginnings of the universe itself are being unraveled with each new observation. At the same time, growth of the internet has allowed for rapid and direct dissemination of fundamental discoveries and scientific results to the public, sometimes even as they occur, and often without adequate scientific context or commentary. This course will provide the conceptual and scientific background necessary for understanding and interpreting the results of missions related to galactic and extragalactic space science. There has never been a more exciting time to become knowledgeable and involved in NASA's plan for the exploration of deep space.
2) Physics 580 *Comparative Planetology: Establishing a Virtual Presence in the Solar System*
   As viewed by the modern astronomer, the solar system is more than 70 diverse worlds interacting as a dynamic system. This online course for K-12 in-service teachers will focus on fundamental questions driving NASA's exploration of the solar system: How did the solar system form? What's in it, and how is it arranged? What does the study of other worlds (planets, moons, asteroids. and comets) teach us about our own? How do we learn about other worlds? How are these worlds similar and different? How do they interact, forming mini-systems within the solar system? What are their surfaces, atmospheres, and interiors like, and how do we know? By taking advantage of NASA's virtual presence in the solar system, course participants will conduct individual investigations and explore how K-12 students can use similar tools to conduct authentic scientific inquiries. Course participants will learn how to integrate NASA products (online images, WWW databases, and other resources) effectively in the classroom by adapting resources for classroom use.

The CERES and NMP on-line materials will be completed soon. Project leadership would like nothing better than to share what we have created and learned. Researchers and educators interested in learning more about CERES and Network Montana are invited to contact the authors for additional information.

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James, P., Clancy, T., Lee, S., & NASA (1997). Photo No.: STScI-PRC97-15b. *Seasonal Changes In Mars' North Polar Ice Cap.* URL http://oposite.stsci.edu/pubinfo/pr/97/15/B.html

Connecting from Nowhere: Application of Remote Satellite Telecomputing for Field-Based Science Teacher Education

Scott Walker, M.A.G.
South Texas Regional Collaborative for
Excellence in Science Teaching
Our Lady of the Lake University
United States
walks@lake.ollusa.edu

Abstract: This paper is a report on the findings of a study conducted on a graduate level virtual conference summer school course. Discourse analysis techniques were used to examine the resulting transcript of texts for evidence of a democratic discourse within a community of learners. Findings indicate that gender is not masked in the text driven discussions on the Internet. Distinctive discursive styles are often sex class linked. Like face to face or classroom contexts, status is accorded unequally within discourse communities. Participants are not equal and are not equally attended or responded to. Educators need to take a serious and wary approach to accepting claims of ensured democratic participation in computer mediated communication formatted classes.

Introduction

As wireless digital communications become more affordable and communication satellites offer increasing global coverage, Internet connections from anywhere in the world become more convenient. Science instructors from a variety of fields and education levels can apply digital satellite communications in their field-study programs without enormous overhead or specialized technical knowledge. Moreover, instructors can offer "virtual field trips" as a part of their higher education curriculum and share their knowledge with K-12 students and teachers around the globe.

In June of 1998, teachers from the Rural South Texas Regional Collaborative for Excellence in Science Teaching (the Collaborative) set out on a week-long paleontology field study in the remote desert of the West Texas Big Bend country. A part of this study included transmitting images, data, e-mail, and web pages from the desert site back to other Collaborative members who could not make the trip either due to financial or logistical reasons. Because of the remote nature of the study area, land-based telephone lines were not available for connecting to an Internet service provider. Cellular/digital phone communications were also not available. A communication solution was developed using a laptop and satellite phone. With this setup I was able to dial up the university modem bank, just as I would in making any other modem connection, and transfer data and e-mail to the university web and e-mail servers from the middle of nowhere.

Wireless data communications are commonplace in disaster relief and corporate settings, as well as in "high-end" virtual field trips sponsored by such entities as Microsoft, the Discovery Channel, or NASA, but there is little "how to" information readily available for the average instructor attempting to communicate via satellite. This paper explains what knowledge and equipment is required to make wireless connections from remote locations, based on my experience. This paper will also expose the difficulties one will want to be aware of and the real costs associated with wireless satellite communications for education.

The Concept

Satellite communication from remote locations is nothing new. In fact, many of the "live" international news reports we find on radio and television news broadcasts are achieved using a satellite phone (sat phone). With a "high-end" satellite communication system journalists can broadcast television quality news footage nearly instantly. However, the scope of this project was much smaller. The intention was to conduct a pilot project of transmitting daily updates from a weeklong teacher education field trip. The fieldtrip itself was designed to take

middle school science teachers to a dinosaur dig, led by professional paleontologists, so they could get a first hand look at how paleontology research is conducted. The group of teachers was to large to take into the field at one time, so half the teachers participated from the field one week while the other half participated from their schools or homes around Texas. The following week the groups switched places. The daily updates were to keep everyone informed of the "dig" activities.

Each day teachers would spend the morning in a field activity and then retreat back to camp during the 118F (48C) daytime heat to write reports, study, participate in lectures, or simply relax. One teacher compiled the morning's activities on her laptop, while I sorted through and edited the morning's digital images on my laptop. After I received the daily report on disk from the teachers, I built a web page for the day on my laptop. After I completed the web report I made a sat phone call via the laptop to my server in San Antonio. Once the connection was established, I transferred the new page and checked the e-mail for the day.

After completing the daily update and receiving the e-mail messages I did a "mail call." Several teachers received e-mail from their families, as well as those from the other teachers in program who were at home. We would answer the e-mails, make another call, transfer the messages, and complete the daily messaging.

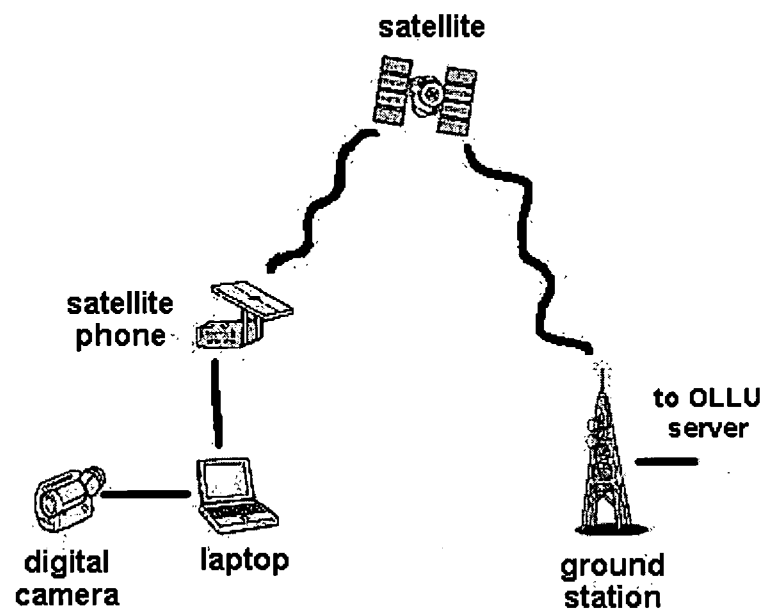

Figure 1: How digital information is transferred via a satellite telephone.

The Hardware and Software

A variety of electronic hardware components were required for this project. Likewise, several software applications were needed to create the web pages and transfer digital information. This section details the equipment and software used from start to finish, in the order that they were used.

Digital Camera

The digital camera I used for this project was a 1994 Apple Quicktake 100. Although the camera was old, it served the purpose of capturing the day's images to illustrate the activities the teachers had participated in. This particular camera will take up to 24 images on the low resolution setting. It takes only 8 pictures on the high setting, however, since computer monitors cannot display all of the data in a resolution rich digital image, I used the low resolution setting throughout. Likewise, the bandwidth requirements of high-resolution images was not available with the satellite phone file transfer.

This particular camera, like many of today's digital cameras, uses a lot of power. Each day I went through one set of three AA batteries. I also found myself having to download images to the laptop during the middle of an

activity. I recommend a digital camera that captures images on an interchangeable flash card or on a 3.5-inch floppy disk.

Laptop Computer

The laptop is an essential part of such a project. In this case the technology budget for the program was sufficient for the purchase of a quality laptop, however, it was not enough for a "rugged" laptop, as used in many expeditions. I did extensive comparison of laptops before I settled on a Toshiba model. The Toshiba laptops, although not rugged by military ruggedness standards, are quality machines.

Due to the limited, yet suitable, nature of the budget I chose a passive matrix computer screen. If I were to do it again I would select the brighter active matrix screen for using the computer in full sun. Also, the battery life of this particular computer is limited to about two hours. A longer-life battery, or a second battery, would be preferable. Technical specifications: Toshiba Satellite 325CDS, 32MB RAM, Pentium 200MHz, 2.0 GB, Windows 95.

Graphics Program

In order to create quality web pages, one needs a quality graphics program. In the creation of the web site that went with this project I used Adobe Photoshop extensively. In the field I used it to color correct the photos and alter the contrast and brightness. I also reduced the image sizes as small as possible, but still viewable in a web page, in order to save bandwidth in the transfer.

HTML Editor

Any HTML editor will work to create web pages. As it happens, our campus has a university-wide agreement with Microsoft and we can use FrontPage on campus or home, thus this was the editor of choice.

FTP Client

To transfer the newly created web pages to the web server I used WS FTP LT (Lite). This FTP client is available free on the web and it works well. I have used this client for several years, thus I had no reason to change or look for different FTP software. Any FTP client will work, once a dial-up connection is made.

Satellite Telephone

When using a satellite phone you are utilizing a telecommunications service, a specific satellite constellation, and the telephone hardware itself. When I conducted this project the only available satellite constellation in place was Inmarsat. As time has passed other companies have entered the satellite telephone picture and a choice may now be available. Likewise, a variety of new satellite phones have entered the market and it would be prudent to investigate the options.

I rented an Inmarsat Mini-M telephone from a service in New York. The service included the phone and the "air time," to put it in terms of cellular service. The phone has a built in modem, so a modem on the laptop itself is not required. The phone connects to the computer via a serial port cable. You configure the call in the Windows Dial-Up Networking just as you would if making a connection with a PC card modem.

Several satellite phone options were available at the time. I used the Mini-M due to the price of service and rental. Below are the specifications of some options:

Mini-M: 2400 baud (24Kb),
Inmarsat A:
Inmarsat B:

DC/AC Inverter

To keep the computer and satellite phone batteries fresh I used the battery power of my automobile. I plugged a 60 watt DC/AC inverter into the cigarette lighter and ran an extension cord to the phone and laptop. Caution is advised, as this can deplete the car battery within a few hours.

An alternative is to purchase a solar power system consisting of a photovoltaic (PV) cell, a transformer, and a deep cycle battery. The PV cell converts sunlight to electric energy, which is stored in the battery. Deep cycle batteries are recommended, as automobile batteries are designed to give strong, but short bursts of energy to start an automobile. Deep cycle batteries deliver a consistent flow of energy over a sustained period. Trolling motor batteries are typically deep cycle batteries and can be found commercially.

Internet Service Provider

To complete the connection from the laptop to the satellite to a location where others can access your information, you need a web server or Internet Service Provider (ISP). Any dial-up account on a web server allowing FTP access is sufficient. To complete my transfer I moved the web pages I created in the field from my laptop to my university Windows NT web server on my pre-existing account. Prior to the trip I had set up the appropriate directory and associated folders. From the field I simply moved the new pages to the proper location on the server.

In addition to the web access I had access to the university e-mail server through a new POP 3 e-mail account. I asked for a new account, rather than using my own, so I didn't have to receive all of my personal e-mail while in the field (I typically receive nearly 40 e-mails daily and those would have tied up my airtime with many needless messages).

The Cost

The entire cost of this project was funded by an Eisenhower Grant through the Texas Higher Education Authority for the Rural South Texas Regional Collaborative for excellence in Science Education. The entire technology portion of the budget was $xxxxxxx. Below is an itemized listing of the hardware and software I used in the project. I also include the costs of optional equipment, or equipment that could make a similar project better. The required equipment/services/software is listed first.

Item	**Cost**
Digital Camera	$400
Laptop Computer	$2000
Mini-M Satellite Phone	Rental/month - $475 Purchase - $3000
"Airtime" per minute	$3.10
AC/DC Inverter	$60
Optional	
Rugged Laptop	$4000
Photovoltaic electrical system	$300
Inmarsat B Satellite Phone	Rental/month - $ Purchase - $10,000

The Result

Be sure to include the drawbacks.

Resources

Laptops

Fieldworks rugged computers - http://www.field-works.com/
Toshiba computers -
Husky Computers -
Metacon Rugged Laptops - http://www.metecon.com/laptops.html

Satellite Telephones/Service

CSS Satellite Service
Inmarsat - http://www.inmarsat.org/inmarsat/index.html
Iridium -
Globe Star -

Electricity

Keep It Simple Systems (KISS) Photovoltaics - http://WildWestWeb.com/

Software

Tu Cows - Freeware FTP clients and HTML editors - http://www.tucows.com

Teacher's Use of Technology to Transform Secondary Science and Learning

Dean Eichorn, Science and Math Department Head, Mountain Secondary School, Langley, B. C., Canada, deichorn@sd35.bc.ca

Janice Woodrow, Professor Ermerita, Department of Curriculum Studies, Faculty of Education, University of British Columbia, Vancouver, B. C., Canada
Janice.Woodrow@ubc.ca

Abstract: This paper describes the practices of seven senior secondary science teachers who have successfully developed ways of teaching in a technology enhanced environment and transformed their classrooms as a result of these practices. Their teaching strategies include the use of interactive assessment procedures to closely monitor student progress, simultaneous supervision of multiple classroom activities, provision for multiple cognitive styles and rates of learning, the promotion of collaborative and active learning and the development of enhanced student skills such as those of time management, goal setting, self monitoring, and problem solving.

Introduction

This paper describes the changes that the application of the TESSI (Technology Enhanced Secondary Science Instruction) model made to science teachers' instructional practice, the new learning styles they accommodated, the curriculum materials that were developed to support technology use, and the outcomes of these changes. These practices were developed within the context of a long-term, field-based, collaborative action project. The founding researcher was one of the authors, Janice Woodrow. The seven participating teachers include: Gordon Spann and Aubry Farenholtz (physics teachers), Dean Eichorn and Axel Krause (biology teachers), and John Shim, Brad Hutchinson and Mike Lew (chemistry teachers) in the Province of British Columbia. The accomplishments of these teachers demonstrate what is possible when one understands that Technology Enhanced Instruction (TEI) signals a new realm of learning opportunities.

Rationale

Technology Enhanced Instruction has the potential to shift teaching from whole-class instruction toward small group tutoring, to motivate and engage learners, to appeal to learners with different learning styles, to stimulate problem solving and creativity, to facilitate variable learning rates, to encourage collaborative as opposed to competitive learning, and to bring the larger world into the classroom, (Collins 1991; Moonen & Collis 1991). Ensuring access to technology is insufficient to effect these changes. Teachers are the essential key in creating successful technology enhanced learning environments. From a teacher's perspective, what is required to implement and integrate technology into the science classroom as envisioned by Collins? Teachers need exemplars of successful technology enhanced environments which clearly demonstrate the new roles of students and teachers and an opportunity to learn new practices from the teachers involved: *"...teachers value learning from other teachers"* (Sandholtz & Ringstaff 1996 p 292). Real educational change occurs when the underlying frameworks of established classroom practice are changed. As one technology-using teacher commented: *"Having computers in my classroom changed everything!" (TESSI Teacher Feedback 1996)* Technology may be the catalyst to produce desired classroom change provided that the teachers are open to re-examining and challenging their beliefs about what constitutes good teaching and learning, are willing to experiment with new teaching practices, and are given professional support during the change process.

Context

The project that provides the context for this paper is the Technology Enhanced Secondary Science Instruction (TESSI) project, (Woodrow, Mayer-Smith, & Pedretti 1996). TESSI has developed a working model or exemplar of how technology might be systematically and successfully integrated into science classrooms to meet the needs of established curricula using state-of-the-art technology. Fundamental to the project is the premise that a variety of technologies must be available *within* the classroom itself and that technology is to be used as an enabling tool to enhance teaching and learning, not as a substitute for the teacher. The long time frame (seven years) of the study, coupled with the consistent use of the technology by both students and teachers were deemed essential for the model's validation.

Instructional and Learning Strategies

"[Class] was great today. At least 6 different things going on in the room at once. 'Teaching heaven'." (TESSI Teacher Feedback 1996)

The project equipped the classroom of each teacher with eight student computers, one teacher computer, a classroom server, a printer, a LAN, and a range of hardware and curriculum-based resources. The introduction of technology into the TESSI teachers' classrooms brought changes in the physical environment, teacher roles, and student behaviors, as well as a plethora of technical problems. Very early in the project, the teachers recognized the need to modify their style of teaching in order to realize the potential of the technology they were implementing. As the teachers and project director examined what was taking place in the TESSI classrooms and explored alternative methods, a pedagogical model for integrating technology with a particular view of learning began to emerge. This model is illustrated in (Fig. 1). The development of this model was guided by the following principles: instruction must be learner centered (i.e., task/learning oriented), technology must be classroom-based, software must be commercially available, software must be used as a tool as opposed to a tutorial, technology must be used to enhance student learning, and the model must be functional, feasible, flexible and transferable to other teachers.

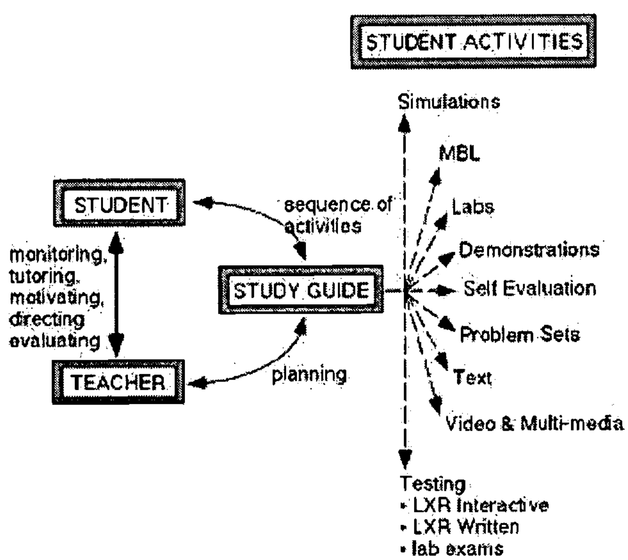

Figure 1: This diagram depicts the components and underlying structure of the TESSI model.

TESSI Study Guides

The TESSI teachers created Study Guides to establish the essential link between the curriculum and technology. The Guides function as "flowcharts" that support the learning of the students, guide them

sequentially through the curricular units, and direct them to the many classroom resources. Each Guide details the essential requirements for the successful completion of each unit. For example, (Fig. 2) shows a page from the Biology 12 DNA & Protein Synthesis Study Guide. One immediate consequence of the Guides is that students learn to manage their time efficiently. For example, if the technology needed for a specific activity is not available, rather than waiting to proceed, the student can carry on to the next activity. An added advantage of this approach is that it reduces the total amount of equipment required for each classroom and maximizes the use of the equipment that is available. The Guides are supplemented by a set of instruction sheets for the students' individualized activities. These activity sheets are completed by the student and either submitted to the teacher for marking or marked by the students and filed in individual assignment folders for review by the teacher. As the Study Guides were developed and implemented, many of the anticipated positive educational outcomes of the technology began to be realized.

PLO: Describe DNA Replication with reference to "Unzipping", complementary base pairing, and joining of adjacent nucleotides.

Select An Activity: Choose *one or two* of these three activities to help you understand the process of DNA replication.	
Computer Animation	**Computer Animation: DNA Replication** This computer animation gives a good review of DNA structure and DNA replication. **Instructions:** Capture three images, one for each step of DNA replication, from this presentation and paste them into a Word processing document with an appropriate description.
Computer Tutorial	**Computer Tutorial: DNA: The Molecule of Life** This tutorial CD provides a good presentation of DNA replication. **Instructions:** View scenes 22-23, and answer the question below. **Questions:** Diagram and describe the 3 steps of DNA replication. DNA
Computer Simulation	**Computer Simulation: DNA Replication** This program allows you to perform DNA replication on a simulated strand of DNA. **Instructions:** Obtain the instruction sheet for this activity from your teacher. Explorer 3.0

Figure 2: Sample from a Biology 12 Study guide illustrating the options provided for students to learn.

Small-Group and Individualized Instruction

The Study Guides made it feasible to replace most whole-class instruction with small group, individualized and guided, flexibly paced instruction that targets teacher intervention to each learner's *current* needs and promotes student time-management skills. As a result of this process, teacher-centered, transmissive instruction quickly gave way to a more learner-centered format. Whereas, before TESSI, the TESSI teachers may have spent 50% or more of class time presenting lectures and demonstrations, they now spend less than 10% of class time in this mode.

> *"I prefer to have my students be active learners rather than passive learners. The technology allows them to become more involved in their own learning—do things for themselves as opposed to me having to spoon-feed it to them all the time." (Eichorn, 1998)*

The physical structure of the TESSI classrooms supports (and almost dictates) the small-group and individual instructional strategies implemented by the teachers. The classrooms operate with a minimum of eight student computers for classes of approximately 26 students. Group work is a necessity given these physical limitations. The TESSI Study Guides are designed to incorporate a wide variety of activities, some of which require the use of computers while others are based upon multimedia (VCR or Laserdisc) or text resources. While some students work in groups of 2-3 on computers, others work on more traditional tasks including many hands-on activities. Rarely is the whole class simultaneously doing exactly the same activity. Students learn to plan their class activities to take turns using the computers. Demand on the computer facilities

is highest when students reach the interactive quizzes spaced throughout the units. These quizzes are, of course, done individually.

So exactly what do the teachers do during the class? Quite definitely, the computers have not replaced the teachers. TESSI teachers constantly circulate through their class dealing with individual students or small groups. The mode of instruction increases both the number and the complexity of student questions and these require the attention of the teacher who frequently has a "waiting list" of three or four groups. Many students bypass this "waiting list" by seeking help from their peers. The TESSI teachers find that this mode of instruction helps them to be more aware of the individual students' level of understanding and more available to enhance that level of understanding with instruction that targets specific needs. Moreover, students who require additional teacher attention do not hold back their peers. Rather than decreasing their workload, the teachers have found that the classroom technology has increased their repertoire of instructional strategies making them more effective teachers.

"Computers let me do a better job of teaching. They make it possible to use any teaching strategy that I want - lecture, research, discovery, exploration. Everything is possible with computers." (Journal entry, TESSI teacher 1998)

Computers have not decreased interaction among students either. In fact, the opposite has occurred. Students have increased their problem solving skills through active learning, collaborative work and peer tutoring. The students have taken greater ownership of their learning responsibilities and seek help rather than commands from their teachers. Improved independent learning skills, time management skills, and self-monitoring skills are some of the other changes in student development that the TESSI teachers have noted as outcomes of their new teaching-learning strategies.

"...[TESSI] provides more choices...more resources to reinforce what you're learning—going beyond the textbook...It's good, I've changed the way I study now—from more than one thing." (TESSI Biology 12 student 1997).

Provision for Multiple Learning Styles

In TESSI, technology is used to provide activities that create multiple representations of knowledge (mathematical, visual, dynamic) and address different learning styles (visual, tactile, verbal, mathematical). Wherever possible, technology is used to give students choices of how they reach course objectives. These choices are based upon variations in preferred student learning style through the use of available multiple technologies. See (Fig. 2). An objective of the Biology 12 course, for example, is that the students understand the process of DNA replication. The students are given the choice of learning this process by viewing a computer animation, a computer tutorial, or performing a computer simulation of the process. These activities achieve the same outcome. Only the method is different. An important outcome of being able to provide choices based upon learning styles is, of course, improved student learning. Another, is that often, students will complete more than one activity or compare results across the options.

"I like [the TESSI classroom]. Seeing a picture on an overhead doesn't help...It's way better in an animation...where you can see that something is fluid and moving." (TESSI Biology 11 student 1997)

Frequent Assessment

TESSI teachers have introduced many new assessment procedures into their courses—both formative and summative. Perhaps the most novel procedure is the use of LXR•TEST™ Interactive® to administer on-line quizzes 2-4 times per unit. Students are given the option of marking their quizzes as they proceed and viewing the correct solution. Most students take advantage of this option, viewing it as an added opportunity to check their understanding and learn the material. After completing the quiz, the students get their quiz score immediately as well as mastery information generated by the software.

"I like having the ability to look at the solutions so that I know how to do the next question." (TESSI Physics 11 Student 1997)

Another assessment strategy that some of the TESSI teachers have introduced is that of having the students set individual goals commensurate with their ability and course objectives. Students who do not initially achieve their goal, are given the opportunity to do some "corrective work" and a requiz on the same

material to raise their mark. See (Fig. 2). The ease with which valid and reliable quizzes can be constructed using LXR•TEST™ makes these assessment procedures feasible. To prepare the students for their Grade 12 Provincial exams, the summative test scheduled at the end of each unit is a traditional, paper and pencil test on which the students have no opportunity to retest.

One of the major outcomes of these assessment strategies has been a significant increase in student responsibility for learning. By knowing what they do and do not know, students are better able to manage their study time.

> *"The mastery reports are extremely useful. When I go to study for a final exam or unit test I simply have to focus on those areas that I did not master." (TESSI Physics 12 Student 1998)*

Interactive Quiz	**Interactive Quiz: DNA Quiz** Test your understanding on the computer. Take the quiz **'DNA Replication'**. Your quiz will be marked automatically. **Print out the results on your quiz and store them in your file folder...**	LXR Interactive

Compare Your Quiz Scores to Your Goal...

Goal Achieved!

Goal Not Met

file your work and move on....

Continue with the next topic...
Protein Synthesis

	Corrective Assignments: DNA Test Corrective Assignment **Assignment:** Audesirk Pg. 191 Review Questions #1, 2, 5, & 6. Label your completed assignment with the title: DNA Replication Test Corrective Assignment, your name, date and block, and hand it in to your teacher.
Interactive Requiz	**Interactive Re-Quiz: DNA Replication Requiz** LXR Interactive Test your progress on the computer. Take the requiz **'DNA Replication Requiz'** Your quiz will be marked automatically.

Figure 3: This excerpt from the Biology 12 Study Guide illustrates the process used to enable the students to retake summative quizzes after additional course work is completed.

TEI Learning Strategies

The availability of technology in the TESSI classrooms has enabled the implementation of a variety of new learning strategies designed to meet individual student needs and enhance student learning. One strategy is to enable students to progress through units at variable rates within teacher designated, global timelines. Another, is to actively encourage peer tutoring. Initially, some students resist tutoring opportunities, feeling that tutoring is not a good use of their time. The teachers overcome this reluctance by describing how the process of tutoring actually helps the tutor to learn and self-monitor just as much as it helps the tutees. Indeed, the uniqueness of the TESSI classrooms has made it essential that the teachers engage in frequent discussions about TESSI's pedagogy with the students. In particular, the teachers emphasize the role and responsibilities of the teacher, the role and responsibilities of the student, and the many benefits of this new method of learning. The need for this discourse is a lesson that was learned early in the project, and has been repeated with each new teacher that has joined TESSI.

> *"The teacher always says we have to 'learn to learn,' it's a little weird but I guess it's true because we're learning how to learn on our own with the different materials that are available, like through other people." (TESSI Physics 11 Student 1995)*

The elimination of teacher lectures has been largely replaced by students working collaboratively in

pairs and triads. Students use the Study Guides to direct their own learning and seek help from their peers and teacher when required. Students monitor their own learning by a) marking their own formative assignments and creating portfolios of their work, b) determining when they are ready for unit quizzes, c) determining when they need assistance and locating it, and d) striving to achieve their personal course goal. One immediate result of the implementation of these learning strategies was a marked increase in student "on task" behaviour. Students enter the class knowing their goal for the period and ready are to work.

> *"One Gr. 12 Biology student has indicated to me that he vastly prefers the TESSI Biology to his other classes. He finds the class more interesting, more involved, and finds that he's more in charge of what he does on a daily basis. Besides PE, it is the only class he says he looks forward to.*" (TESSI Teacher Feedback 1997)

Conclusion

TESSI is a scaleable and reproducible model of TEI implementation, which has encouraged greater student enrollment and retention in senior science electives (i.e. greater success for more students), and has prepared students for post-secondary education and the realities of an information-based workplace. The results of the TESSI project support claims that learning can be enhanced through the thoughtful implementation of TEI. Further, the practices developed by TESSI illustrate *how* technology can be successfully integrated into daily classroom practice. Teachers are the key to whether or not technology is used appropriately in education. The TEI model developed by the TESSI project exemplifies Baker, Herman and Gearhart's (1996) principle that "*Technology use must be grounded firmly in curriculum goals, incorporated in sound instructional process, and deeply integrated with subject-matter content.*" (p 200).

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Acknowledgments

The authors would like acknowledge the support of the many agencies and firms that have provided financial and in-kind support to TESSI including the Vancouver Foundation, the Chawker's Foundation, the Langely, Richmond, Abbotsford, Kelowna and Powell River School Districts, the University of British Columbia, Prentice Hall, Canada, Apple Computers, Canada, Logic eXtension Resources, Knowledge Revolution, Merlan Scientific, Pasco Scientific, Texas Instruments, Center for Image Processing in Education, the B. C. Ministry of Education, and the TeleLearning Research Network.

WhaleWatch: An Intelligent Multimedia Math Tutor

David M. Hart, Ivon Arroyo, Joseph E. Beck and Beverly P. Woolf
Center for Computer-Based Instructional Technology
Department of Computer Science
University of Massachusetts, Amherst
United States
{dhart,ivon,beck,bev}@cs.umass.edu

Carole R. Beal
Department of Psychology
University of Massachusetts, Amherst
United States
cbeal@psych.umass.edu

Abstract: Mathematics training is essential for participation in science and engineering careers, yet many students, especially girls, dislike and avoid math, and are therefore unprepared for university science majors and graduate programs. The goal of this project is to increase students' interest in math and their confidence in their ability to learn math through an intelligent, model-based multimedia tutor, WhaleWatch. Based on a dynamically updated student model, WhaleWatch selects problems of appropriate difficulty and provides help and instruction as needed. The results of several evaluation studies indicate that WhaleWatch had a positive impact on students' math self concept and beliefs in the value of learning mathematics. These results also suggest beneficial tutor modifications that will be incorporated WhaleWatch's successor, AnimalWatch.

Increasing Girls' Self-Confidence in Math

It is well documented that women are under-represented in math and science career fields, a problem that is getting worse instead of better in areas such as Computer Science. This problem can be attributed in part to math avoidance among girls, who frequently drop out of mathematics courses when they become optional at the secondary level, and as a result perform less well on math achievement tests (Beal, 1994; Beller & Gafni, 1996). Because these same math courses are prerequisites for most math and science careers, many girls find themselves shut out of these fields early on. Even the most mathematically gifted girls have less math training and are less interested in science careers than their male peers (Benbow, 1992). One phenomena often cited as a turning point for girls in their math education is a drop in their self-confidence that occurs between 5th grade (11 years old) and 8th grade (14). Before fifth grade girls participate fully and perform as well as boys; after this period they lose interest.

A collaborative of researchers from Psychology, Computer Science and Education have joined in a project to create an intelligent tutoring system called WhaleWatch whose goal is to raise girls' self-confidence in their math skills during this critical period in their development. Why an intelligent computer tutor? Feedback from teachers, whether conscious or unconscious, has been shown to reinforce boys' self-confidence while lowering girls' (Beal, 1994; Boggiano & Barrett, 1991). The WhaleWatch tutor is designed to be encouraging of both girls and boys in its response.

An inherent danger exists, however, in addressing this problem with computers – computer programs have traditionally been designed by men, and typically use competitive and excitement-oriented paradigms to engage the user. Studies have shown that girls are not as attracted to these paradigms, preferring instead activities whose content is less game-like and which feature more characterization and role playing. They also like to work together, interacting cooperatively rather than competitively. WhaleWatch has been designed with these features in mind, using the study of endangered species such as

Right Whales as a context for problem-solving [1], and providing the student the opportunity to select a mentoring character as a guide through the activity. While it does not yet provide a good method for students to collaborate while working with the tutor, we are exploring ways to incorporate this.

WhaleWatch is being developed with the collaboration of two local school systems, the Frontier Regional Schools in suburban/rural Western Massachusetts, and the Springfield Public Schools, and urban school setting also in Western Massachusetts. These two systems are an interesting contrast in demographics and in the kinds of computer resources available for students, which provides a wide range of conditions for testing WhaleWatch. We have tested a WhaleWatch prototype in four different trials in these systems between 1996 and the present. These formative tests have yielded encouraging data on the potential for boosting girls' self-confidence in math, while at the same time giving us critical feedback on the effectiveness of the tutor for both girls and boys. This feedback will be incorporated into the design of an expanded tutor under development now called AnimalWatch, which will build on WhaleWatch by adding more species and a broader range of math topics.

WhaleWatch: The Tutor

WhaleWatch uses intelligent tutoring techniques to help students learn fractions, decimals and percentages at a 5th-6th grade level. In contrast to common drill-and-practice systems, intelligent tutoring systems modify themselves to conform to the students' learning styles (Anderson, et al., 1995). WhaleWatch begins students with whole-number arithmetic problems in order to build a profile of what the student already knows and how fast the student can advance. Once the student demonstrates mastery of whole numbers, the tutor presents simple fractional problems that require increasingly challenging application of the cognitive subtasks involved in solving the problems (e.g. adding fractions with like denominators, adding fractions with different denominators, etc.).

Interaction between the student and WhaleWatch is built around word problems that are contextualized using the endangered species theme. These include questions about Right Whales' feeding habits, migration patterns and population, as we see in (Fig. 1). Graphics of whales are used to help set the scene for students. AnimalWatch will expand on this contextualization, adding more narrative, using various other endangered species, and increasing the connection between the problems and the students' ability to manipulate the objects onscreen in order to solve the problems presented.

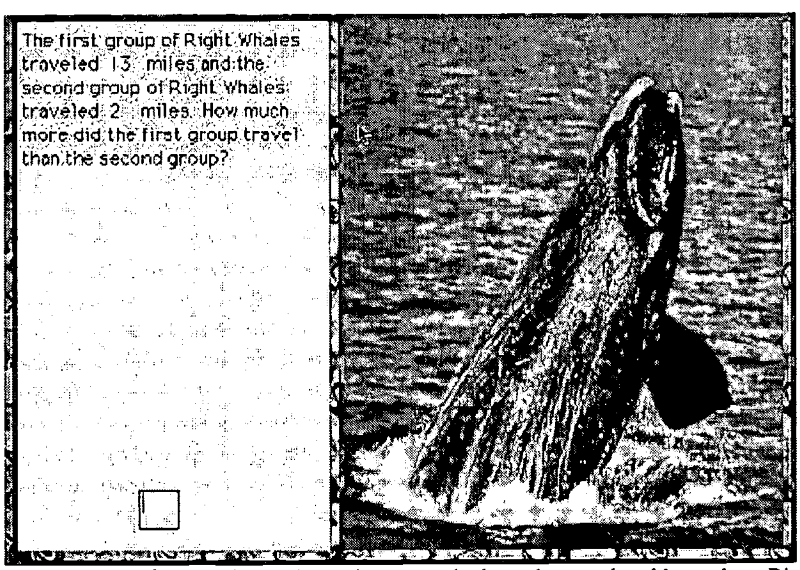

Figure 1: WhaleWatch Tutoring Interface. The students are asked to solve word problems about Right Whales, an endangered species.

[1][] Of all the sciences, women are best represented in biology and especially environmental science.

When a student has trouble solving a problem, WhaleWatch initiates a tutoring interaction such as the one shown in (Fig. 2) that provides tailored hints and guidance that helps the student work through the problem. Similar problems involving the same subskills are given until the student can successfully work the problems. The example shown in (Fig. 2) is a tutoring aid to help a student understand Equivalent Fractions. To solve the fractions problem shown here, 1/4 + 1/2, the fractions must first be converted to equivalent forms (i.e. fractions of the same denominator). The window shown overlaying the picture of the whale is an interactive calculator for finding equivalent fractions. As the student clicks on the Up and Down buttons, the fraction is multiplied or divided. At the same time, the Cuisenaire Bars shown under the fractions are divided into parts that coincide with the fraction above. For example, the bar under the 1/4 fraction in the top right is divided into four parts, one of which is colored to show the fraction of four given by the numerator one. By alternately multiplying and dividing the upper and lower fractions, the student can use this calculator to find their equivalent forms. Once they are found, 1/4 and 2/4, the student can add them and enter the answer in the boxes at the lower left in the main problem window. A correct answer elicits positive auditory feedback, while an incorrect answer elicits encouragement to try again. The next problem the student is given will be easier or harder, based on the student's ease in solving this one.

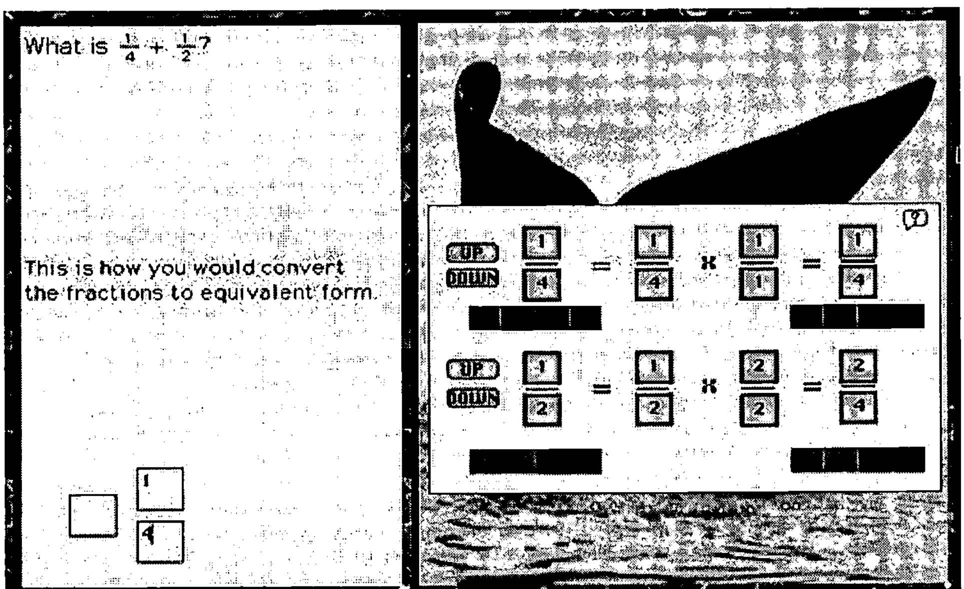

Figure 2: WhaleWatch Hinting. When the student makes a mistake solving a word problem, WhaleWatch offers hints in the right window pane that are designed to help the student understand her mistake and master the subskill in question.

For WhaleWatch to be successful in its tutoring, it must maintain an accurate assessment of the student's strengths and weaknesses in this task domain. Online self-assessment surveys conducted as students work with WhaleWatch have shown that the tutor generates a more accurate assessment of each student's abilities than the students themselves (Beck, et al., 1997a). WhaleWatch uses Artificial Intelligence techniques for problem generation, hint selection and student modeling (Beck, et al., 1997b; Beal, et al., 1998). Multimedia is used judiciously to engage the student by animating key concepts and providing interactive manipulables based on those used by classroom teachers.

WhaleWatch Testing and Results

Classroom trials of the WhaleWatch prototype for purposes of formative evaluation have been conducted on four occasions, three times in Deerfield, and once in Springfield. Typically these trials involve two or three classes for as many as 60 students who use the tutor for up to five hours (in 60- or 90-minute sittings over several days). Standardized tests of self-confidence (Eccles, et al., 1993) are given by paper and pencil as pretests before students start the trials, and then afterward the same tests are given

again. In future trials we will introduce standardized testing for math proficiency as well. We briefly summarize results of these trials here.

Evaluation Study 1

The first evaluation study was designed to determine if WhaleWatch could in fact have a positive effect on girls' self-confidence. Results of this study, conducted with three classes in the spring of 1997, showed that WhaleWatch did increase girls' self-confidence, raising it to a level on par with the boys'. The boys' confidence level, which started out higher, remained the same (Beal, et al., 1998; Beck, et al., 1997a; Beck, et al., 1999).

Evaluation Study 2

While the first evaluation study gave promising results, it did not clearly show that the change in girls' confidence was due to the help and guidance of the tutor itself. To test this hypothesis, we designed an experiment in which half of the students from each class using the "tutor" would get all the help and guidance the system had provided in Evaluation Study 1 (the treatment group), and half would get none of this help (the control). This second group would see word problems about whales and could enter solutions, but would get no feedback other than the answer was correct or incorrect. In effect, these students were doing drill-and-practice while the treatment group would receive the full benefits of intelligent tutoring.

In conjunction with this evaluation study we administered for the first time an online Piagetian pretest designed to identify each student's level of mathematical cognitive development (Arroyo, et al., 1999a; Arroyo, et al., 1999b). Results of this test allowed us to correlate student performance and changes in self-confidence with cognitive ability.

Results of this evaluation study, detailed in (Beck, et al., 1999) held several surprises. Reassuringly, girls benefited from the help provided by the tutor, though this was not seen as clearly as in Evaluation Study 1 [2]. Boys, on the other hand, had their confidence levels increased in the control condition (no tutor help), while their confidence level *decreased* in the treatment condition (tutor help). We hypothesize that boys felt constrained by the amount of time taken by hinting (hints could be elaborate), and subconsciously preferred not to be slowed down. This would argue for changing the hinting mechanism to be less elaborate and allow user termination of each hint during delivery. AnimalWatch is being designed to support this method of hinting.

Another surprising finding is that the tutor was most helpful to a group of students in the mid range of cognitive abilities, as determined by the Piagetian pretest (Arroyo, et al., 1999b). These students' performance using the tutor was increased significantly, while students at the upper and lower cognitive ranges were not significantly helped. This suggests that we broaden the scope of the hinting capabilities as we create AnimalWatch, producing hints that are more concrete and that use interactive manipulables for the low cognitive ability students, while also providing more abstract and symbolic hinting for students at the higher end of the cognitive scale (Arroyo, et al., 1999b). An example of the former, a more concrete hint, is shown in (Fig. 3).

This AnimalWatch hint employs Cuisenaire Rods, a commonly used classroom manipulative. In the simple addition-of-wholes example shown, the student is assisted through the steps in adding 25 and 79. Unlike WhaleWatch, which used a static set of values for its hints, AnimalWatch hints will be passed the values of the actual problem the student is trying to solve. Cuisenaire Rods representing each value can be manipulated by the student. Unit boxes are dragged into the lower right box, where the sum box (shown here as zero) accumulates a value for the number of Units dragged in. Similarly, rods representing Tens are dragged into lower center box, where their sum is incremented with each bar that is added. Next the student is encouraged to move groups of ten unit boxes from the Units box to the Tens box, and then to move groups of Tens to the Hundreds box (lower left). This form of concrete, manipulative-driven hint is

[2][] It appears that the assignment of girls to control and treatment groups, while random, produced biased samples. Specifically, the girls in the treatment group had confidence levels and pretest scores that were significantly higher than those in the control group. In fact, their confidence levels before using the tutor were higher than the confidence levels of girls from the previous year *after* they had used the tutor. This seems to have produced a ceiling effect on confidence levels in the girls' treatment group, preventing us from seeing an increase corresponding to that seen in Evaluation Study 1.

designed to be particularly useful to students at the lower end of the cognitive ability scale. AnimalWatch will include hint-selection capabilities that will factor in differences in student ability (among other attributes) and select hints that are more targeted than those in WhaleWatch.

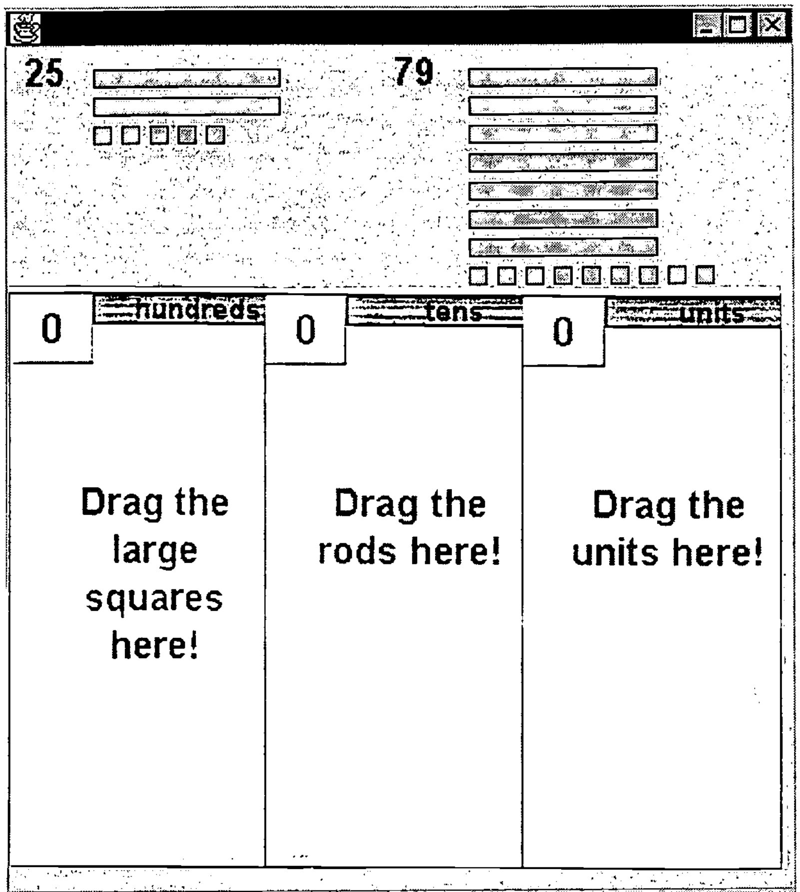

Figure 3: AnimalWatch hinting will be more interactive, allowing students to manipulate objects onscreen as they explore the concepts underlying operations on fractions, decimals and percentages.

From WhaleWatch to AnimalWatch

Over the next three years WhaleWatch will be expanded to include many of the new features described above, and will also have more content added (increasing the average student contact time to 20 hours) and will see the introduction of other endangered species for added context, necessitating the name change to AnimalWatch. Larger scale trials with more contact time will be conducted in Deerfield and Springfield during this time.

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Acknowledgments

This material is based upon work supported by the National Science Foundation's Program for Gender Equity in Science, Mathematics, Engineering and Technology (NSF HRD-9555737 and NSF HRD-9714757). It has also received support from the University of Massachusetts at Amherst and from the Frontier Regional School System and the Springfield School System. Collaborators include Klaus Schultz from the University's School of Education, Diana Campbell and Charlene Galenski from the Frontier Schools, and many others who have contributed their talents and expertise to this project. Ivon Arroyo is supported by a Fulbright Fellowship from the U.S. government.

Museums in the Classroom: Using Technology to Bridge Formal and Informal Science Education

Bryan Wunar
Department of Education
Adler Planetarium & Astronomy Museum
United States
Wunar@adlernet.org

Michael Childs
Department of Education
Adler Planetarium & Astronomy Museum
United States
Childs@adlernet.org

Abstract: The educational technology program outlined in this paper was developed by Adler Planetarium & Astronomy Museum for the Illinois State Board of EducationÕs Museums in the Classroom Program. The *MIC* program partners the Adler Planetarium, as well as other Illinois Museums, with K - 12 teachers and students, throughout the state. AdlerÕs *MIC* program empowers teachers with effective ways of utilizing technology to expand the museum experience and bring museum resources into the classroom. Using Internet-based technologies *Museums in the Classroom* will expand teachers abilities and students understanding of science and astronomy.

Program Overview

Throughout human history, we have set out on a quest to identify our place in space and time. This ongoing endeavor has challenged us to give meaning to the mysteries of the universe through the pursuit of science. *Museums in the Classroom* uses astronomy as a context to promote interdisciplinary learning, providing natural links between the domains of science and across the curriculum by utilizing technology. The focus of this integration is to develop inquiry-based projects which allow the students to learn about universal phenomena, by using the resources of the Adler Planetarium & Astronomy Museum.

Museums in the Classroom is a professional development program designed to empower teachers with innovative and effective ways of integrating Internet-based technologies, museum resources and astronomy-related themes into their instructional program to create student-centered web-based curriculum projects. The *Museums in the Classroom* model builds upon the successes of the previous educational technology projects implemented by the Adler Planetarium & Astronomy Museum, and relies on mobilizing a force of teachers who are developing more advanced skills and greater capacities at each level of participation to drive the progression of technology-based teaching and learning. The program is aligned with the Center for Children and TechnologyÕs recommendations for establishing effective staff development practices to support teachers in integrating Internet resources into the curriculum and introduce development and design techniques to build creative and functional web sites (Honey et al, 1998). The *MIC* program is a collaborative endeavor that links the institutional resources with classrooms throughout Illinois to nurture and support engaged learning and teaching strategies that prepare students for a technologically advancing society. On visits to Adler, participants gather content from exhibits, galleries, and collections, inquire and discuss topics with expert staff members, and gather research material for their projects. The program continues in the classrooms by giving teachers the materials and means to involve students in the design of project web sites, utilizing technology to communicate, research, develop and learn.

Institutional Background

The Adler Planetarium & Astronomy Museum opened in 1930 and has become one of the nationÕs leading science centers for the interpretation of the exploration of the Universe to the broadest possible audience. In January 1999, the Adler opens the new Sky Pavilion which includes 40,000 square feet of new exhibit space, state of the art computer-driven technologies connecting visitors to a wealth of science and astronomy resources, and the total immersion technology of the worldÕs first StarRider Theater. AdlerÕs world-renowned collection of historical astronomical instruments, a staff of research astronomers and educators, and the new exhibits and theater facilities, makes it an institution offering unique opportunities for all visitors.

Program Components

Museums in the Classroom is composed of several components that will enable teachers and students to approach the process in unique and effective ways. Technology is a major component in this program and consists of the capabilities and resources of Adler as well as those provided to the participants. The technology resources used by the teachers and students in the classrooms both expand and extend the experience they receive at the museum.

Adler Technology Resources

The Adler is uniquely positioned to assume a leadership role in incorporating telecommunications into education, especially science education. AdlerÕs Internet activities and experience with distance learning, coupled with years of educational programming, places it at the forefront of learning technology applications. With the forthcoming facilities expansion, the Adler is poised to communicate the wonders of astronomy and the Universe in unique ways not readily accessible to schools and families...*Museums in the Classroom* will make those links not only for schools in Illinois, but for our global communities as well.

At the completion of the PlanetariumÕs new Sky Pavilion, minimally fast ethernet connectivity will be capable of being brought to any point on the exhibit floor. Further, during the construction phase a fiber-optic backbone capable of handling very high speed data transmission internally will be installed. AdlerÕs Internet connection currently consists of two T-1 lines. One line originates from the University of Chicago and provides connectivity for AdlerÕs staff and internal network. The second line from the State of Illinois provides connectivity for one of the Educational Networking ConsortiumÕs 8-modem terminal servers for Chicago area teachers, the AdlerÕs computer classroom and for higher bandwidth applications such as existing websites and video reflector sites.

This year the Adler has started utilizing a high quality teleconferencing classroom. Funded through a collaborative grant from the Chicago Consortium for Higher Education (CCHE), it will consist of the equipment necessary to operate the video classroom, funding to remodel the classroom space and a dedicated T-1 line connected to the CCHE video network of schools and community colleges. With the addition of two ISDN lines, the Adler will be able to teleconference with virtually any teleconferencing center in the United States.

Teacher Technology Resources

Participating teachers are provided with both a laptop and a desktop computers for use in the classroom for Internet research, web development, and communication like e-mail, FTP and distance learning. Increasing teacher and student communication capacities is at the core of *Museums in the Classroom*. The following describes how this communication will be facilitated and the training structure developed to ensure effective participation. All participants will be provided with First Class, a user-friendly e-mail communication software package. Through First Class, teachers and students will have the ability to engage in an ongoing dialogue with other schools, project staff, museum educators and research scientists, reducing the isolation between schools and within school communities. This will be accomplished through direct e-mail between project members as well as through the project listserve and e-mail conferences that will be scheduled throughout the project. In addition to e-mail resources, teacher participants will receive the equipment, training and support necessary to effectively participate in

on-line videoconferencing. Regularly scheduled videoconferences will be established to encourage interaction between participants and to provide ongoing professional development for participating teachers. These videoconferences will be opportunities for teachers to share their experiences and solicit help from members of the learning community to address issues they are facing in their teaching. Videoconferencing will also serve as a means of connecting students in the classroom to museum staff and resources from remote sites. In order to ensure the development of skills necessary to effectively use educational technology, teacher training will play a significant role at all levels of program activities. The initial workshop will provide the teachers with the necessary background to use e-mail, participate in the on-line discussions and videoconferences. The media technology specialist will provide assistance in the use of the technology and web page development through the field experience and school site visits. The project staff will also coordinate the activities with the Illinois State Board of Education regional technology hub sites in an effort to standardize the training the teachers receive.

Teacher Workshops

Teachers participate in a two day workshop where they have the opportunity to explore the emense resources of the Adler Planetarium & Astronomy Museum. The workshop introduces the participants to the museums project staff and focuses on a range of topics, including teaching strategies using museum exhibits, inquiry-based astronomy and science education activities, aligning their curriculum projects with the National Science Education Standards (National Research Council, 1996) and the Illinois Learning Standards (Illinois State Board of Education, 1997), and how to facilitate learning through Internet-based distance learning experiences. Teachers spend time exploring the museum floor, both guided and on their own, as well as utilize AdlerÕs technology resources to investigate further content and learning opportunities. The workshops will provide the foundation for successful participation in *Museums in the Classroom* throughout the academic year. The model set forth in the initial workshop sets the standard for follow-up workshops to continue presenting astronomy activities and projects as well as technology issues throughout the program.

Student/Teacher Field Experiences

After the first Teacher Workshop teachers return with students to investigate the exhibits and collections at the Adler Planetarium & Astronomy Museum. The students and teachers take digital photographs of exhibit elements, go behind the scenes to investigate exhibit development and sky show production, and talk with staff astronomers, historians, scientists, artists, technology specialists, and educators to gain an understanding of various approaches to the development of their web-based curriculum projects.

Communication: Onsite and Online

An integral part of *Museums in the Classroom* is a structure for ongoing communication and continued learning between all participants. Physical visits, by Adler staff, will be supplemented by online communication with the staff as well as other participating teachers. This communication structure will consist of the use of the First Class e-mail system as a primary source of networking between project staff and the teacher participants. On-line conferences will be set up to allow teachers to communicate with one another, to promote the sharing of ideas, breaking down the isolation between teachers and establishing professional networks. In addition to e-mail, the project staff will continue to provide professional support to the teachers through videoconferencing. Regularly scheduled videoconferences will be established, and teachers will be encourage to participate in the discussions. The videoconferences will also enable the teacher to bring museum personnel and resources into the classroom from remote sites.

Throughout the school year, Adler project staff will provide sustained support for teachers and students in the development of their projects. The media technology specialist and other project staff will visit each school to offer additional training for teachers and to work with students on web page design. This classroom support, in addition to the field experiences and ongoing electronic communication, will result in a system for building teachersÕ professional capacity as well as engaging the students at all stages of the learning process.

Conclusion

Museums in the Classroom provides important outcomes for both students and teachers. Throughout the academic year, teacher participants are be involved in sustained professional development activities that upgrade their skills and provide support for their classroom instruction by broadening their professional networks. The teachers will work with their students to define the scope of the curriculum project, involving students in the research process both in and out of the classroom. The students and teachers who participate in this program will become members of a learning community in which technology promotes communication and increases access to information. Interaction with museum staff and other members of this community will occur within the museum sites, in the classroom and from remote sites via distance learning. Through these multiple modes of learning, students will be provided with opportunities to expand their knowledge beyond the traditional classroom approach and to interact with students and experts alike. The results of the learning process will be expressed by the students through the web pages they design, allowing the world to access their representations, their discoveries and their understanding of the world around them.

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Acknowledgments

Funding for Adler Planetarium & Astronomy MuseumÕs *Museums in the Classroom Project* has been provided by the Illinois State Board of Education Museums in the Classroom Grant Program.

A Model for Problem Solving in Introductory Science Courses

Douglas N. Yarger, Rex Thomas, Leslie Pease, Vicki Boysen, Peter
Boysen
Iowa State University Ames, IA 50011
United States
doug@iastate.edu

Abstract: Simulations are being used to help promote active-student learning and stimulate knowledge-construction in a large undergraduate survey course in meteorology. The use of these activities has revealed a prevailing lack of problem solving skills possessed by students while, at the same time, provided a means for remedying these shortcomings. The paper addresses the design and use of simulations as instruments for the development of learning skills as well as science content acquisition.

Introduction

Meaningful learning requires the establishment of relationships among the elements of new material to be learned and between the new material and relevant previous learning. Meaningful learning has two parts: the process of establishing relationships, and the relationships themselves. The strength of learning is reflected in the number and worth of the relationships established, whereas success in future learning is dependent on the students' understanding and internalization of learning and problem solving strategies. To encourage meaningful learning it is essential that we provide students with learning opportunities where the relationships are not immediately evident

knowledge, developing appropriate strategies and reflecting on the results. Unfortunately, these learning experiences can encourage excessive confusion, frustration and failure.

Due to the fine line between motivational impediments and debilitating obstacles the goal of making learning meaningful presents a major challenge for educators. It is no longer appropriate to simply organize information, deliver it to the students and test for recall. New procedures for developing curricular materials, creating learning activities, managing the learning environment, and evaluation must be found. Unfortunately, the pathway for producing effective learning is not well lighted, but the following factors are emerging. (1) Clear goals must be established. (2) Opportunities must exist for students to solve authentic problems to accomplish the goals. (3) Material and processes to be learned must be available in order to accomplish the goal. (4) Guidance must be available, at the time it is needed to help students improve their strategies for learning. (5) Evaluation must place primary emphasis on acquisition and use of learning strategies.

Fortunately, educators also have two new tools for meeting the challenge. Technology is available which can serve as a major tool in providing and controlling the learning environment and the theory of constructivism is evolving to enable better understanding of student learning. This paper describes a project designed to use these tools to restructure and transform the university classroom.

The Project

An Iowa State University introductory meteorology class is being restructured in light of constructivist principles. The primary course goals have been elevated from the learning of science content to learning how to learn science. Of course, in the process of learning how to learn science, much science content is learned. The focus of the course is on the understanding of weather phenomena, and a primary vehicle for learning is simulation. At this time an authentic forecasting activity where each student routinely predicts weather events and supports their prediction by identifying determining factors, and an accompanying ensemble of Java-based microworlds of scientific phenomena are being used. Together these simulations provide opportunities for students to be cast into the role of scientists. They take data, attempt to make sense of the data, seek to determine why it should happen that

way, put it into context by relating it to things they already know and then interact with experts in order to resolve issues which they can't explain.

Activities and management of the course have been facilitated by World Wide Web server software developed by Van Gorp and Boysen, 1997 that manages Internet class activities (ClassNet, http://classnet.cc.iastate.edu/). This allows every student to be an active participant in learning activities with easy access to course materials, enhanced communication with the instructor and with other students, rapid feedback concerning assignment evaluations and exams and ready access to their private records of course performance. Although the course enrollment is in the 250-300 range, ClassNet software enables ease of constructing, distributing and evaluating assignments. The assignments involve authentic activities (forecasting), simulated learning environments (Java-based simulations) and more standard evaluations of content understanding (short answer responses).

Forecasting Exercise

Prediction is a key goal of science and one which students eagerly embrace. They quickly realize that to improve their predictive skills they must develop additional skills of observation, hypothesis-generation and testing, and analysis. One goal for students in the introductory meteorology course is to successfully forecast weather parameters for a significant number of carefully selected cases. This is accomplished by using a web-based weather forecasting exercise (Figure 1). This activity is the common thread for the course and serves as an ever-present opportunity to apply course concepts in real-world contexts. The forecast exercise provides students repeated opportunities to test their understanding of various weather processes in a forum that is: Goal-directed (students are asked to predict various weather parameters and select the appropriate physical reasons), Failure-driven (for example, students now seek explanations for advection and ask how to estimate its influence on temperature changes as a necessary element in a successful forecast), Case-based (lecture discussions of advection processes now have context), and learning-by-doing (each student must forecast a minimum number of times).

The forecast exercise requires that participants use available weather products to predict next-day weather parameters for near sunrise and noon for cities across the United States. These times were selected to correspond to nighttime and mid-day periods. Participants in the forecast exercise are also required to provide supporting rationales for predictions of weather parameters. Producing these rationales raises the expectations from merely guessing values for temperature, wind and precipitation to requiring students to ponder the important factors which are responsible for changes in conditions from one period to the next.

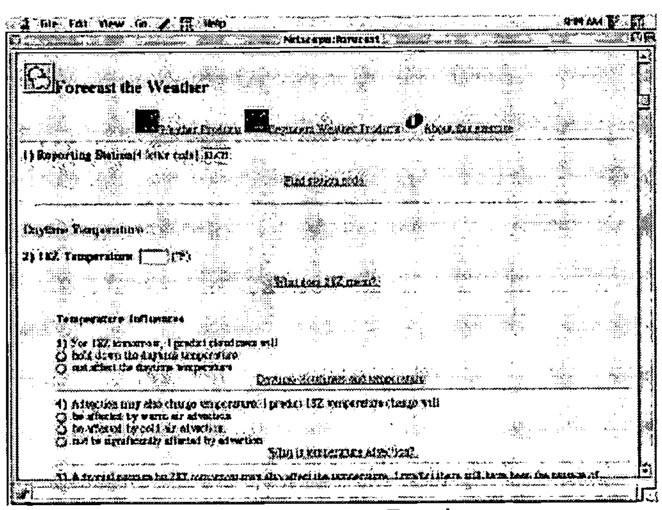

Figure 1: Forecast Exercise

To stimulate individual interest, coordinate course content with prediction experiences and help maintain the intended learning goals, several versions of the prediction activity are being used. In one version, each participant can select a city from more than 1200 in the United States for which to forecast following-day weather

conditions. In the weeks prior to Spring Break this is a popular option. In another version, the instructor can specify a forecast city that is expected to experience interesting or unusual weather conditions.

Another version of the activity is needed because weather conditions infrequently correspond with the sequence of course topics. In fact, spring semester in Iowa has largely winter conditions so students aren't exposed to forecasting summer events. A version of the prediction activity that uses archived weather data is used to provide "controlled weather" that can be coordinated with course objectives. This version is also valuable for use early in the course when the complete forecast exercise can be unnecessarily overwhelming. In the first part of the course only those factors that affect the temperature of the atmosphere and the earth during the day and night, are covered. Thus, the first forecast activities address only the simplest conditions - no clouds, no frontal activities and no advection (winds replace one air mass with another having a different temperature). Later forecast exercises increase the complexities by including days when clouds, fronts and advection processes become important. Finally, with the proliferation of weather oriented web sites it has become a concern that a portion of the student population may "mimic forecasts". This temptation has provided further motivation for the development of archived sets of forecasting exercises.

Another key to learning is the outcomes assessment provided by ClassNet. Students may access ClassNet anytime from anywhere to submit forecasts, view forecast verifications after the forecast period has passed and see their current scores. These automated outcomes assessments provide students with data concerning the correct responses. If students need additional explanations they are provided by either the instructor or a graduate assistant through ClassNet managed e-mail.

Java-based Simulations

As one example, a Java-based simulation, called RadiationSim, will be discussed that has both "learning to learn" and "content learning" opportunities. RadiationSim (Figure 2) is a simulation that reflects the effects of radiation processes caused by solar and atmospheric radiation transfer. In using the simulation, students analyze temperature data measured by a balloon (radiosonde) that they "launch" both in the morning and evening over four types of terrain (sand, plowed field, grass or fresh snow). As the balloon is dragged and dropped to various heights in the simulated atmosphere, the temperatures at these altitudes are automatically plotted on a graph. Several temperature profiles can be plotted concurrently to compare differences before clearing the graph.

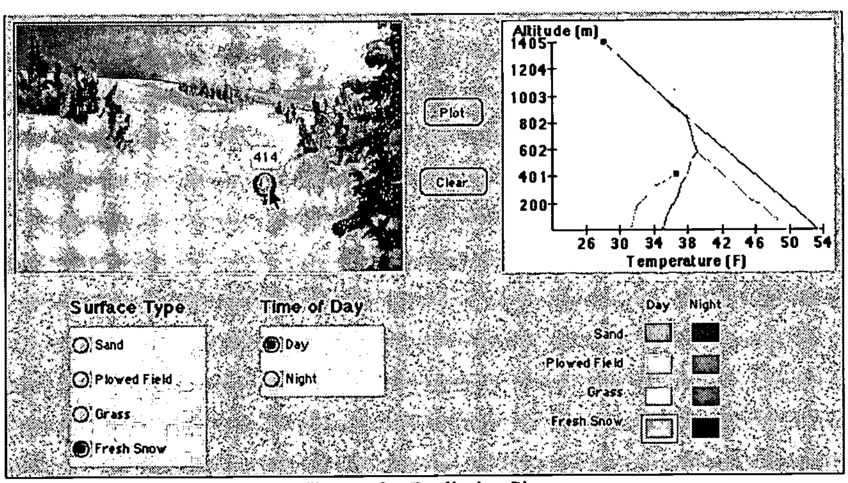

Figure 2: RadiationSim

The Radiation Balance Simulation has two instructional goals. First, it provides an environment in which beginning students can assume the role of scientist. Second, if students reason beyond the data collected, the simulation raises some interesting "why" questions that lead to a much deeper understanding of long and short wave radiation. For these goals to be met, the instructor must support the simulation by creating the proper initial

environment, emphasizing the process of scientific discovery, and building higher level discussions on the student's RadiationSim experience. Use of this simulation involves individual, small group and large group activities.

This simulation is intended to be the initial simulated activity the students encounter in the meteorology course. It is also intended to be a pre-lecture experience rather than a post-lecture practice assignment. Experience has shown that this is a new type of learning endeavor for most students and much scaffolding needs to be provided. In assigning this activity, the mechanics of the simulation is demonstrated and some global strategies are discussed. It is most important, however, that the teacher's role not usurp the critical learning opportunities from the students. The teacher's role can be seen more clearly if the learning goals are understood.

During this initial simulation students should begin to develop a strong Problem Solving Strategy. Most students are very weak in this area and need considerable encouragement in developing this skill. An example of a Problem Solving Strategy that is a desired result from the use of RadiationSim follows:

1. Explore the simulation, identifying the inputs, outputs and goals.
2. Estimate and note the expected outcomes.
3. Develop a plan to test these expectations.
4. Collect sufficient data and record results.
5. Analyze and summarize the data.
6. Compare and contrast the results with the expected results.
7. Question the reasonableness of the results and seek explanations for them.
8. Rethink the process, identifying additional data that needs to be collected and important questions that need to be resolved.

With these expectations in mind, the teacher demonstrates the simulation by showing how to activate it, set the parameters, move the balloon, plot the points and read the graph. Students are then challenged to "become a meteorologist" and make predictions about the relationships among ground cover, time of day, altitude and temperature. Students are encouraged to develop a plan to test their expectations and, after using the simulation, reach a conclusion about the accuracy of their predictions. At this point in the learning process, it is important for students to develop their own strategy to test their theories.

Following students' use of the simulation, they are assigned a small group activity of sharing strategies used with the simulation exercise and agreeing on a good strategy. Following this the teacher solicits strategies from selected groups, outlines one or two interesting approaches and discusses their merits. During this time the eight steps in the Problem Solving Strategy listed above are presented and "methods" of meteorology are be described. Experience has shown that special attention also needs to be given to interpretation of graphs and their use to represent relationships of this type. The use of symbolic representation is a deficiency in many students' knowledge base.

After the strategies have been covered, the results from the simulation are shared, first in small groups and then in the class as a whole. During this period many of the issues inherent in the questions listed below are addressed. Most of the issues are raised by the students but are shaped by the teacher's questions of reasonableness of the conclusions and scientific basis. Some typical questions that lead directly to lectures on long and short wave radiation and their interaction with the earth's temperature follow.

1. Of the four surfaces in RadiationSim (sand, plowed field, grass and snow), which one gets the hottest during the daytime? The coldest? Why?
2. How does temperature change with altitude? How do the daytime air temperatures above each surface compare with nighttime? How are they the same? How are they different? What causes the differences?
3. Focus on the temperature changes between 0 and 600 meters for all four surfaces. As altitude increases in the daytime, what happens to the temperature? What about nighttime? What causes nighttime temperatures to increase below 600 meters?
4. What makes the earth warm?
5. What happens to the sun's energy after it strikes the earth? Where does it go? Why doesn't the earth become progressively warmer with time?
6. If energy from the sun passes through the atmosphere on its way to the earth's surface, does this energy make the atmosphere as warm as the earth's surface? Explain the reasons for your answer.
7. What change (if any) would there be in the average temperature of the earth's surface if there were no atmosphere?

RadiationSim transmits very little information to the students. It functions more like a mirror reflecting to the students the existing status of their knowledge and learning strategies. It also provides a common experience for sharing and sets that stage for the instructor to transmit meaningful principles and practices of the discipline. When

supported effectively, it enables the students to acquire a very clear and early picture of the discipline they are studying.

Partnerships To Advance Learning In Science (PALS)

A collection of supporting materials that can be used to supplement existing courses is available through a web resource called Partnerships to Advance Learning in Science (PALS) (http://www.pals.iastate.edu/). These materials include: 1) selected course materials, 2) an archive developed from COMET animations, 3) examples of Java simulations, 4) examples of forecast exercises and 5) an archive of annotated weather data. This is a work in progress but it does provide a convenient way to view some of the materials discussed in this paper.

Conclusions

Teaching and learning in undergraduate science courses have changed little during the memory of most of us in the university community. Now rapid changes in technology, advancements in theories of human learning, and changing visions of the goals of education have created an environment where radically different approaches to teaching and learning are expected. In this paper we have described how we are using technology to help provide an environment for expanding the learning goals and implementing modern theories of learning in a large introductory science course. These efforts represent works in progress that are freely available for use by other faculty.

References

Van Gorp, M., and P. Boysen, 1997: ClassNet: Managing the virtual classroom. *International Journal of Educational Telecommunications*, (3/2), 279-292.

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