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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. This proceedings contains a corporate paper, a paper by an invited speaker, 44 full papers, and abstracts of 39 poster/demo papers. An author index is also included. Most papers contain references. (MES)

INTERNATIONAL CONFERENCE ON M/SET 2000 MATHEMATICS/SCIENCE EDUCATION & TECHNOLOGY

Proceedings of M/SET 2000–

February 5-8, 2000
San Diego, California

Editor
Robby Robson

AACE Association for the Advancement of Computing in Education

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Educational Technology Review

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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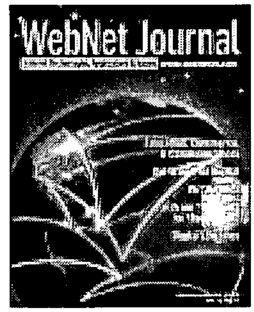


Focused on WWW, Internet, and Intranet-based technologies, applications, research, and issues, the *WebNet Journal* is an innovative collaboration between the top academic and corporate laboratory researchers, developers, and end-users. Columnists offer how-to articles and expert commentary on the latest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

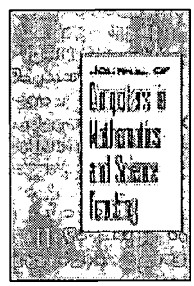
Journal of Educational Multimedia and Hypermedia

(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

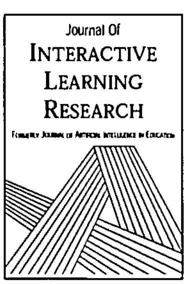
(JCMST) ISSN# 0731-9258 *Quarterly*



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 exchange of information in the fields of science, mathematics, and computer science.

Journal of Interactive Learning Research

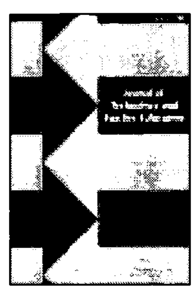
(JILR) ISSN# 1093-023X *Quarterly*



The *Journal's* 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, micro-worlds, and virtual reality based learning systems.

Journal of Technology and Teacher Education

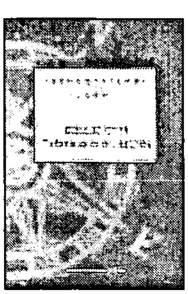
(JTATE) ISSN# 1059-7069 *Quarterly*



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

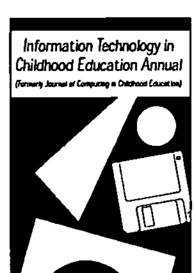
(IJET) ISSN# 1077-9124 *Quarterly*



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# 1522-8185



A primary information source and forum to report the research and applications for 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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The exchange of ideas and experiences is essential to the advancement of the field and the professional growth of AACE members. AACE sponsors conferences each year where members learn about research, developments, and applications in their fields, have an opportunity to participate in papers, panels, poster/demonstrations and workshops, and meet invited speakers.

ED-MEDIA 2000

World Conference on Educational Multimedia, Hypermedia & Telecommunications

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JUNE 25-30, 2001 • TAMPERE, FINLAND

ED-MEDIA - World Conference on Educational Multimedia, Hypermedia & Telecommunications

This annual conference serves as a multidisciplinary forum for the discussion of the latest research, developments, and applications of multimedia, hypermedia, and telecommunications for all levels of education.

WebNet 2000

World Conference on the WWW and Internet

OCT. 30-NOV. 4, 2000 • SAN ANTONIO, TX USA

WebNet - World Conference on the WWW & Internet

This annual conference facilitates the exchange of information in these major topics: Commercial, Business, Professional, and Community Applications; Education Applications; Electronic Publishing and Digital Libraries; Ergonomic, Interface, and Cognitive Issues; General Web Tools and Facilities; Medical Applications of the Web; Personal Applications and Environments; Societal Issues, including Legal, Standards, and International Issues; and Web Technical Facilities.

International Conference on M/SET 2001

Mathematics/Science Education & Technology

MARCH 3-6, 2001 • ORLANDO, FL USA

M/SET - International Conference on Mathematics/ Science Education & Technology

The conference focuses upon information technology in mathematics, science and computer science education across all levels and settings, including elementary, secondary, college, and teacher education. Learn about the current research, development, classroom applications, issues, theory, and trends.

Society for Information Technology & Teacher Education 2001

12TH INTERNATIONAL CONFERENCE

MARCH 6-10, 2001 • ORLANDO, FL USA

SITE - Society for Information Technology and Teacher Education International Conference

This conference, held annually, offers opportunities to share ideas and expertise on all topics related to the use of information technology in teacher education and instruction about information technology for all disciplines in preservice, inservice, and graduate teacher education.

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TABLE OF CONTENTS

George Lucas, Web-based Astronomy, and Teacher Beliefs

James C Adams, Chetek, WI High School, USA; Dr. Robert E. Hollon, University of Wisconsin, Eau Claire, USA

The Internet provides an excellent resource for students, teachers, and others to explore current science. In particular, it provides a vehicle for developing technology-rich courses that provide students with great autonomy in selecting and carrying out learning. Course development is a very complex endeavor linking subject matter, developmentally appropriate learning processes, available resources, technology, time, and assessment techniques. Less obvious, but of equal importance, is the interaction of teacher beliefs and design decisions. Development proceeds in a context of implicit and explicit beliefs about the nature of science, learning, and curriculum. Astronomy provided the context for illustrating the ways that one teacher's beliefs about science, learning, and curriculum were embedded in the development of a web-based high school course.

ESSTEP - The Earth and Space Science Technological Education Project

Bryan Aivazian, Wyoming Center for Problem Based Learning, USA; Ed Geary, Earth Science Insights, USA; Holly Devaul, The Geological Society of America, USA

The Earth and Space Science Technological Education Project (ESSTEP) is a professional development program for secondary and college faculty. This program addresses the growing need to provide students with the critical academic and personal skills necessary for successful technical careers in the earth, space and environmental sciences. ESSTEP has provided educators with the skills to infuse global positioning system, geographic information systems and image processing into their classrooms. As a result of their ESSTEP experiences, educators are enhancing student learning, promoting science and technology careers, and catalyzing the development of new courses and materials.

A Manipulative World For Learning Addition Of Numbers

Yavuz Akpinar, Bogazici University, Istanbul, Turkey

Technological developments provided types of tools to be employed in teaching different subject matters and allowed to make some problematic subjects easier. This paper critically outlines the major trends of the employment of computer based learning packages and argues for environments in which the domain tasks can be proceduralised. The design considerations of a procedural environment, BALANCER for learning addition, is described, implementation studies and a small informative evaluation on the interface are also explained. The interface facilities of the system were found interesting and helpful, so is interpreted promising. The paper concludes with some suggestions for more comprehensive evaluation studies.

Motion Games and Thinker Tools: Using Prior Simulations to Promote Learning about Motion

Thomas Andre, Iowa State University, USA; Charlotte Haselhuhn, Des Moines Community School District, USA; Katherine Kreiter, Iowa State University, USA; William Baldwin, Iowa State University, USA; Catherine Leo, Iowa State University, USA

This presentation demonstrated computer software that helps students better understand Newton's first law. Two studies of effectiveness of the software were reported. The first found that males benefited from use of a fanciful version of the software. but females did not. The male oriented scenario used in the simulation and the lower interest and prior experience of females in physics may have made more difficult for females to transfer the computer experience to the first law concepts taught in the chapter. A second study, using software that more explicitly related itself to the chapter, found that both male and females students profited from prior use of the simulation. They developed and demonstrated a better conceptual understanding of the implications of the first law. The results suggest that, contrary to much current practice, simulations may be more effective instructional tools if used prior to more direct instruction.

Dynamic and Parameterised Animation of Computer Science Topics

Andreas Ausserhofer, Technical University of Graz, Austria

The purpose of this paper is to introduce an Animation Module CSAnim as extension to the S.E.A.L. web-based education system. The main application of CSAnim is the generation and the display of a dynamically processed graphical visualisation of computer-science topics based upon user-input. The introduction will set the focus to the problem in general whereas the problem-analysis will show, why

animation techniques - which have found to be a successful extension to traditional teaching methods - are not sufficient enough. A new approach is presented as solution to this and the integration into an existing education system is shown. The paper ends with future aspects and possible applications.

Development of an Effective Multimedia/WWW Training Model for Faculty

Patricia Backer, San Jose State University, USA; Miriam Saltmarch, San Jose State University, USA

This paper describes the results of three summers of teacher training initiatives in multimedia and the Web for the classroom as well as a trainer of trainers model currently being undertaken for faculty at San Jose State University based upon the results of the summer workshops. An original objective of the summer workshops was directed at providing faculty who could function as trainers of other faculty. Moving from the year one model (training faculty to utilize a wide range of multimedia equipment and tools to build complete projects) to the year three model (training faculty in specific applications) changed the extent to which faculty could act as trainers of other faculty at their school sites. The current model focuses on empowering faculty to complete technology-based projects for their university classrooms and become trainers of other faculty in their academic units, within the realistic constraints imposed in a teaching-centered university.

The Collaboratory Project's Science Fair Repository

Richard Barone, Northwestern University, USA; Ann Blythe, Alan B.Shepard Junior High School, USA; Beatrise Revelins, Charles J. Caruso Junior High School, USA

Northwestern University and Deerfield School District 109 in Illinois are collaborating on a project that seeks to encourage cross-district collaboration and the sharing of resources between teachers and students via the internet. The setting for this initiative is the annual school science fair with its broad scientific scope and need for community involvement. Northwestern's Collaboratory Project has developed an internet application that is being piloted in classes at both junior high schools in District 109. The results thus far have been encouraging and are reported here by a member of the development team and the two teachers adopting this technology.

"A Tour Before": Interpretations of a Science Gallery & the Interactive Videoconference Which Preceded It

Timothy Barshinger, Purdue University, USA

This study examined how elementary children and their classroom teacher interpreted a visit to a museum's science gallery and the videoconferencing link that preceded it. The interactive "virtual tour" was meant to serve as an advance organizer for the children. This interpretive, non-comparative project specifically involved four fifth grade "key informants" and their teacher. Data were gathered through interviews, observations, artifacts, and researcher reflections. Individual informant data was analyzed for common patterns and compared cross case for synthesis into key themes about the nature of the experiences. Data analysis revealed that the students' learning styles and peer group structure had an impact on the nature of their investigations during the on-site visit. Also noted was how the videoconference was a successful advance organizer. Students were able to create mental organizers, such as mental maps and interest agendas, following the link which helped direct and focus their exploration during the museum visit.

Gaining confidence in mathematics: Instructional technology for girls

Carole Beal, University of Massachusetts, USA; Beverly Woolf, University of Massachusetts, USA; Joseph Beck, University of Massachusetts, USA; Ivon Arroyo, University of Massachusetts, USA; Klaus Schultz, University of Massachusetts, USA; David Hart, University of Massachusetts, USA

AnimalWatch is a matehmatics tutor with enhanced adaptive feedback precisely tailored to girls' instructional needs. Three evaluation studies with fifth grade students support our hypothesis that adaptive feedback is beneficial to girls' math confidence. We have also had high levels of teacher participation including classroom activities, after-school presentations and summer workshops. This paper describes features of the tutor, evaluation studies, work with classroom teachers and dissemination activities.

Communication between problem solving groups in an On-line Geometry course: results and lessons learned

Brian Beaudrie, Northern Arizona University, USA; David A. Thomas, Montana State University, USA

The purpose of this study was to investigate the relationship between communication and achievement among cooperative learning groups performing problem-solving activities in a WWW-based Geometry for Teachers distance education course. This paper presents an overview of the preliminary findings of the study.

Partners in Science - Collaboration, Mewntorships, and Technology

Gary Bender, Office of Instructional Technology, Fairbanks North Star Borough School District, Fairbanks, Alaska, USA

This paper is a preliminary report discussing initial results of the five year Partners in Science project. Partners in Science is a project linking K-12 students and teachers with practicing university, industry and agency scientists using networked technology, with the aim of increasing the practice of authentic, project-based math and science. The project's goals are to: 1) Improve the student's understanding of science by designing and conducting their own research; 2) Effectively utilize technology as a part of the learning and teaching of science and mathematics; 3) Bring active scientists into the teaching and learning process, both in and out of the classroom. Research data gathered from teachers, students, and scientists indicates that the project shows promise in each of the three areas.

Strategies For Developing a Precalculus Course With Web Based Activities

Jean Bevis, Georgia State University, USA; Margo Alexander, Georgia State University, USA; Draga Vidakovic, Georgia State University, USA

In the precalculus course under development, students have the option of accessing interactive web based materials in lieu of attending lectures. They also have the option of taking daily quizzes in class or over the web. When students complete their daily work, it keeps them involved in the course material in a regular and beneficial manner. When students do not complete their daily work, the easy accessibility of options, helps students to accept responsibility for their decisions. We also report on a successful strategy for the rapid development of this Web-based course.

Some Psychological Aspects Of Using Information Technologies In Teaching Linear Algebra.

Mikhail Bouniaev, Southern Utah University, USA

Despite the indisputable advantages of using information technologies in teaching mathematics in general and linear algebra in particular certain problems related to technology-oriented education have become quite evident now. The presentation reviews and analyses efficiency and expediency of using information technologies at different stages of teaching linear algebra. Our research is based on the results of the experiment conducted during the last five years in teaching linear algebra with MATLAB and modern calculators. This paper is a follow up of an earlier article "Linear Algebra With MATLAB Package In Preservice Teacher Education" (Bouniaev, 1997).

A Modularized Competency-Based Science /Math Curriculum for Associate Degrees in Information Technology

Douglas Brown, NorthWest Center for Emerging Technologies / Bellevue Community College, USA; Arthur Goss, Bellevue Community College, USA

This session will present the Science & Math for Information Technology (SMIT) core curriculum developed through the NorthWest Center for Emerging Technologies at Bellevue Community College (Washington) and a selection of representative hands-on activities. Designed to provide an efficient and flexible tool for strengthening the analytical component of IT programs by infusing appropriate science and math learning experiences, it has several distinguishing features: Competency-based and linked to the nationally recognized, industry-based NWCET IT Skill Standards, Individual units can be incorporated into existing IT courses or combined into stand-alone courses, Curricular goal is not topical coverage but for students to "learn how to learn science" and acquire a foundation for broadly applicable science/math-based analytical techniques, and Organized around team projects with a real world structure and format. They are inquiry-based but require a concrete deliverable outcome.

Visual Venture: Investigations with Images and Videos

Lisa M. Brown, IBM TJ Watson Research Center, US; Susan Crayne, IBM TJ Watson Research Center, US

In this paper, we describe an educational software tool, which allows students to take measurements on images and videos. Students become scientists as they measure, collect and analyze data from a wide range of imagery. We will describe two major emphases of this work. First of all, as a corollary to scientific image processing software, this program was fundamentally designed as a general, open-ended tool for investigation. Students have the opportunity to learn the scientific process first hand. We discuss the relationship of this software to scientific tools, the potential for true inquiry-based learning, and the associated issues and problems that occurred in bringing this to the classroom. Our second emphasis in this work was to create a tool, which could be used for curriculum development and interdisciplinary learning. The software exploits the recent availability to students and teachers of an extraordinary plethora of scientific images and videos. This allows content to correspond closely to a specific curriculum, to pertinent events and to student and teacher interest. We detail several ways that curriculum specialists and teachers can take advantage of the wealth of imagery that is currently accessible. Lastly, we briefly describe the evolution of the software and the feedback we have received from students, teachers, and curriculum/technology specialists.

Teachers Implementing GIS in 5th-12th Grade Classrooms: An Investigation of the Necessary Staff Development Experiences and Support

Alan Buss, University of Wyoming, USA; Patricia McClurg, University of Wyoming, USA

This paper reports the results of a two year study investigating the types of experiences and support necessary for in-service teachers to effectively integrate Geographic Information Systems (GIS) in their teaching/learning environments. Questions guiding the investigation included 1) can GIS be a useful tool in the classroom and 2) will teachers' participation in an extensive in-service affect their level of confidence in their ability to use GIS and/or their attitudes toward GIS as an effective tool in the classroom. Assessment measures included (1) contrasting the level and type of teacher use based on classroom observations, interviews, participation in web-based discussions, and lesson plan analyses; and, (2) teacher self-ratings on a 14-item Likert confidence and attitude instrument. The large majority of participants did plan and implement GIS lessons in meaningful contexts. Statistically significant gains were detected ($p<.001$) for each of the fourteen items on the teacher survey.

Computer Assisted Synthesis of Visual and Symbolic Meaning in Mathematics Education

Stephen Campbell, University of California, Irvine, U.S.A.

A number of factors pertaining to a wide variety of distinctions -- such as particular-general, arithmetic-geometry, sense-reference, procedural-declarative, concrete-abstract, object-attribute -- are implicated in developing a meaningful understanding of visual and symbolic aspects of mathematics. A rather simplistic "association-abstraction" model of mathematical cognition, as it stands, appears inadequate to account for these factors, particularly with respect to instructional design and assessment. Such fundamental inadequacies warrant better theory and more research. Methodology directed to this end, drawing on digital video technology, is sketched out.

Digital Photography for Math and Science

Catherine Cavanaugh, Ph.D., University of South Florida, USA; Terence Cavanaugh, Ph.D., University of South Florida, USA

Digital cameras have many advantages over film cameras for math and science education, and add a multimedia dimension to learning. Today's digital cameras offer a variety of features, and are as easy to use as film cameras without the expense of film processing. Digital images are available more rapidly than film images, allow unlimited low-cost duplication, and can be controlled and manipulated easily. Using a digital camera, students make personal meaning of documents, presentations, and electronic communications such as email and web pages. Math and science teaching and assessment are enhanced through electronic field trips, demonstrations and portfolios. Digital cameras enable students to visualize the mathematical and natural worlds in unique ways. Many cameras have panorama and limited audio/video capabilities. Most offer live or recorded video output, and can be used with special lenses, including microscopes and telescopes.

Interactivity in Mathematics and Science Education

Ozlem Cezikturk, State University of NewYork at Albany, USA; Murat Kahveci, Florida State University, USA; Gulcin Cirik, San Diego State University, USA

Today, interactivity is seen as a key factor for achieving effective learning environments. Research says that "Interactivity" is a messy idea that takes its meaning from a system of metaphysical oppositions. These oppositions range from learner control issue to the debate. A group of academicians and researchers were asked to imagine a "Richly Interactive Learning Environment" to the fullest degree possible. The commonalities and differences in their ideas are investigated in order to come up with a shared understanding of interactivity for the new millennium. The aim of this article, is to both deconstruct and reconstruct a theory for interactivity with some real ground from previous research, ideas from that group, and from the ideas of the authors, as a whole. With this framework in hand, we hope that it will be possible to differentiate the real promises of "interactivity" from the wonderland promises.

The Teacher's Attention Empowering Children's Math Learning With Computers

Ni Chang, University of Wisconsin-Whitewater, USA

This paper reports the findings of a study, a pilot study, conducted in a childcare center in Whitewater, WI. Eight children were involved and divided into two groups: control and experimental groups. Quantitative and qualitative methodologies were used to analyze the data collected from pre- and post tests and interactions of a child with a computer. Findings show that children who are observed and helped by a teacher gain mathematical concepts faster and more efficient than those who are completely left alone at the computer. This pilot study implies that the teacher needs to pay attention to children at computers while working with or supervising children doing other activities. An extended study is suggested to replicate the findings of this pilot study.

Math at Midnight: Teaching and Learning Implications

Faith Chao, Golden Gate University, US; Jim Davis, Golden Gate University, US; Peg McPartland, Golden Gate University, US; TJ Tabara, Golden Gate University, US

In this presentation we will discuss some of our course explorations that utilize the asynchronous features of the Internet together with its graphic capabilities to build web-based math courses at Golden Gate University. We will focus on the internet technology that gives students the flexibility to participate in classes at any time of the day and any day of the week and how this flexibility affects their expectations of the course. We will also discuss course design features and teaching strategies in order to motivate students to achieve understanding at a deep level for the varied learning styles of this new medium. The techniques utilized in a variety of math courses will be discussed along with student comments and our findings of learning outcomes.

Using Maple V (Graphics and Programming) for Calculus Teaching

Mingxiang Chen, Department of Mathematics, North Carolina Agricultural and Technical State University, Greensboro, NC 27411, U.S.A.

Maple V is an elaborate Computer Algebra Systems (CAS). We use Maple as a tool in teaching Calculus. We give students brief tutorial on Maple commands and syntax. We use Maple to plot graphs of library functions and user-defined functions, of one variable and two variables, implicit functions, and parametric equations. This part of activities helps students become familiar with curves and surfaces in two-dimensional and three-dimensional spaces, and with polar, cylindrical and spherical coordinate systems. We use Maple programming language to write procedures such as Trapezoidal Approximation and Simpson's Rule in numerical integrations. We combine programming and plotting to demonstrate intrinsic points such as relationship between a function's monotone and convex properties and the sign of its derivatives, graphs of a function and its inverse function, Taylor Approximations, and dynamics of a family of functions with parameters.

Progressive Comparison of the Effectivness of Computer-Assisted Instruction on Science Achievement: A Meta-Analysis

Edwin P. Christmann & John L. Badgett, Slippery Rock University, USA

This study compared science students who were exposed to traditional methodology with those who received traditional methodology supplemented with computer-assisted instruction (CAI). From the 24 conclusions, an overall mean effect size of 0.266 was calculated, indicating that, on the average, students receiving traditional instruction supplemented with CAI attained higher academic

achievement than did 60.4% of those receiving only traditional instruction. The effect sizes were categorized into four subject areas. In descending order, the mean effect sizes in general science, physics, chemistry, and biology are: 0.707, 0.280, 0.085, and 0.042, respectively. Differences in educational settings revealed that CAI is most effective among science students in urban areas; followed by those in suburban areas; and weakest among rural students. However, a -0.335 correlation between effect size and years indicates that the effect of CAI on academic achievement has declined during this period. Some of the findings were reported in Christmann and Badgett (1999).

Enhancing Science Field Trips with a Digital Camera

Kenneth Clark, Georgia Southern University, USA; Alice Hosticka, Georgia Southern University, USA

Digital cameras in the science classroom can be used as a tool to enhance field trips. Field trips are meant to provide students with important hands-on experiences to further the goals and objectives of the curriculum. Many times they turn into no more than a day away from school. These trips can add value to the curriculum by providing pre-trip preparation, structured experiences on the trip, and experiences taken back to the classroom from the trip. The digital camera can be used to develop materials to use in preparation for the trip and record aspects of the trip to bring back to the classroom for further study. Although film based technologies can provide the same opportunities, the use of the digital camera provides a hassle-free way to capture, manipulate, and present images relative to the instruction.

Realism and Credibility in a Simulation-Based Learning Environment: the Virtual Physics Laboratory (VPLab)

Marc Couture, Télé-université, Canada; Alexandre Francis, Université de Montréal, Canada

Realism and effectiveness of computer simulation-based learning or training environments have been examined in several studies. It was shown that under certain conditions, simulations can be as efficient as real experiments, and that increased realism may result in gains in 'practical appreciation'. However, few have investigated the relationship between realism and credibility, or between credibility and effectiveness. The VPLab is a simulation-based learning environment featuring many characteristics and constraints normally associated with real experiments. These include uncertainty in measurement, random fluctuation of parameters, and limitations in user control over the simulation. We believe that our approach, which distinguishes the VPLab from most existing simulation-based laboratories, greatly increases its credibility. It also makes possible the teaching of laboratory skills not usually associated with simulation.

RiverWatch Project: The Confluence of Science and Technology

Gregory A. Coverdale, Penn State Harrisburg, USA

National standards in science education argue that science learning should be interdisciplinary, inquiry-based, and involve students in real-world projects. Most rhetoric in science education also argues for technology integration in science instruction. This paper describes the RiverWatch project, which integrates science and technology, and models scientific collaboration between 5th grade students in Indiana and preservice teachers at the Pennsylvania State University in Harrisburg.

Effects on Attitudes Toward Computer Programming of Using Java Versus C++ to Teach Introductory Programming to Non-Computer Science Majors

Fred Croop, College Misericordia, USA

Several non-Computer Science disciplines may require students to take computer programming courses. Examples include Information Systems, Educational Technology, Engineering, and Business Management. These curricula typically are designed to provide the enrollees with exposure to the application of computer programming, development of problem-solving skills, and possibly the background in a language that can be used for further study in research, analysis, or data structure design. Some non-Computer Science majors fear, and/or do poorly in programming. Other students find programming interesting and non-threatening. For all students there is a possibility that their attitudes toward computer programming will change during and as a result of their introductory course(s) in the subject. Two languages used to teach object-oriented programming are Java and C++. This poster demonstration summaries self-expressed attitudes toward computer programming of a small group of students who have studied both Java and C++.

Animations in Physics Learning

Patric Dahlqvist, Stockholm University/KTH, Sweden.

The study reported on in this paper investigates the effects of different presentation formats on learning an important principle in classical mechanics (the principle of equivalence). The presentation formats were abstract (classical vector representation), analogue (a more experience based illustration) and animated analogue. The study was conducted (N = 55) at the department of physics, Stockholm University. Analyses indicate that animations do not facilitate learning in this case. An interesting observation is that the analogue and animated groups performed better than the abstract group on the analogue problems. But the abstract group did not outperform the other groups on the abstract problems. A tentative interpretation is that it is easier to move from an analogue representation to an abstract than vice versa. Another interpretation is that it may be the case that the students in the concrete conditions expended more effort into applying an abstract thinking on their concrete memory image.

Investigating Families of Quartic Polynomials via a Computer Algebra System

Tilak de Alwis, Southeastern Louisiana University, USA

Consider the one parameter family of quartic polynomials given by f(x)=(x-a)(x-t)^2*(x-b) where a and b are distinct real constants, and t is a real parameter. Let A(a,0), B(b,0) and C(t,0) be its x-intercepts, and D(0,abt^2) be its y-intercept. Suppose that the normal lines to the graph of f at the points A and B meet at R, and the tangent lines to the graph at those points meet at S. As the parameter t changes, the graph of f changes. However, the points A and B remain fixed while all other points C, D, R and S change. This paper discusses some geometric properties such as centroids, circumcenters, orthocenters, and locus problems of the variable triangles ABR, ABS etc.

Geometric Skills: Hands-on Manipulatives to the Logo Turtle's Path

Estella De Los Santos, University of Houston-Victoria, USA; Barba Patton, University of Houston-Victoria, USA

There is much evidence to support the fact that manipulatives create a visual representation as well as provide a tactile (hands-on) approach to many geometric situations. De Los Santos and Patton believe that while computers create a visual representation, the tactile (hands-on) approach is missing. They conjecture that, in order for children to be the most successful, tactile (hands-on) activities using manipulatives must be included in the lessons and precede any LOGO activities. The study in progress follows a post-test only experimental design. The control group receives LOGO instruction while the experimental group receives instruction using manipulatives prior to the LOGO instruction. The post-test will measure the ability to construct interior and exterior angles and given polygons.

An Authoring Tool for Hint Generation.

Rachel DiPaolo, The University of Memphis, USA; Holly White, The University of Memphis, USA; Arthur Graesser, The University of Memphis, USA

Hinting is important during the learning process, because it facilitates the active construction of knowledge. Constructive activities lead the student to an integrated and prolonged involvement with the material. Hints encourage the student to generate information and enhance memory for the learned information. Hinting increases student control during the learning process. We propose an authoring tool for hint generation that is based on conceptual graph structures. Conceptual graph structures have been used in the study of text comprehension (Graesser & Clark, 1985). These knowledge structures are made up of different types of nodes, which are interconnected by different types of arcs. Our hint generation model makes use of the information embodied in the relationship between the arcs and the nodes of these structures. This model is currently being implemented in computer based tutoring and has potential applications in related areas, such as web-based training.

Mathematics Standards 2000 and the Virtual Environment

Jim Dorward, Utah State University, USA; Robert Heal, Utah State University, USA

This paper describes the rationale for the forthcoming Principles and Standards for School Mathematics and accompanying electronic pedagogical examples. Many of these electronic examples are part of a web-based national library of virtual tools and manipulatives being developed at Utah State University with support from the National Science Foundation. Also included is a review of research on the use of computer-based manipulatives, description of applet design considerations and characteristics, and a discussion of research implications.

Teaching Computer Programming Languages Through WWW

Mahmoud El-Khouly, Saitama University, Japan; Behrouz Far, Saitama University, Japan; Zenya Koono, Saitama University, Japan

This paper presents web-based tutoring system (W-TCL) for teaching computer programming languages through WWW. In this version, two new features have been added: blackboard module and adaptive interface. With blackboard module a teacher can exchange his expertise with other teachers, and with adaptive interface the novice student will be satisfied because the system avoids complex interfaces. The system contains three sub-agents: the personal assistant agent for teacher (PAA-T), the personal assistant agent for student (PAA-S) and tutoring agent (TA). Using PAA-T, many teachers can cooperate together to: (a) put the curriculum of one/more computer programming language(s), (b) add or modify the commands' structure that will be taught, (c) generate different tutoring dialogs for the same command, and (d) generate different tutoring styles (e.g. text or Q&A).

College Science via Internet: How effective is it?

Kathleen Flickinger, Maui Community College, US; Contance Hargrave, Iowa State University, US

In this paper college science instruction via the Internet is examined from three perspectives: students' on-line learning experiences; a comparative examination of learning on-line versus traditional instruction; and instructors' experiences teaching on-line. The setting was a freshman-level human anatomy / physiology course. Three students participated in a collective case study to describe the learning environment created by the Internet course. Motivation, computer savvy, and self-confidence were important to their success. A quantitative study of the on-line course and the traditional course evaluated the comparative effectiveness of the learning environments. Achievement scores and survey results indicated content understanding and retention were not effected, while desirable student study habits were used more frequently in the Internet section. To better understand the instructional implications of on-line courses, a case study was conducted. Internet instructor's time commitment and level of teaching satisfaction were high. The instructor's role changed, causing some lessening of job satisfaction.

Computer Visualization in the Mathematics Classroom

Erzsebet Forczek, Albert Szent-Györgyi Medical University, Hungary; Janos Karsai, Albert Szent-Györgyi Medical University, Hungary

This paper reviews of the education in mathematics at the University of Szeged. Mathematics is a fundamental course for Pharmacy students. The main topics are basic concepts and properties of functions of one or several variables, limit, derivative and 1D differential equations. All the topics are illustrated with practical examples. The abstract concepts are somewhat difficult for the student to understand consequently, we emphasize the geometrical meaning and this is the point where we apply computers, so visual images are important aids in making matematics understood, because visualization is essential for understanding. The 3D scenes, the animation and the possibility of students interactivity are real advantages of the computer.

Issues in the Preparation of Prospective Elementary School Teachers to use the Internet in the Teaching of Mathematics

Jane Friedman, University of San Diego, USA

The Internet, particularly, the World Wide Web, has had a substantial impact on society. Whether or not these technologies will be able to effect beneficial change in K-12 education is another question. In the past educational reforms have often foundered due to a lack of teacher preparedness and on-going teacher support. This paper will discuss the experience and attitudes of a group of pre-service elementary school teachers enrolled in a required content mathematics course.

Development of Distance Education Technology on the Example of Course "Artificial Intelligence"

Tatiana Gavrilova, St.Petersburg State Technical University, Russia; Sergey Udaltsov, Institute for High Perfprmance Computing and Databases, Russia; Natalie Stash, St.Petersburg State Electrotechnical University, Russia

The paper presents the way of organizing distance learning course on the sample of discipline "Artificial intelligence". Peculiarity of the project is in adaptive character of education, i.e. in possibility of distance learning system implemented for development courseware to be arranged under

individual features of the concrete user. The aim of the system is to define the best program of education for him by adapting scenario of the learning material and to help in the process of navigation. Adaptability is especially important for educational applications on World Wide Web which are expected to be used by very different groups of users without assistance of a human teacher.

Conceptual Learning of Physics - Science

Ivan Gerlic, University of Maribor, Slovenia

One of the main objectives of physics is to lead students to an undestanding of basic concepts which can serve as basis for an explanation or prediction of natural and technical processes. Mathematical methods play a decisive role while pursuing this goal since an explanation or prediction is only reliable if the underlying law can be formulated in mathematical terms. Therefore mathematics is an essential part of physics teaching; however, it causes at the same time severe learning difficulties, well-known and especially important for physics teaching. To understand an unknown piece of knowledge, the use of an abstract tool has first to be acquired and then this tool has to be applied to the yet unknown part of reality. With modern computers and their advanced possibilities to animated graphics it is now possible to model and visualise a major part of classical physics by using rather simple numerical methods. All needed calculations can be left to the computer. Only after a qualitative understanding has been reached, the advantage of abstract mathematical methods can be demonstrated and corresponding learning goals can be acquired.

Constructing Physics Understanding: Simulation Software for Exploring Physics

Fred Goldberg, San Diego State University, USA

The Constructing Physics Understanding Project is a National Science Foundation supported project (Grant No. ESI-9454341) aimed at creating laboratory and computer-based materials to support a learning environment where students take primary responsibility for developing valid and robust knowledge in physics. As part of this project we have developed 20 pedagogically-oriented computer simulations, covering several topical areas in physics: light and color, static electricity and magnetism, force and motion, current electricity, waves and sound, and the small particle model of matter. The simulations are written as Java applets to run under Internet Explorer on individual computers (not over the Web). Students use the simulators to explore phenomena, both qualitatively and quantitatively, and they can receive both phenomenological and model-based feedback. The simulations can be used to complement all types of physics courses, but were especially designed to be integrated into the CPU curriculum, where they are used to complement and extend hands-on laboratory activities.

The Constructing Physics Understanding Project: Integrating computer simulators, hands-on experiments and group discussions to promote meaningful learning in physics

Fred Goldberg, San Diego State University, USA; Valerie Otero, San Diego State University, USA; Andy Johnson, Black Hills State University, USA

The Constructing Physics Understanding Project is a National Science Foundation supported project (Grant No. ESI-9454341) aimed at creating laboratory and computer-based materials to support a learning environment where students take primary responsibility for developing valid and robust knowledge in physics. The CPU project has developed a student-centered pedagogy, carefully sequenced sets of activities in several different topical areas of physical science, and a set of pedagogically-designed computer simulators. Rather than depending on the instructor as the source of knowledge, in the CPU classroom students develop, test and modify their own ideas through experimentation and discussion with their peers. The materials have been used successfully with secondary school physics and physical science students, and with prospective and practicing elementary teachers (through workshops and University courses).

Virtual-Real Lab: an electronics laboratory using real devices and the internet

Humberto Gomes, UFRGS, Brazil; Rita Machado, UFRGS, Brazil; Luigi Carro, UFRGS, Brazil

This paper presents the design and utilization of an Electronics Laboratory, physically available through the Internet. One of the greatest advantages of this project is to offer to many students the possibility of achieving practical experiments in the electronics field without the need of their presence in the laboratory room. This paper shows the hardware used to develop the system and the frontend web page with the required security involved.

The Influence of Instructional Video materials on Student Acquisition of Biological Concepts

Moses Gostev, Teachers College of Columbia University, USA; O. Roger Anderson, Teachers College of Columbia University, USA

Students' cognitive preferences in using scientific information were analyzed using a paper and pencil inventory. We found strong and weak cognitive components. Strong components ("questioning-preference") predicted higher academic performance ($p = 0.03$, d.f.=19) compared to the remaining "weaker" components (more knowledge-based), which were not readily discriminable from one another. Moreover, "questioning"-type students, compared to the "weaker"- component group, achieved better test scores on higher-level cognitive skills (e.g., application and analysis) ($p < 0.02$, d.f.=18), but not with basic knowledge, indicating their greater capacity with increasing cognitive demands in learning. Furthermore, use of a video that served as a theme or guiding framework for instruction significantly increased achievement compared to a control group taught in a more conventional way ($p = 0.04$, d.f.=16). These results suggest that use of thematic-centered video segments, and due attention to strengthening higher order cognitive preferences, in other instructional settings such as computer-based learning may enhance achievement.

Influence of Graphing Software (Mathematica, Wolfram) in Conjunction with the Interactive White Board on the Students' Learning of Exponential Functions in a High School.

Livia Gouriliova de Vargas, New Horizons Bilingual School, Dominican Republic

This paper describes a work-in-progress project that examines the effects of the graphing software and interactive white board used as an audiovisual mean to display graphs on students' learning of exponential functions, as well as the nature of the content that we teach, and changes of teaching techniques. Through group work in the computer laboratory, students analyzed, discussed, and made generalizations about properties of exponential functions. The teacher's role was facilitating students' interaction, helping them with basic syntax and techniques, and monitoring students' discussions in order to reach conclusions correctly. Even if students' showed positive attitudes toward mathematics and rated their class as more interesting, some questions (for example, why some students rely too much on their graphing utility and do not see errors in their graphs produced because of improper use of a software syntax) were raised later. Therefore, it is important to find concrete answers in further work.

Education and the Internet Opportunity

Jennifer Degnan, SmarterKids.com , USA; Beth Standring, SmarterKids.com, USA;

SmarterKids.com, is the number one educational store on the Internet that is dedicated to providing quality services and products to help parents instill a love of learning in their children. Smarterkids.com is unique for several reasons including the site's assessment and personalization options. Our Learning Style Survey allows parents and teachers to quickly and easily assess how a child learns best and find appropriate educational tools best suited to that child's individual style. Our MySmarterKids feature enables parents to develop distinct learning profiles for a child to ensure personalized product recommendations based on the child's individual learning needs, goals, and styles. Additionally, partnerships with Lightspan.com and National Computer Systems Inc. allow us to better bridge the gap between home and school. Together, we combine award-winning content and up to date statewide standards and assessment information with a unique educational shopping experience.

Mathematical Modeling within a Technology Based Learning Environment: Some Principles for Adaptive Instruction

Neal Grandgenett, University of Nebraska at Omaha, U.S.; Elliott Ostler, University of Nebraska at Omaha, U.S.; Art Zygielbaum, University of Nebraska at Lincoln, U.S.; Scott Henninger, University of Nebraska at Lincoln, U.S.; Char Hazzard, University of Nebraska at Lincoln, U.S.

This paper describes a set of research based instructional plans being developed by a multidisciplinary team of researchers at the University of Nebraska within a National Science Foundation Proof-of-Concept Grant. The project is seeking to establish a prototype effort for teaching mathematical modeling within a technology based learning environment, which includes components of adaptive

instruction for the student. Seven curriculum based design principles for the adaptive instruction that are being followed in the development of the project are described in the paper as they relate to research on effective mathematics instruction, and in particular the enhancement of mathematical modeling activities.

Can the same results be obtained using computer-mediated tests as for paper-based tests for National Curriculum assessment?

Lillian Greenwood, The Queen's University of Belfast, Northern Ireland; Fred McBride, The Queen's University of Belfast, NI; Hugh Morrison, The Queen's University of Belfast, NI; Palama Cowan, The Queen's University of Belfast, NI; Maria Lee, The Queen's University of Belfast, NI

This paper describes part of a research programme designed to explore the validity of using computer mediated tests as opposed to paper-based ones for National Curriculum testing in mathematics at Key stage 3. Previous research in this area has focused primarily on the comparison between computer-based and paper-based multiple choice questions while this research uses constructed response questions similar to those used at present in National Curriculum testing. A total of 127 pupils was tested using questions based on items selected from National tests in mathematics at Key stage 3. The study showed that where questions tested similar cognitive tasks there were no significant differences in outcomes. Questions requiring spatial awareness were more difficult when presented in a computer environment. Also the study illustrated that constant care is required to ensure that computer-based questions do not change the level of cognitive tasks of paper-based examples. The paper demonstrates the potential and limitations of a shift to computer based assessment.

Evidence of College Students' Graphic Decoding Gaps During Use of a Computer Simulation of Photosynthesis

Phyllis Baudoin Griffard, University of Houston-Downtown, USA; James H. Wandersee, Louisiana State University, USA

Twelve college science majors enrolled in introductory biology participated in two in-depth clinical interviews in which they verbalized while working with an award-winning computer simulation of a complex biochemical process, photosynthesis (Logal Corporation 1994). Their verbalizations during this and other cognitive tasks led to the identification and categorization of gaps that exist in their conceptual frameworks. Gaps fell into two major categories: propositional gaps and processing gaps. The graphic decoding gaps discussed in this paper comprise one category of the processing gaps. Graphic decoding gaps included gaps in icon-decoding and gaps in graphic literacy skills. Icons in the simulation for sugar output, photorespiration, oxygen production rate, flow lines, Calvin cycle and the radiolabel button were erroneously decoded. Gaps in participants' graphic literacy skills included design convention gaps, orientation gaps, and representation gaps.

STeam- Designing a Framework for New Forms of Cooperation in Education

Thorsten Hampel, University of Paderborn, Germany

The explosion-like distribution of worldwide data networks has changed and formed our life with lasting results. Surely the education sector at our universities and schools is substantially affected by this development. Unfortunately the development and distribution of cooperation supporting systems, i.e. tools that are not only like the WWW geared to the passive consumption of information, is still in its infancy. Following, the research project STeam (structuring information in a team) of the Heinz Nixdorf Institut deals with the conception and development of new learning scenarios and infrastructures which are adapted to the advanced "interactive" level of the WWW, enabling the user to explore and design their learning materials cooperatively.

Making Movies on the Web Accessible to People With Disabilities

Eric G. Hansen, Educational Testing Service, USA; Douglas C. Forer, Educational Testing Service, USA; Louis S. Mang, Educational Testing Service, USA

This paper describes basic requirements for making movies on the Web accessible for people with disabilities. The paper focuses on important alternative content that needs to be added to movies, such as captions, auditory descriptions, and collated text transcripts. It also describes a prototype system for delivering movie-using test questions accessibly over the Web. Resources for going beyond the basics are then presented.

Real education from virtual objects: active learning in science on-line

Roy Hawkey, The Natural History Museum, UK

This paper describes, analyses and evaluates an on-line science education project - QUEST - that was designed to develop a constructivist approach to learning by enabling students to carry out a series of investigations on a range of natural objects, by applying virtual tools, and to share their findings. It examines the project and explores the effectiveness of such an approach to learning science on-line, which is focused on the search for solutions rather than on the solutions themselves. Particular emphasis is given to issues relating to interactivity, the representation of scientific methodology and the role of names in the natural world.

Demos with Positive Impact: A resource for mathematics instructors

David R. Hill, Temple University, USA; Lila F. Roberts, Georgia Southern University, USA

In any form of instruction the instructor plays an important role as facilitator of learning. Demonstrations to accompany ideas and concepts are a requirement for effective instruction. Experienced instructors have private toolboxes of demos, conceptual approaches, or physical gadgets they use to encourage students to tune-in to mathematics. This rich, but largely unharvested source of tried-and-tested ideas forms the basis for Demos with Positive Impact, a project that will develop a web-based database of instructional demos and connect this resource to university mathematics instructors. This project takes advantage of the knowledge and experience of colleagues across the country and presents these valuable resources to the mathematics community in an attractive, user-friendly format. Demos with Positive Impact is a resource for instructors who are looking for ideas or demonstrations adaptable for various teaching styles and learning environments.

Synergy Education Press: Tools for Teachers' Professional Development

Jeffrey Horvath, Synergy Education Press, Inc., USA; Richard Lehrer, University of Wisconsin-Madison, USA; Matthew Koehler, Michigan State University, USA; Anthony Petrosino, University of Texas-Austin, USA

Synergy Education Press, Inc. is developing a series of Internet-based, video-intensive, case-based teacher professional development products for elementary math and science educators. New teaching and learning standards, the need to ground teacher professional development in practice, and recent technological advances allow us to create these cutting-edge products. Our product design is based on over a decade of research on children's thinking, teacher practices, and educational technology. Our design has been extensively tested and shown to significantly improve teachers' understanding of key ideas about math and teaching as well as their ability to integrate those ideas and apply them in the classroom. Also, our entire product line will be firmly grounded in the practice of actual classrooms. Finally, our entire product line will be consistent with national standards for math and science education.

Hypermodels: Embedding Curriculum and Assessment in Computer-Based Manipulatives

Paul Horwitz, The Concord Consortium, USA

This talk will demonstrate "BioLogica," a new kind of educational technology which combines an open-ended, manipulable model of biology with a multimedia module. A scriptable control engine sets up a series of challenges for students, and monitors their actions. In this way, curriculum and assessment activities can be embedded in the software. BioLogica scripts are written in a simplified version of Java. Their creation requires a degree of familiarity with programming, but we plan to enable non-programmers to customize them.

Changing the Rules: Children, Creativity and Computer Games

Celia Hoyles, Institute of Education, University of London, UK; Richard Noss, Institute of Education, University of London, UK

Computer games are important in children's culture. They afford opportunities for fantasy, challenge, collaboration and competition, all essential elements of play and learning. Yet their relationship with learning remains tenuous. This paper will present some work that seeks to build computational 'playgrounds' where children will learn about rules, by designing, building and playing their own computer games.

Development of Multimedia Learning Modules in Chemistry Using Authorware 5.0

Christie Jester, University of Texas at Austin, USA; Joanne Williams, University of Texas at Austin, USA

Valence Shell Electron Pair Repulsion and Valence Bond Theories pose great difficulties for chemistry students. Using Authorware, we developed a user-friendly computer tutorial with multiple interactions and animations, an interactive glossary, periodic table, and practice problems and quizzes with personalized feedback. Students will use hyperlinks to move throughout the tutorial at their own pace, will be able to revisit sections of interest for extra help, and look up key words in the glossary. Three-dimensional molecular models and movie clips help students visualize molecular structure and hybridized orbitals. To encourage active participation and practice, students will be given short segments of text accompanied by a graphic, followed by several practice problems. End-of-chapter review questions will be similar in scope and form to those that students encounter on course exams.

Web-Based Writing and Peer Reviewing in Chemistry Education

Christie Jester, University of Texas at Austin, USA

Research has been done showing the usefulness of writing in learning academic subject material. In college programs, numerous techniques, such as summary writing and peer reviewing have been adopted. In the sciences, however, large class sizes often preclude students from having frequent writing opportunities. We solved this problem by creating a semi-automated web-based peer-editing program. Our goals were to help students learn chemistry concepts by writing about them and to prepare students for future careers by developing their writing skills. A peer-reviewing process and assessment rubric was devised to allow upper-level chemistry students to read, critique, and grade their classmates' papers. Results of the rubric were stored to a database and were available to the writer through an on-line search. The course was served using a Macintosh and the inexpensive software FileMaker Pro 4.0 and Claris Home Page 3.0.

Predictors of Class Use of Computers

Johan Van Braak, Vrije Universiteit Brussels, Belgium

A survey was performed to investigate the influence of personal factors on class use of computers. Subjects were 236 secondary school teachers who were using computers, either for teaching or non-teaching purposes. A logistic regression technique was used to examine differences between class users and non-class users of computers on a set of personal characteristics: age, gender, computer attitudes, computer experience, technological and general innovativeness. Results indicate that only technological innovativeness and computer experience accounted for significant variance in explaining class use of computers.

Problem Solving with the TI-92: A Report on a Problem Seminar

Clifford Johnston, West Chester University, USA

The paper will report on a graduate level Problem Seminar offered at West Chester University that focused on using technology, particularly the TI-92, to assist problem solving. The course merged the traditional problem seminar with an introduction to computer algebra systems and their applications. Traditional and non-traditional problems that required the use of technology beyond routine numerical computation were the focus of the course. In particular, problems from the fields of number theory, algebra, calculus, geometry, probability, and statistics were used to investigate the role of technology in problem solving.

Integrating Space Science Research into an Interactive Web-Based Curriculum: Implementation and Evaluation

Rita K. Karl, Lunar and Planetary Institute, USA; Leslie C. Hunt, University of Houston Clear Lake, USA.

This poster illustrates two prototype web-based instructional modules created for the Lunar and Planetary Institute's Mars Millennium web site and CD-ROM project to support the National Aeronautic and Space Administration's Jet Propulsion Laboratory.

Discovery Chemistry Using Statistics and Minitab

Patrick Keller, Castleton State College, USA; Abbess Rajia, Castleton State College, USA

Students entering general chemistry courses are weak in fundamental math skills and knowledge of statistics even though they have been exposed to basic concepts in statistics through their preparatory

math courses. There is a difficulty in transferring knowledge of statistics to science courses and this is found throughout the K-16 curriculum. The problem is that students lack statistical knowledge in the context of applications in sciences. Discovery Chemistry Using Statistics and Minitab overcomes these difficulties through its integrated and inquiry based laboratory approach. Most importantly, the course shows how statistics is a fundamental part of the process of acquiring knowledge in chemistry. The discovery approach includes an inquiry based laboratory designed to stimulate students to think creatively about analyzing and modeling data that they generate through experimentation. This laboratory environment helps immerse the student in a learning process that is rich in technology, data analysis and fundamental explorations in statistics and chemistry . Students are presented with a series of laboratory experiences in which they are asked to design experiments, collect, analyze and model data to solve problems while working in small collaborative groups. Each student generates data sets from his/her experiment and these data sets are pooled together to form a data base that is used for class discussion and to explain concepts in statistics. This integrated approach stimulates interest in statistics and encourages students to take the risk to ask questions and get engaged in a discussion. This teaching approach moves statistics from a pure methods approach to one which is founded in applications.

Global Warming - Should We Worry? A Problem-based, Simulation, and Teamwork Approach to Teaching Integrated Science

Terry Kiser, CSU, Chico, USA; Jeff Bell, CSU, Chico, USA; Richard Flory, CSU, Chico, USA; Randy Miller, CSU, Chico, USA; Roger Lederer, CSU, Chico, USA; James Pushnik, CSU, Chico, USA

For the past year, a team of six faculty from the College of Natural Sciences at California State University, Chico have been working on the NSF-funded development of integrated science materials employing a problem-based approach and infusing computer modeling and simulation with traditional laboratory experimentation. This paper will report on a one-semester course we have developed based on the theme: Global Warming – Should We Worry? The course covers topics such as: an introduction to climate change with web-based research, an introduction to computer modeling and simulation using the program Stella, and a series of modules, Solar Radiation and The Earth, C02 and The Ocean, and Photosynthesis and Respiration, where computer models are developed tied to pertinent laboratory experiments. The course concludes with student teams taking on the task of representing various countries or regions of the world in a mock Kyoto accord.

FCell3D: A Central Example to Visualize Safety Critical Processes in the Construction and Control of Distributed Applications

Hans-F. Kötter, FernUniversität Hagen, Germany; Norbert Völker, University of Essex, United Kingdom

This paper reports on the design and implementation of a case study for the step-by-step development of distributed, safety critical control programs. The case study is a key ingredient in a new distance learning course for graduate students at the Electrical Engineering Department of the FernUniversitaet. It is implemented completely in VRML and Java and serves as a running, interactive example in our course. Via a variety of interfaces, students can model the control components and implement them in suitable programming languages.

HIPPODAMUS: A WWW Based Expanded Learning Environment

Georgios Kouroupetroglou, National and Kapodistrian University of Athens, Greece; Despina Deligiorgi, National and Kapodistrian University of Athens, Greece; Alexandros Pino, National and Kapodistrian University of Athens, Greece; Constantinos Viglas, National and Kapodistrian University of Athens, Greece; Ioannis Kalogiros, National and Kapodistrian University of Athens, Greece

This paper discusses the theoretical model, the design, and the implementation of a learning web entitled HIPPODAMUS, namely a cluster of interactive networks of persons and technological networks which harmonically collaborate with the aim to perform effective learning. The technological networks include the equipment for supporting the studies of the students (e.g. specific measuring instruments or networks of sensors) as well as the technology for supporting the learning process (such as computer systems and networks and especially the Internet). HIPPODAMUS constitutes an expanded learning environment that incorporates extensive use of the Internet and its services,

effectively promoting the active participation of all the partners involved in the educational process, namely of students, teachers, academic / research community and the administration of the education. This web is based upon the use of information and communication systems built for the World Wide Web, and it constitutes the application of an experimental educational framework on subjects such as Informatics, Technology and Environmental Education. HIPPODAMUS ties with the current trends and requirements, concerning the joined preparation of high-school students towards the Information Society, the Learning Society and the Environment-aware Society.

Teaching Functional Programming for High School Students

Tami Lapidot, Technion, Israel Institute of Technology, Israel; Dalit Levy, Technion, Israel Institute of Technology, Israel; Tamar Paz, Technion, Israel Institute of Technology, Israel

Functional programming includes complex concepts and advanced ideas such as building abstractions with functions, compound data and list processing. As part of a new computer science curriculum for high school students in Israel, we developed a functional programming course, using DrScheme environment [1], based on recent research in science education that emphasizes the constructivist nature of learning. This paper deals with some preliminary findings from our field research and discusses some of the successes and difficulties of the high school students who took part in the course.

A new efficient retrieval interface for primary school students

Chien-I Lee, National Tainan Teachers College, Taiwan, R.O.C.; H. Chen, Graduate Institute for Computer and Education, National Tainan Teachers College,, Taiwan, R.O.C.

Through the Internet, users can conveniently get their desired information. However, in general, it is not quite easy for the users get what they just want though the Internet by using some keywords to do the conventional full-text searching. Most notably, such a searching process will be a heavy load for primary school students who are not able to choose the proper keywords because they are not familiar with the knowledge and semantic words about their desired topic. Therefore, in this paper, we will propose a new retrieval interface for primary school students, called leading-question retrieval interface, which applies a series of questions to inquire and analyze the answers from the users to understand their queried intentions. Such an inquiring process is embodied with the spirit of Construction and can omit the difficult task to choose proper keywords.

Classification and discussion of recursive phenomena by computer science teachers

Dalit Levy, Technion, Israel Institute of Technology, Israel

Recursion is a significant concept, appearing in almost every introductory course in computer science (CS). CS educators and educational researchers often refer to difficulties in learning and teaching recursion. However, the research literature barely addresses the unique ways in which students and teachers relate to this interdisciplinary concept and their particular language concerning recursive phenomena. This paper reports on a study in which groups of mathematics and computer science teachers collaboratively classified and discussed several recursive phenomena. The discourse was recorded and analyzed, and a grounded categorical system was formed and examined. Preliminary results indicate some basic aspects of recursion in the discourse, although these teachers apparently talk a slightly different language from that of expert computer scientists. Some 'potentially rich' discourse episodes were evident as well, representing conflicts among alternative conceptions. Such episodes can serve as a springboard for further understanding of recursive phenomena.

USD's Web Group: A service learning experience in Computer Science

Jane Friedman, University of San Diego, USA; Luby Liao, University of San Diego, USA

This paper will describe the University of San Diego's web group, an unique and innovative service-learning experience for computer science students.

An integrated common theme-based web site for teaching Science and Technology in Australian Primary Schools

Min-Jin Lin, National Hualien Teachers College, Taiwan, R.O.C.

The paper describes an integrated common theme-based web site that supports the teaching of Science and Technology in Australian primary schools. There are ten components in the web site. The "Background Information" component strengthens teachers' background scientific knowledge and

skills. The "Content Strands", "Learning Outcomes", "Program Overviews", and "Links to other key learning areas" components assist Australian primary school teachers implementing the theme-based programs for teaching Science & Technology. Moreover, the "Internet Lesson Plans" and "Teaching Resources" components help teachers to reflect on their designs of the program. The "Fun Web Sites for Kids" motivates students to learn by exploring fun sites that are specially designed for children. The "Ask Expert a Question" and "News Discussion Group" components help teachers to solve problems in subject domain or teaching. This web site reveals the common theme-based characteristics of Australian primary curriculum, and it contributes to improve Australian primary school science teaching.

Representation of Problem-Solving Procedures in MathCAL

Janet Lin, National Taiwan Normal University, Taiwan; Jie-Yong Juang, National Taiwan University, Taiwan; Ponson Sun, National Taiwan Normal University, Taiwan

MathCAL is a network-based learning system for users to practice mathematical problem solving. Math knowledge is pre-analyzed to derive a set of macro functions for use in solving problems in a specific domain. Each macro function typically represents a math concept or rule which may be used to transform a math problem from a state into the next. Learners select problems to work on from the problem bank and proceed with problem solving step by step. The kernel of the system uses Petri nets to dynamically record a learner's problem-solving activities. The Petri-net representation allows the system to determine appropriateness of a user's application of a function at a certain step. It also enables the system to understand a user's thinking process when it is requested to offer guidance. MathCAL also supports synchronous and asynchronous network functions which may be used to establish a collaborative problem-solving environment. In addition, MathCAL allows users to add new problems and/or new solution paths to its databases.

PCLogo and Mathematical Thinking Processes

Leping Liu, Towson University, USA

While Piaget's theory of cognitive development stages and van Hiele's theory of geometrical thinking levels emphasize the "state" of children's thinking, and describe the characteristics and applications of thinking at each particular stage or level, this paper demonstrates the thinking "processes" that advance thinking from one level to another higher level, with a C-A-C (concrete-abstract-concrete) learning model. Specifically, the C-A-C model using PCLogo assumes that repeated practice on concrete procedures of solving geometry tasks can lead a child's thinking to a higher level of abstract thinking. However, how much practice can be considered "enough"? This paper investigates how many tasks, or what difficulty-level of the tasks would be necessary for a child to advance his/her thinking from concrete level to abstract level and solve the abstract geometry problems. Current data and results in this is on-going study indicate that different "amount" of practice makes significant difference in children's geometry concept learning.

Math in a Web Environment

Marcelo Llarull, New Jersey City University and William Paterson University, USA;

This paper addresses two issues, one is writing mathematical expressions on the web and the other is creating interactive math websites to teach and learn mathematics. In both cases, helper applications play a crucial role to successfully achieve both.

The Development of an Index to Measure Sense of Learning Community in Computer Science

Robert Lucking, Old Dominion University, USA; Fred Rovai, Old Dominion University, USA; Dean Cristol, Old Dominion University, USA; & Katherine King, Old Dominion University, USA

The purposes of this study were to develop, refine, and field test the Sense of Learning Community Index (SLCI), and to determine its validity and reliability for use with college students in traditional and distance education environments. The 40-item SLCI measures sense of learning community within a group of learners. The SLCI was field tested with university students in traditional and synchronous distance education courses. Data were collected from 135 students. Instrument reliability is very high (Cronbach's coefficient alpha = .97). The SLCI also exhibits high content validity covering the domains of collaborative learning, teamwork, shared goals, and active creation of knowledge and meaning. No evidence of differences in sense of learning community was found between traditional and distance learning courses and between content areas. However, differences were found between

groups taught by different instructors. It was concluded that the SLCI is an effective measure of sense of learning community.

Project Links: Interactive Web-based Modules for Teaching Mathematics and Its Applications

Kenneth S. Manning, Ph.D., Rensselaer Polytechnic Institute, USA

Project Links at Rensselaer is a cooperative effort to develop materials linking mathematical topics with their applications in engineering and science. The product of this effort is a set of interactive, web-based learning modules that rely on hypertext, animations, and interactive Java applets. We employ interactive web-based modules in the studio classroom environment, pioneered at Rensselaer, to engage students in guided learning. The intent is to provide students with an experience unavailable in traditional lecture or textbook lessons. These modules are designed for use in more than one course, with a topic-qualified instructor and assistant available in the classroom during use. They are not intended as self-paced learning modules, nor as text replacements, but are to supplement existing courses with a degree of interactivity and universality not available before the advent of the World Wide Web. There are currently 47 modules in development. All modules will be available for examination.

Student-Instructor E-mail Exchange in Active-Learning Biol 100

Gili Marbach-Ad, University of Maryland Baltimore County, USA; Phillip G. Sokolove, University of Maryland Baltimore County, USA.

Student-instructor communication was examined in a large, introductory biology class for majors (enrollment ~250). Students were encouraged to send questions, comments and suggestions to the instructor using e-mail. All messages were collected after the semester and classified as either content-related or procedural. Content-related messages typically contained questions, comments or suggestions about a topic that had been discussed the same day in class. Procedural messages included questions or requests concerning homework exercises and exams, reports about student absence from class, or requests to switch classes or sections. Messages from females and males reflected class gender distribution, but Asian and African Americans were more likely than Caucasians (relative to their class distribution) to send content-related messages. Most students whose messages were classified as content-related had earned final grades of A or B.

Developing Prairie to Mountain Explorer: A GIS and Remote Sensing Data Set for the Fifth-Twelfth Grade Classroom

Patricia McClurg, University of Wyoming, USA; Alan Buss, University of Wyoming, USA

Results of a three-year collaborative investigation into what constitutes viable GIS data sets for use with fifth through twelfth grade students will be reported and the product Prairie to Mountain Explorer (PTME) will be demonstrated. This collaboration involved teachers, teacher educators and scientists participating in a NASA funded five-state consortium (Upper Midwest Aerospace Consortium-UMAC). PTME is a spatial data base which provides a rich context for student investigations using the Internet, Geographical Information Systems (GIS), Global Positioning Systems (GPS), and Calculator Based Laboratories with sensing instrumentation (CBL). PTME contains selected base-line data sets at regional and county scales (ranging from 1:2,000,000 to 1:100,000), and a user's guide with meta-data for over 300 themes. Results from extensive pilot testing coupled with input from agriculture/natural resource researchers contributed to this powerful educational resource. UMAC maintains a web-site to support PTME and to provide a growing resource of classroom tested lesson plans (nasc.uwyo.edu/edparc).

Math and Science Software for the Young Child: Developomentally Approporiate or Marketing Ploy?

Robin McGrew-Zoubi, Sam Houston State University, USA; Joan Livingston Prouty, Sam Houston State University, USA; Kim Arp, Sam Houston State University, USA

This paper describes a study of mathematics and science software marketed for preschool children. Preservice teachers observed young children at work, reviewed the literature available about computers and young children, and interviewed early childhood, technology, mathematics, and science specialists. Teachers, childcare providers, and parents shared their beliefs about the value of computers for young children. Analysis of specific software packages and their alignment with developmental benchmarks, still in progress, will be presented.

Modelling Three-Dimensional Surfaces On A Spreadsheet

Abas Md Said, Universiti Teknologi Petronas, Malaysia; Mohd Yunus Nayan, Universiti Teknologi Petronas, Malaysia

This paper describes how three-dimensional surfaces can be drawn using an electronic spreadsheet. This program is useful and an inexpensive way for both teachers and students to visualize 3D surfaces from almost any angle and interval. This when blend and together with theory will be a promising approach for them to get a firmer understanding of the subject.

LAAP: Learn Anytime Anywhere Physics I

Jerry Meisner, UNCGreensboro, USA; Harol Hoffman, UNCGreensboro, USA; Mike Strickland, U. Washington, USA; Wolfgang Christian, Davidson College, USA; Aaron Titus, NCA&T, USA

The Extended Physics Community Consortium will author Learn Anytime Anywhere Physics (LAAP). LAAP will provide both synchronous and asynchronous learning experiences for undergraduate students, high school physics students with various needs as well as preservice and inservice teachers. We will use Java technology to develop and build an online physics laboratory learning environment comprised of typical introductory, algebra-based physics modules, in an innovative pedagogically sound format: - virtual lab equipment applets (Laaplets) - virtual lab setup device applets (Laaplets) - associated curriculum modules in which students perform experiments in the virtual lab - student assessment components - peer interactions and peer mentoring By means of interactivity between client machine and servers, student input will be stored in server side databases. This will permit just in time analysis (JITA) for immediate feedback.

Inservice programs: Does Their Effectiveness Last?

Michelle Merriweather, West Chester University, USA

This paper discusses the findings of a study conducted on two types of in-service programs. The program, Virginia Network for Technology (VANT) consisted of an overview course and an intensive course. The study examined the differences in both the attitudes toward and actual use of calculators between the participants who participated in the overview course, intensive course, and those who did not complete either course. The results indicate a trend that after attending VANT, teachers incorporate technology into the classroom and continue to use it in the years following VANT. In addition, the teachers who participated in VANT have a more positive attitude toward calculator use in the mathematics classroom than when they first completed VANT. However, there was not a significant difference in attitude between those who completed the overview course, intensive course, and those who did not complete either course.

Quantitative courses in distance learning

Antoni Meseguer-Artola, Universitat Oberta de Catalunya, Spain

In distance learning through Internet, where the Universitat Oberta de Catalunya (UOC) is one of the pioneers in the world, the particular type of students attending the courses and the difficulties in the transmission of mathematical texts create the necessity of developing new strategies which facilitate the learning–training process. These strategies are based on the development of ad-hoc learning guides that establish a particular link between self-directed learning and directed learning. We focus our study on a particular type of courses: quantitative courses, i.e., courses that use mathematical language for its development or courses where mathematical concepts are the aim of study. The design of appropriate learning guides for quantitative courses and their classification are the main objectives of this paper. In this sense, from different educative experiences in low, medium and high level courses in mathematics, this work proposes different items that a learning guide has to contain and it also gives a classification criteria of such these guides.

Discovering xyAlgebra: Intelligent Interactive Internet Instruction

John Miller,The City College of CUNY,USA

Passive activities such as watching presentations, listening to explanations of general principles and watching experts solve sample problems are helpful, but peripheral, to the mathematical learning process. For students the indispensable step is solving problems for themselves. Yet most commercial mathematics software still concentrates on presentations and sample problems, while sending students off line to do practice problems on paper without interactive support. Answers are either multiple choice or limited to a single simplified final step. Early Internet courses are even less interactive. In contrast, students using xyAlgebra can enter each step of each problem solution. They enjoy

intelligent support at every step as xyAlgebra's suggested solution strategy changes in response to their steps in simplifying expressions, solving equations and even in setting up and solving verbal problems. The next version of xyAlgebra will support instruction over the Internet, yet the entire package can be downloaded without cost at math0.sci.ccny.cuny.edu/xyalgebra.

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Building and Using Simulation Based Environments for Learning about Complex Domains

Marcelo Milrad, The Institute for Media Technology, SWEDEN; J. Michael Spector, University of Bergen, Norway; Pal Davidsen, University of Bergen, Norway

A variety of substantive issues confront education with respect to technology support for learning increasingly complex knowledge. How can learners acquire and maintain deep understanding about difficult-to-understand subjects? We argue that because students are learning for real life and preparing to solve real complex problems in the future, the complexity of the world should be taken into account much more and much earlier than usually happens. In this paper we describe and illustrate our approach to the design of interactive learning environments for complex domains and the role technology can play on these environments.

Using Controls to Construct Dynamic Spreadsheets for Teaching Math and Physics: the Design of Interfaces and Worksheets.

Simon Mochon, Center for Research and Advanced Studies, IPN, Mexico

In this article we discuss the advantages of using controls in spreadsheets for educational purposes. The most evident is that graphs change in a dynamic way, which gives a powerful visual support to the understanding of the situation represented in the spreadsheet. We will show some spreadsheets with controls that were designed for an educational project in Mexico to teach math and physics with computers. The article also describes the structure given to the corresponding worksheets and the pedagogical model followed within the classroom to ensure an efficient use of the computational activities developed.

Science education in alternative programs: Building bridges with technology

Barbara Moore, The University of South Florida, USA

Science educators, using technology, can build bridges across the digital divide by helping alternative education students graduate and break the cycle of poverty. Alternative students often miss various segments of content. The results are poor grades and low scores on standardized tests. These students need resources for self-paced acquisition of knowledge, comprehension, and application levels of missing content. They also need resources for individualized drill and practice, as well as stimulation of higher level thinking skills. The Digital Bridge, URL http://typhoon.coedu.usf.edu/~bmoore/bridge.htm, is an on-line learning resource designed to address individual differences in student learning style and ability. The site offers short, self-paced units of content. It features objectives, key terms, tutorials of several types, links to related information, flashcards, and timed quizzes. The Digital Bridge helps students learn and allows teachers to focus on individual students or community-based class projects.

The Effects of Technology on an Undergraduate Mathematics Department

Leigh Myers, Northwestern State University of Louisiana, USA; Stan Chadick, Northwestern State University of Louisiana, USA

Technology in hand-held form is changing the manner in which we teach mathematics. The first and most important question is whether to require every student to have a graphing calculator. An immediate effect is the classroom itself with calculators in the hands of all students and an overhead for the instructor. The positive effect on the faculty, curriculum, and pre-calculus sequence makes the change to mathematics with technology worthwhile. We look forward to future developments in technology and their impact on mathematics.

Mining The Internet: Integrating Real-World Data And Interactivity In The Online Classroom

Gerald "Jerry" Nelson, Casper College, USA; Susan Nelson, Casper College, USA

The internet does three things extremely well that can promote interactivity in the online classroom: communications, immediacy of data, and the internet's ability to archive data sets. These three taken together can produce opportunities for true interactivity between students and scientific theory and mathematics.

A Computer Simulator Can Transform "Dictums of Authority" into "Evidence" for Model Construction in Physics

Valerie Otero, San Deigo State University, USA; Fred Goldberg, San Diego State University, USA

Urban systemic reform initiatives call for increased use of computers in K-12 science classrooms. It therefore becomes increasingly important to understand how particular types of computer software and pedagogical structures can support interactions that lead to meaningful learning by students. In this paper, we describe some results from our research that focuses on learning in a collaborative-inquiry science classroom. We have found that the computer can make a difference in this environment. We discuss how special computer simulators made it easier for groups of students to construct explanatory models. It did so by providing the opportunity for students to make model-like observations that could not be made using hands-on apparatus. Model-like computer results helped students bridge the gap between phenomenological and conceptual domains.

From the abstract to the practical: How the Motion Media Grapher helps students understand and interpret abstract mathematical concepts

Evangeline S. Pianfetti, University of Illinois, College of Education, USA; Brian Pianfetti, University of Illinois, College of Education, USA

Hiebert & Carpenter (1992) state that "school-learned procedures often cannot be used flexibly to solve problems other than those on which they were practiced, and thus, do not transfer well (p. 79). The Motion Media Grapher (MMG) is a Web-based software utility created by the authors of this paper to help students make the link between the abstract mathematical concepts they learn in the classroom and their occurrences in the real world. The students may easily interact with the MMG and it may be efficiently adapted by classroom teachers for integration into an existing curriculum. The MMG attempts to enhance the students' internal representations with socially situated events. Hence, the concepts are taught through their application in familiar environments and not in abstraction. Based on a yearlong research study, this paper introduces its readers to the MMG and discusses its efficacy as a visualization tool for high school mathematics students.

Issues Involved in a Large Scale Implementation of Web-Based Mathematics Instruction

Michael Pilant, Texas A&M University, USA; Robert Hall, Texas A&M University, USA; Janice Epstein, Texas A&M University, USA; Yvette Hester, Texas A&M University, USA; Arlen Strader, Texas A&M University, USA

As the capability of the World Wide Web (WWW) for delivery of mediated instruction increases, it is natural to consider it as a primary delivery mechanism for distance education. Several issues must be addressed, however. Two of these issues, access and ease of use, are primarily matters of technology. As equipment gets better and more affordable, we move closer to the goal of "universal access." Two other issues, assessment and motivation, are more complex due to human factors, thus, involve long-term research efforts. This study addresses each of these issues but focuses principally on problems

associated with assessing student performance and increasing motivation in mathematics via self-contained, interactive, web-based instructional modules. For the past several years, a traditional finite mathematics course has been the testbed for developing web-based instructional methods. Results from this long-term project are summarized.

Technological Tools to Enhance Performance in Calculus I

Olga M. Ramirez, University of Texas-Pan American, USA; John E. Bernard, University of Texas-Pan American, USA; William Heller, University of Texas-Pan American, USA; Wendy A. Lawrence-Fowler, University of Texas-Pan American, USA; Gerald Brazier, University of Texas-Pan American, USA

In 1998, the Minority Student Improvement Program at the University of Texas- Pan American, Edinburg, Texas began the process of developing and implementing an enhanced instructional model for Calculus I that integrates technological tools for teaching and evaluation of learning purposes. The objectives of this work focus on developing and disseminating an affordable, highly interactive, student-centered learning environment which will increase success rates for minority science and engineering students enrolled in Calculus I. As a result of the project, faculty aim to better help students gain understanding of different types of significant mathematical knowledge that will further assist them to succeed in Calculus I and beyond. A questionnaire was developed to assess descriptive and content knowledge variables. The preliminary results of the data collected via the questionnaire comprise a part of this paper, as well as the ramifications of the students' level of preparedness as measured by key questionnaire items, and some specifics about the instructional modifications that are being made to meet the students' needs.

The application of Maple V in learning activities for courses in transport phenomena

Araceli Reyes, Instituto Tecnologico Autónomo de Mexico, MEXICO; Bernardo Hernández-Morales, Universidad Nacional Autónoma de México, MEXICO

Courses on Transport Phenomena (Fluid Flow, Heat Transfer and Mass Transfer) are taught at the junior level in the engineering curricula. These courses require the use of mathematical-oriented skills, in particular the application of methods for solving differential equations, in the context of an applied problem. To aid in the learning process, we are developing a series of activities based on the Maple V R4 software package — a language for symbolic mathe-matical calculation. Each activity is based on a Maple V R4 worksheet, accompanied by a handout. The worksheet must be completed by the students as an extra-class activity. The handout is divided in two parts: i) a brief descrip-tion of the problem, where the objective of the exercise is clearly defined; and ii) instructions on how to complete the worksheet, followed by questions that can only be answered after the worksheet has been successfully completed.

Math/Science/Technology: An Academic Major.

Timothy Riegle, Kean University, USA

This is a report of a current developmental efforts for a Liberal Arts based academic major in Math, Science & Technology. There are still a number of serious issues that need to be addressed. There are discipline specific views that could be seen as having very little common ground. The flexible and equitable resolution of those issues can lead to an exciting and valuable program.

Flexible Generation of Animations Using Animal

Guido Roessling, University of Siegen, Germany; Bernd Freisleben, University of Siegen, Germany

ANIMAL is a tool for generating animations suitable for integration in lectures. Animations can be generated by visual editing using drag and drop, scripting using the built-in scripting language and generation by function calls in the ANIMAL API. ANIMAL offers the primitives point, polyline / polygon, text, arc and list element. All elements are adaptable to subtypes such as square, ellipse or circle segment. Animations consist of separate steps containing an arbitrary number of effects each. Current effects include show/hide, move, rotate and change color and can be given both offset and duration, measured in milliseconds or internal time units. Both scripting and API support inclusion of source/pseudo code with indentation, element and code highlighting, arrays including index pointers and relative object placement. Automating animation generation is easily accomplished. The resulting

animation files seldom exceed 10kB. ANIMAL is implemented in Java and available at http://www.informatik.uni-siegen.de/~inf/Software/Animal/.

Hypertexts and Hypermedia to Present the Interconnections Between Mathematics and Arts

Nicoletta Sala, Academy of arch- University of Italian Switzerland, Switzerland

The computer plays a central role in educational environment, for this reason I describe an educational approach where some mathematical concepts are presented with their artistic connections, using also the hypermedia, and the Web. For example, to explain the platonic solids and the polyhedra I have used some hypertexts and hypermedia (on CD-ROM and online) and I have also researched in the Internet some interesting Applet Java. At the Internet address: http:// home.a-city.de/ walter.fendt/mathengl/platonengl.htm there is an Applet Java which contains an animation where we can choose and rotate the platonic solids (changing the rotation angle). To present the polyhedral components and the tessellation in the M.C. Escher's paintings I have proposed to my students the CD-ROM Escher Interactive (for Windows) which contains an audio/ visual life of M. C. Escher and videos of the artist at work. To introduce the basic concepts of the fractal geometry I have created a hypertext using HTML language. It is available at the Internet address: http: // www. arch.unisi.ch / fractals/fract1e.htm inside of my hypertext there is a page dedicated to the fractal architecture with the building's self-similarity (e.g., an Indian fractal temple, the fractal floor of the church of Anagni, Italy).

Mathematics, Arts, and New Media : Some Interesting Interconnections

Nicoletta Sala, Academy of Arch. - University of Italian Switzerland, Switzerland

Imagination and creativity are among the qualities of a good mathematician. The academic mathematics course has become, for many students, a highly structured sequence of definitions, theorems, and proofs that lead only to additional definitions, theorems, and proofs. This work describes an educational approach, in two different undergraduate course (first and fourth year), where some mathematical concepts are presented with their artistic connections (e.g., the polyhedra, the golden section, the fractal geometry, and so forth), using also the new educational tools (e.g., hypertext, hypermedia, virtual reality). I refer of my experience at the Academy of Architecture of Mendrisio, University of Italian Switzerland where I have researched the interconnections between Mathematics, Arts and Architecture using the new media and I have observed that they can help: to reach good cognitive goals, to increase the students' attention, to do more interactive the learning process.

ZELIG: Statistics For All

Teresa Sancho, Universitat Oberta de Catalunya, Catalunya; Antoni Meseguer, Universitat Oberta de Catalunya, Catalunya; Francesc Vallverdu, Universitat Oberta de Catalunya, Catalunya; Eloi Batlle, Universitat Oberta de Catalunya

This work presents a web-format framework for teaching and learning Statistics in the Universitat Oberta de Catalunya (UOC). UOC is an Open University with a virtual campus where both students and teachers interact, breaking time and distance constraints. The learning and teaching process is evolving with the information and communication technologies. These technologies facilitate the interaction between the student and the material through the resolution of exercises and the experimentation with simulated cases. Statistics is a transversal subject or tool used, at different levels and skills, in most of Higher School studies. In this sense, we propose a digital and navigable didactic framework that integrates the basic elements of the self-learning process and adapts the learning material to the student, according to his personal profile (career, previous knowledge, skills, behavior, etc). A tailor-made and oriented evolution implies an intelligent tracking of the student's actions. In this respect, we might say that this kind of activity allows either the student to learn significantly or the teacher to keep the process under control.

Evaluation of Web-Based Instruction: A Case Study in Brazilian High Schools

Dietrich Schiel, University of São Paulo, Brazil; Joan Dassin, Fulbright Comission, United States; Monica Magalhães, São Paulo State University, Brazil; Iria Guerrini, University of São Paulo, Brazil

This paper describes the evolution of a distance education program where students perform physical experiments in their school assisted by a distance tutorial system. 20 public high schools in 14 cities in the interior of Brazil participate. Using an already described evaluation method which works on-line, it

were collected the opinions of a sample of 228 students from an universe of 2200 participants. The results indicate a positive impact on students learning and success in helping a distant teacher and his (her) students in the innovating experimental activities.

Realizing an IDEA/ Computer-aided instruction and learning

W. Udo Schroeder, Univ. Rochester, USA

An Interactive Distributed Educational Application (IDEA) has been realized for an undergraduate physical-chemistry course at the University of Rochester. It supports the educational goals of generating a more intuitive, yet realistic, understanding of complex, abstract physical theory by the students and helping them develop numeracy and important skills in actively simulating physical processes. Interactive Study/Lecture Notes (ISLN), containing an electronic text, hyper-linked to explanations, tutorials, "hot" data plots, simulations, and quizzes, represents the core of the IDEA. They are embedded in a Web-based course frame, together with course annunciator and communicator segments. ISLNs and course frame have been produced with MS-Word TM and MathcadTM software and can be viewed with freely available browsers. This widely used software makes the tasks achievable for both students and instructor. The IDEA course system has been accessible via the University's local network but may serve as a more general model of an effective self-paced, distance-learning environment.

Computer Enhanced Learning Environments for Meta-Competencies in Software Engineering

Mildred Shaw, University of Calgary, Canada; Brian Gaines, University of Calgary, Canada

Industrial priorities for the competencies of both undergraduate and graduate software engineers include not only technical knowledge but also meta-competencies which are not normally addressed in standard computer science learning environments. These meta-competencies include the capability to operate effectively in teams and to be able to communicate with customers, suppliers and co-workers. This article describes the underlying principles, practical implementation, and several years experience with the learning environments at both undergraduate and graduate level that support the rapid development of such meta-competencies within the framework of normal academic courses.

Using Graphing Software, Computers And Ekg's To Help Students Learn About The Behavior Of The Heart

Leonard Simons, Elmira College, USA; Jerry Przybylski, Elmira College, USA

Reading the output of an EKG is often confusing for students in beginning biology courses. A variety of distances, ratios and slopes need to be read from the graph to obtain the pertinent information for describing the behavior of the heart. However, many students in these classes do not have a good background in graphical analysis. We propose that doing some mathematical work in a biology course before encountering circulation lab activities will greatly aid in the students' understanding of the material. The students first generate some very simple graphs. They see how various distances, slopes and ratios obtained from the graphs describe different quantitative behaviors. The students work through a small set of increasingly complicated periodic graphs leading to a graph that looks like the output of an EKG. Then, when running the actual EKG's, the students can concentrate on the biological concepts rather than learning new mathematics.

Grades 4 and 5 Teachers' Perceptions of Technology Implementation in Mathematics Instruction

Scott W. Slough, Georgia Southern University, USA; Gregory E. Chamblee, Georgia Southern University, USA

The purpose of this paper is to examine and describe the change process as technology is implemented in grades 4 and 5 mathematics classrooms. For this study technology is defined as manipulatives, calculators and computers. The Concerns Based Adoption Model (CBAM) provided a theoretical framework for data analysis. Data was collected through open-ended ethnographic interviews of six (n=6) grades 4 and 5 demonstration teachers identified by the university. Results were organized into four major themes: perceptions of technology (personal), availability and use of technology (technological), implementation of technology in the mathematics classroom (curricular), and technology's role in teaching mathematics (philosophy).

I.MO.PHY. a net-course supporting the Introduction to MOdeling in Physics education at high school level

Rosa Maria Sperandeo-Mineo, University of Palermo, Italy

IMOPHY (Introduction to MOdeling in PHYsics-education) is a teacher training Course delivered on the Web. It consists of various Net-Seminars (on line seminars using on-line discussion groups) concerning different physics topics. Each Net-Seminar is tailored to train teachers in transforming their teaching by promoting a constructivistic teaching practice and computer-enhanced instructional approaches that enable students to learn about the process of modeling physical phenomena. The Net-Course approach involves a construction of the physics content structure that has to be taught not mainly, or even solely, oriented to physics issues but also including educational issues and pupils' conceptions. These two issues, students spontaneous models and statements of the scientific knowledge, are therefore accepted to be of the same relevance and treated as resources for physics education. The Net-Seminar about thermal interaction between bodies will be described and the pedagogical tools prepared (experiments using Microcomputer Based Laboratory and software) will be analyzed.

Interactive Distance Education: A Database Model to Facilitate Peer Interaction for Asynchronous Learners

G. A. Stringer, Southern Oregon University, USA; J. J. A. Smit, Potchefstroom University, South Africa;P. J. Enslin, Potchefstroom University, South Africa

A pilot project at Potchefstroom University has tested the feasibility and effectiveness of using a database to store and retrieve peer interactions for asynchronous telematic learners. The study involved twelve members selected from a cohort of 43, enrolled in the second year of Project SEDIBA, a residential certificate program designed to upgrade the skills of science teachers from black rural high schools. A telematic module consisting of three units on basic electricity was developed using the database model. Practical work required in the module was done using a loaned electronic parts kit. Pre- and post-testing made use of an instrument called DIRECT developed and tested at North Carolina State University. Normalized learning gains of 0.10-0.12 were measured for the pilot and control groups.

The Effectiveness of a Computer-Interfaced Experiment in Helping Students Understand Chemical Phenomenon

Jerry P. Suits, McNeese State University, USA

This paper discusses the use and evaluation of a computer-interfaced experiment (CAL-001) in helping college students understand and appreciate a common chemical phenomenon—an acid/base titration curve. This study included two subgroups based upon academic major, i.e., Chem 110 students in science and engineering majors, and Chem 123 students in nursing and agricultural majors. Results showed that most Chem 110 students selected CAL-001 as their favorite experiment, whereas Chem 123 students were ambivalent about it. Many of the Chem 110 students who liked CAL-001 expressed a metacognitive awareness of the conceptual/analytical nature of the experiment. The graphic representation of CAL-001 (mL titrant vs pH) may serve as a bridge that connects the more concrete level of hands-on laboratory activities to the more abstract mathematical/symbolic representation level.

Teaching "Computers & Society" - The Medium and The Message

Brendan Tangney, Trinity College Dublin, Ireland; Bryn Holmes, Trinity College Dublin, Ireland; Ann FitzGibbon, Trinity College Dublin, Ireland

There are a number of significant challenges faced in teaching Computers & Society courses. The research described in this paper is based upon experience with teaching one such course. In-class group debates are the cornerstone of the course and these have been recorded and analyzed with a view to understanding what specific pedagogical forces are at work. The analysis to date suggests that in the teaching and model being used significant peer learning is taking place, students learn how to adopt different ways of interaction and collaboration depending upon the role that they are performing and that cognitive skills can be supported by allowing learners the opportunities to chunk information into smaller, meaningful parts. Above all the analysis supports the view that learning environments are key to the development of intellectual skills.

Learning Mathematics Through Image Processing: Constructing Cylindrical Anamorphoses

Steven Tanimoto, University of Washington, USA; James King, University of Washington, USA; Richard Rice, Alias/Wavefront, Inc, USA

Anamorphic images are distorted images that can be seen normally when viewed in special ways. A very popular form of anamorphosis in the 1700s and 1800s is a type of image that is intended to be viewed by placing a cylindrical mirror in the middle of it and observing the reflection. These images are fun to look at because without the mirror, an observer can make out just enough of the structure of the scene to be tantalized, and then the cylindrical mirror brings a visual resolution to the puzzle, answering the question "What is it supposed to really look like?" These kinds of images can be used today in compelling educational activities involving mathematics and computers. With the aid of special software for image processing in a mathematics context, students can construct their own anamorphic images while learning about image transformations, polar coordinates, ray tracing, digital image representation, and programming of computer operations on images.

Critical Issues in Distance Education: Partnership, Content, and Delivery

David A. Thomas, Montana State University, USA

This paper addresses three issues critical in the development of high-quality distance education courses in mathematics, science, and engineering: Creating stakeholder partnerships; reforming the content of mathematics and science education; and developing powerful, adaptable WWW-based instructional delivery systems. As each issue is discussed, recommendations are made for engaging interested parties in government, education, and the private sector in a search for solutions.

Teaching of "Spreadsheets- design and use" by Learning Activity Package

Daniela Touparova, "N. Rilski" South-West University, Bulgaria

The focus of this paper is application of Learning Activity Package (LAP) and the Web- based variant of LAP in teaching "Spreadsheets- design and use". In the Section 1 the background of education concerning Information Technology (IT) and Computer Science(CS) in Bulgarian secondary school is described. Section two deals with the architecture of LAP. More precisely the types of problem solving tasks and their components are proposed and discussed. Section 3 concerns the analysis of the experimental study of using LAP for module "Spreadsheets- design and use.". The study has been carried out with 184 students from Language School and Vocational School in Business and Agriculture. In Section 4 one point of view for Web- based presenting of LAP are given. Also some ideas for future research of application of Web- based LAP in teaching different IT and CS modules at the Bulgarian Secondary Schools are discussed.

A Navigable Book To Learn Discrete Mathematics

Francesc Vallverdu, Universitat Oberta de Catalunya, Catalunya; Teresa Sancho, Universitat Oberta de Catalunya, Catalunya

This work will discuss on a course material in web-format for teaching and learning Discrete Mathematics, a subject that is offered at the Computer Science School of the Universitat Oberta de Catalunya (UOC). UOC is an Open University with a virtual campus where both students and teachers interact, breaking time and distance constraints. The learning and teaching process is evolving with the new information technologies. The teacher-student relationship is changing, even more in distance education. The interactivity between the student and the material can be done through the resolution of exercises and the experimentation with simulated cases. The simple exercises are usually Java Applets embedded in the same html page where the exercise evolves, in a xml framework. Depending on the student's behavior and skills, different paths are presented in order to optimize the learning process. The more the student knows, the more difficult questions are. A tailor-made and oriented evolution implies an intelligent tracking of the student's actions. In this respect, we might say that this kind of activity allows either the student to learn significantly or the teacher to keep the process under control.

The Effect Of Advisement & Mode Of Instruction On Transfer, Advisor Use, And Attitude Toward Mathematics Using A Computer-Based Simulation Game

Rick Van Eck, University of Memphis, USA

This study examined the use of a computer-based mathematics simulation game with differing forms of advisement on transfer of mathematics skills, and attitude toward instruction. A game was developed using the principles of anchored instruction and piloted on middle school students in a gulf

coast city. The independent variables were context of advisement and mode of instruction. The dependent variables were performance on an authentic transfer task and attitude towards mathematics. Preliminary analysis of the data indicate that the game was more effective than the computerized word problems. Analysis of gender, competition, and other variables are ongoing.

Web-Based Implementation of the Little Man Computer

Joaquin Vila, Illinois State University, USA; Barbara Beccue, Illinois State University, USA

This paper describes the implementation of a well-known paradigm to depict the architecture and operations of a computer. The model, originally introduced by Dr. Stuart Madnick at MIT, is called the Little Man Computer (LMC). This simplistic metaphor is an effective method to introduce students to the workings of a computer. The LMC uses familiar objects and actions to represent computer components and operations. The "Little Man" visibly interprets and performs all the assigned tasks that are equivalent to the fetch and execute cycles in a traditional CPU. The LMC model uses a small instruction set that lets students write simple programs in code which resembles that of low-level languages. The LMC simulation was implemented in Java and operates in two modes, edit and execute. This application has proven to be very useful for teaching the Von Neumann architecture.

Computer-Based Interactive Math Courses - The Guam Experience

Yu-mei Wang, College of Education, University of Guam, U.S.A; Carl Swanson, College of Arts and Science, University of Guam, U.S.A

The island of Guam is a U.S. unincorporated territory in the Western Pacific Rim. Guam is the largest and most heavily inhabited of the Marianas Islands with a population of 146,000. With 85% to 90% of college students forced to take remedial math, clearly, students in this region are mathematically challenged. To counter this problem, the Guam Community College introduced interactive multimedia computer-based learning system into their math courses. This study presents a survey result regarding students' attitudes towards interactive computer based math course. The sample for the study was the students enrolled in computer-based math courses at the level of ranging from Basic Math to Precalculus. Data collection spanned two semesters in 1999. Sixty-nine students participated in the study. Data analysis shows that students were overwhelmingly positive towards computer-based interactive math courses and interactive multimedia learning system.

Knowledge Retention Following Problem-Solving Versus Information Gathering

Jeanne Weidner, University of California at Berkeley, USA; Michael Ranney, University of California at Berkeley, USA

This study investigated the retention of concepts and knowledge organizations six months after an initial phase during which subject pairs used computer technology to support two divergent instructional goals: (a) the solving of a clinical problem versus (b) gathering factual information to answer direct questions. After the intervention, the information gathering activity yielded significantly higher performance on the outcome measures (e.g., gain scores, post-tests and PFNET correlations) compared to the problem solving activity. However, this advantage disappeared upon delayed testing six months later, as the information gathering context yielded significant declines on all measures, while there were no such declines regarding the problem solving context. In addition, heterogenous academic pairs and homogenous gender pairs exhibited superior performance on initial testing, a finding that persisted to some degree upon delayed testing.

Experiences in teaching an asynchronous web-enabled course to a diverse student

Chris Wild, Old Dominion University, USA

This paper describes a transition course in the C++ programming language aimed at transfer students and students with associate's degrees who wish to obtain an undergraduate or graduate degree in Computer Science. Because of the diversity of background of students entering the university, an adaptive web-enabled presentation of material was chosen. The instructor defines a course of study that links educational objectives to course material stored in a database and indexed by subject matter, media type, difficulty level and background. A given subject area may be covered by several explanations each appealing to a different level of prior experience, preferred mode of delivery, background and previous retrievals in the data base. Experience to date has shown there is a need to support a diverse student population. Of the 19 students taking this course, only 1 or 2 could be considered "traditional" students.

Improving Instruction and Reducing Costs with a Web-based Learning Environment

Beverly Woolf, University of Massachusetts/Amherst; David Hart, University of Massachusetts/Amherst; Roberta Day, University of Massachusetts/Amherst; Beatrice Botch, University of Massavchusetts/Amherst; William Vining, University of Massachusetts/Amherst

An electronic learning environment manages homework assignments for more than 3,000 students in large enrollment courses at the University of Massachusetts at Amherst. Originally developed to fulfill a critical need in the Chemistry Department, the system has been so successful that it has been expanded to other departments and supports new, interactive forms of learning over the World Wide Web. Careful and thorough evaluation has been an integral part of the system's development, which has now been adopted by ten departments and seven other institutions. We report here on the costs and benefits of using the basic system and on significant increases in student performance.

Creating microworlds for exploration of mathematical concepts

Yelland Nicola, Queensland Uni of Technology, Australia

This paper describes the strategies and interactions of pairs of children (average age 7 years 4 months) while they worked on novel tasks in a computer microworld embedded within a mathematics curriculum. The curriculum encouraged the active exploration of ideas in both on and off computer tasks, which complemented each other. Observations of the children supported the notion that the active construction of knowledge in a computer supported collaborative learning context, enabled the children to engage with powerful ideas and use metastrategic strategies. Further, their spontaneous comments and persistence with tasks indicated a high level of interest and enthusiasm for the tasks.

Making Sense of Science: The University of Iowa Science Information Literacy Initiative

Karen Zimmerman, University of Iowa, USA; Barbara Dewey, University of Iowa, USA

The University Libraries is in the process of developing a new initiative in partnership with faculty to integrate acquisition of information literacy skills into the fabric of the undergraduate science and technology curriculum. Called the University of Iowa Science Information Literacy Initiative, the project's primary goal is to ensure that UI undergraduate science and technology majors develop effective information seeking and analysis skills in science and technology for use during their academic and professional careers.

CORPORATE PAPERS

Synergy Education Press: Tools for Teachers' Professional Development

Jeffrey Horvath, Synergy Education Press, Inc., USA
Richard Lehrer, University of Wisconsin-Madison, USA
Matthew Koehler, Michigan State University, USA
Anthony Petrosino, University of Texas-Austin, USA; , ,

Synergy Education Press, Inc. is a small company whose aim is to provide high-quality research-based teacher professional development materials for elementary mathematics and science educators. We will provide packages of multimedia and text-based products to help elementary math and science teachers develop deeper understandings of how children think about core math and science ideas (e.g., measurement, spatial reasoning, or inquiry-based science) and how to go about teaching these powerful ideas to their students. We differ from other companies in that we are not developing software or curriculum materials to be used by students, per se, nor will we explicitly help teachers learn how to use technology in their classrooms. Rather, we will use technology to help teachers learn how to be better teachers. Our products are intended for pre- and in-service teachers, home-school teachers, teacher education programs, and anyone interested in learning how to be a better teacher of math and science to young children.

Three factors have converged in recent years to create a new opportunity to provide teacher professional development solutions. First, based on research done by many of the nation's leading experts on children's math and science learning (including Synergy's founders), we now understand that young children can and do begin reasoning about powerful mathematical and scientific ideas that had, until recently, been reserved for later grades (Lehrer, et. al., 1998). For example, the National Council for Teachers of Mathematics' new Standards 2000 project (1999) calls for children in the elementary grades to be taught five key content areas (Number and Operation; Patterns, Functions, and Algebra; Geometry and Spatial Sense; Measurement; and Data Analysis, Statistics, and Probability) as well as five key mathematical processes (Problem Solving; Reasoning and Proof; Communication; Connections; and Representation). Many educators, unfortunately, do not understand these topics in enough detail to teach them to children. Today's educators need to understand these topics, have a sense for how children think about them, and know how to successfully teach these ideas to children.

The second factor affecting this new opportunity for the development of teacher professional development materials has been the recent push to raise the standards to which we should hold teachers professionally accountable. As the President argued in his 1997 State of The Union Address (1997), in order for our educational system to work, we need the best teachers. To have the best teachers, we must hold them to higher standards in their understanding of children's thinking and in their own teaching abilities. In order to improve the overall quality of our teaching force, national teaching standards such as those of the National Board for Professional Teaching Standards (1999) have argued for a shift away from traditional recitation-based methods of teacher education and toward a more practice-based way of helping teacher's develop their professional skills. In other words, prospective teachers need to spend less time listening to general methods for how they should teach and spend more time exploring the nature of teaching in practice in depth.

The final factor affecting this new opportunity for the development of teacher professional development materials has been technological improvements that have made it possible to realize educational opportunities which have, until recently, not been possible. As most recent research has argued, the best way to help teachers understand what it means to teach in a real classroom is to allow them to become immersed in the culture of that classroom (Lampert & Ball, 1998). However, depositing a prospective teacher in an existing classroom is not an ideal solution - things go by too quickly for novices to reflect and appreciate. Recent advances in multimedia technologies have made it possible, however, to bring well-crafted versions of the classroom to prospective teachers. Advances in digital video technologies as well as hypermedia techniques have made it possible for teacher educators to represent the classroom and structure that representation in ways that allow prospective teachers the opportunity to explore teaching and learning in practice.

The convergence of these three factors has created a new niche for high-quality, research-based, hypermedia-enhanced teacher professional development. Synergy Education Press is uniquely qualified to provide solutions to these new market needs. Synergy's founders have a unique blend of research and practical experience

which enables the company to provide high quality professional development packages in this new arena. We have decades of combined research on children's thinking. We have spent years in real classrooms helping teachers develop their skills in teaching these ideas to children. We have years of teaching experience ourselves. Finally, we have developed multimedia and text-based teacher professional development products for elementary math and science that have proven successful (e.g., Horvath, 1998; Koehler & Lehrer, 1998; Lehrer & Horvath, 1998).

Over the next year, we will be completing development of our first three products on measurement, geometry and spatial sense, and inquiry-based science. Each of our products will be comprised of a core video-intensive, case-based multimedia tool and an accompanying text. We have prototyped the first of these (HyperMeasure) and proven that it has significantly improved teachers knowledge of how to teach measurement to elementary-aged children after only four hours of interaction with the hypermedia system (Horvath, 1998).

HyperMeasure has several features which make it a uniquely powerful teacher professional development tool. It elaborates a theory of children's developing thinking about the domain (Lehrer, et. al, 1998) . It provides hours of carefully selected, structured, and annotated video from classrooms showing real teachers teaching measure to their students. And, HyperMeasure puts all of this together into a comprehensive hypermedia application whose design is based on a series of foundational principles for the development of case-based hypermedia educational products (Koehler, in preparation; Koehler & Lehrer, 1998). HyperMeasure is designed for educators with the needs of educators in mind. For example, since most educators are relatively new to hypermedia applications, our products are designed with navigational and structural aids to support these less-experienced users. The HyperMeasure hypermedia application is accompanied by a text-based teacher manual which elaborates on some of the ideas in the application as well as provides a number of classroom curriculum ideas.

In summary, Synergy Education Press, Inc. is developing professional development solutions for today's educators. With Synergy's help, teachers will learn how to teach today's students the mathematics and science they will need for the future.

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INVITED SPEAKERS

Critical Issues in Distance Education: Partnership, Content, and Delivery

David A. Thomas
Department of Mathematical Sciences
Montana State University
United States
dave@math.montana.edu

Abstract. This paper addresses three issues critical in the development of high-quality distance education courses in mathematics, science, and engineering: Creating stakeholder partnerships; reforming the content of mathematics and science education; and developing powerful, adaptable WWW-based instructional delivery systems. As each issue is discussed, recommendations are made for engaging interested parties in government, education, and the private sector in a search for solutions.

Introduction

Contemporary culture is continuously reshaped by the power of new ideas. In particular, economic growth and development are driven, more and more, by commercial applications of new technologies. For those of us accustomed to life in the technological "fast lane", this is a time of unprecedented opportunity. For many others, however, this is a time of crisis. For instance, while there are currently over 44 million host computers on the Internet and an estimated 150 million users, only half of the population of Earth has ever made a telephone call. While the technologically literate entertain multiple job offers, other workers worry about corporate downsizing and pink slips. And third world countries worry about losing their hard-won economic progress and political standing as the emerging global marketplace redefines the value of labor, location, and other resources.

In this context, convenient access to high quality, life-long education is a critical strategic factor in our individual and collective responses to the challenges posed by shifts in our cultural, economic, and political environments. Educated individuals and nations are more adaptable and therefore more competitive. Consequently, governments are under pressure to increase access to life-long learning for all their citizens. A nearly universal hope is that the Internet will play a major role in facilitating the development and delivery of educational services to people throughout their lives. Indeed, it appears that "The people of the world will not be satisfied until the Internet is "in every home, in every business, in every school, in every town and every country on the Globe, available without limitation, at any time and in every language (Cerf, 1999)."

Realizing the goal of universal life-long learning will take more than clever corporate planning and political strategy, however. Nothing less than our collective best efforts will be adequate to the challenge. This paper briefly examines three issues related to the development and delivery of distance education courses in mathematics, science, and engineering. The issues are:

1. *Partnership.* The stakeholders in distance education from government, education, and the private sector rarely meet to discuss mutual interests, barely understand one another's goals and capabilities, and have little grasp of what might be accomplished through cooperation. Until these stakeholders forge productive partnerships, fundamental problems of access, affordability, and sustainability cannot be solved in a systemic manner.
2. *Content.* Although a technologically literate workforce and electorate is of increasing value worldwide, student enrollment in science, mathematics, and engineering courses in many countries is flat or declining. Until the content of mathematics, science, and engineering education is more meaningful to students of all ages, enrollments in mathematics, science, and engineering courses and programs will not keep pace with workforce demands.
3. *Delivery.* Mathematics, science, and engineering make extensive use of textual, graphical, and symbolic notations not generally supported by current WWW-based browsers and conferencing tools. Furthermore, application sharing across the Internet is often difficult and expensive. Until the tools available to distance education match the tools available in conventional classrooms and laboratories, degrees earned via distance will be regarded as of lesser value than degrees earned in residence at the same universities.

Partnership

Distance education needs powerful, affordable, adaptable course development and delivery systems that make intelligent use of current technologies and human resources without limiting future options. To create such systems, we need powerful partnerships involving government, education, and the private sector. Unfortunately, the stakeholders in distance education rarely meet to discuss mutual interests, barely understand one another's goals and capabilities, and have little grasp of what might be accomplished through cooperation. For instance, program developers rarely meet with representatives of government or the private sector to discuss their interests, concerns, and needs. If meetings of this sort did occur regularly, I suspect that we might discover a pattern of differentiated interests and concerns something like that found in Figure 1.

	Network Specialists	Program Designers	Program Managers
Government	Obstacles Regulation	Effective Accredit	Compliant Flexible
Education	Usability Capability	Quality Approve	Accountable Responsive
Private Sector	Stability Sustainable	Value Investment	Cooperative Supportive

Figure 1: Differentiated Interests

The following hypothetical exchanges illustrate the differentiated interests illustrated in Figure 1:

1.	Program Designer Government Worker	"Are you going to accredit my program?" "Is it effective?"	[Accredit] [Effective]
2.	Program Designer Education	"Are you going to approve my course." "How does it's quality compare to on-campus courses?	[Approve] [Quality]
3.	Private Sector Program Designer	"Will the public pay for this service?" "If it's good enough. Will you invest in its development?"	[Value] [Investment]

Discussions of this sort must take place before stakeholders can develop a shared vision and meaningful partnerships. For that to take place, a collaborative model is needed for creating, structuring, and sustaining such partnerships. While a wide variety of collaborative models exist, it is unclear precisely which models are best suited to the sort of partnerships called for in this paper and to what extent potential partners in government, education, and the private sector will support the use of various models. Therefore the following recommendation is offered for consideration by representatives of government, education, and the private sector interested in the theoretical and practical aspects of creating productive partnerships for distance education.

Recommendation 1. A series of regional meetings involving representatives of government, education, and the private sector …

- Organized and conducted by a working group of mathematicians, scientists, engineers, educators, government officials, and private sector leadership appointed by the National Research Council;
- To present information and take testimony on proposed collaborative models and partnerships; and
- Prepare a white paper identifying stakeholder interests and concerns, successful collaborative models, and credible potential partnerships.

Content

If science is a well-defined process for *discovering* the natural world, and engineering is a well-defined process for *adapting* the natural world, and mathematics is a well-defined process for *abstracting* quantitative & spatial relationships suggested by the natural world, why do mathematics and science education so often focus on the products of science rather than the processes of science? Shouldn't mathematics and science education value mastery of the scientific method over retention of scientific knowledge? Because scientific knowledge doubles every 18 months, it will undergo a $2^8 = 256$-fold increase during any 12 year period, the span of a child's elementary and secondary education. How should we decide which sliver of that vast knowledge domain to teach? Do the publishers of traditional textbooks really know the answer to that question?

Since science is a process for creating new knowledge, learning to participate in that process is the essence of becoming a scientist. If students learned that lesson, they would have some idea of what scientists do for a living. Unfortunately, many students believe that the day-to-day lives of scientists have more to do with remembering established knowledge than discovering, adapting, and abstracting new knowledge. Where did they learn that lesson? They learned it in school, of course. It is no wonder, that by junior high school ("The Graveyard of Great Ambitions"), most students have dismissed science as a career path.

One of the principal challenges faced by reformers in mathematics and science education is that of presenting science and mathematics content in ways that engage the student in the scientific process, recognize and reward scientific thinking, and make meaningful connections to the real world. M/SET participants are particularly interested in how information technologies may be used to reawaken student interest in mathematics and the sciences, revitalize mathematics and science instruction, and attract more students to careers in mathematics, science, engineering, and technology. Since there is little evidence that using information technologies to present scientific facts results in greater understanding or retention than conventional means, most researchers' and practitioners' efforts focus on the development and use of modeling, simulation, data management and analysis tools, and communication tools that facilitate the formulation of questions, conjectures, and hypotheses, the design of experiments and models, the interpretation of results, and the presentation of findings. Figure 2 illustrates this differentiated use of technologies.

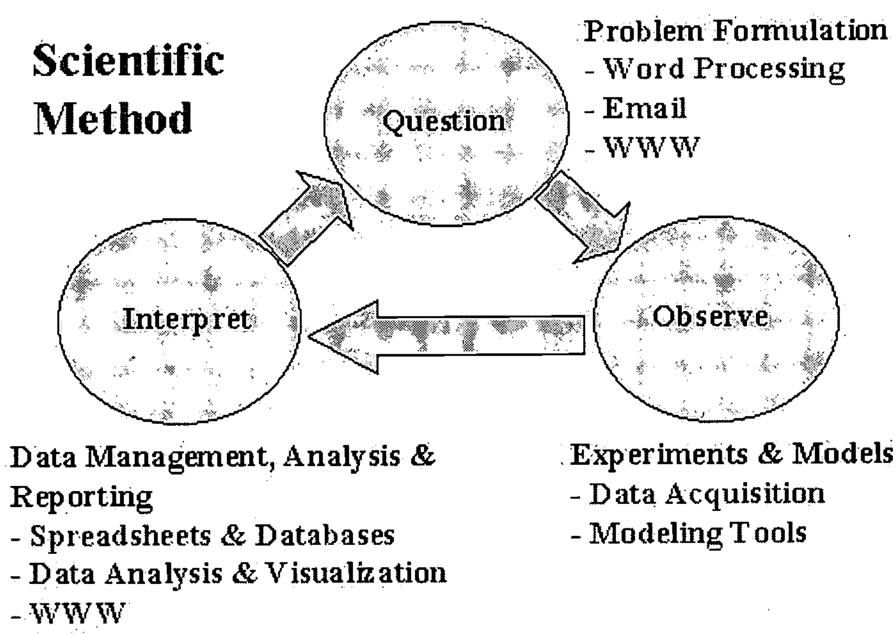

Figure 2: Differentiated Use of Technologies

Figure 3 presents a conceptual metaphor for discussing the benefits of information technologies at different levels of education. The fundamental concept presented is that, as one moves from elementary school to high school to university, the range of questions considered becomes more and more complex and includes a high and higher

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proportion of questions that are not decidable. For instance, most of the science questions considered by elementary school students are answerable by direct observation. "Do some rocks float? Do pure water and salt water boil at the same temperature?" And so on. Few questions of an undecidable nature are entertained at that level. By contrast, by the time one enters graduate school, it becomes clear that a great many interesting questions are not decidable for lack of theoretical knowledge, scientific data, and other reasons. However, as high performance computing has shown repeatedly, some previously intractable questions may be investigated and answered using models, simulations, and other information technologies.

The purpose of Figure 3 is to convey the idea that information technologies play an important role in the investigation of problems for which no analytic solutions exist. Having a workforce capable of solving such problems is a critical factor in determining the economic competitiveness of both corporations and nations. Furthermore, having a scientifically literate electorate facilitates informed public debate on matters with scientific content, such as public health, national defense, the federal government's role in basic research, and the value of information technologies in education.

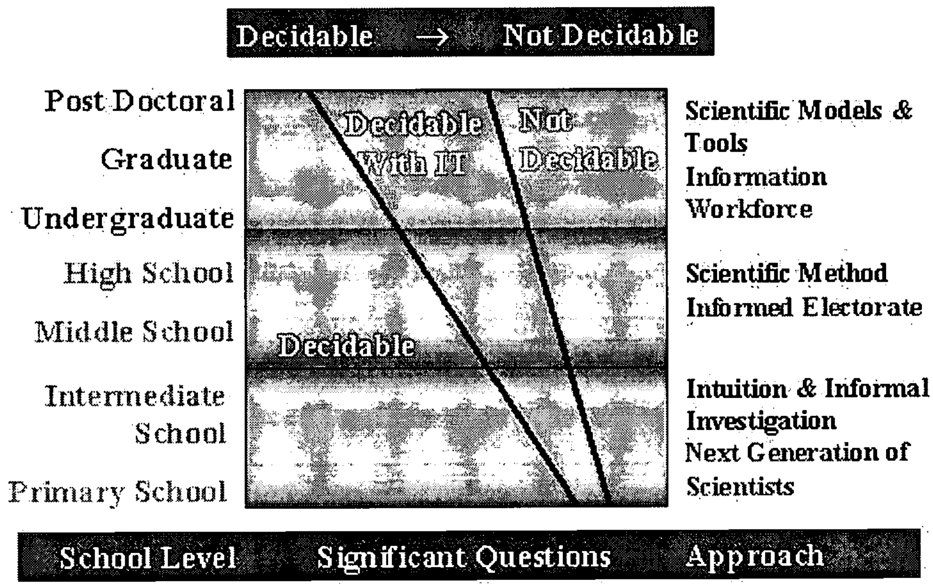

Figure 3: Benefits of Information Technologies

Recommendation 2. A WWW site featuring exemplary uses of information technologies in mathematics, science, and engineering education ...

- Commissioned and managed by AACE;
- For demonstrating how the use of information technologies, including distance education, enhance student achievement and attitudes toward mathematics, science, and engineering;
- Disseminated through authorized presentations at regional and national NCTM, NSTA, and other meetings in subsequent years and via a distance education course developed specifically for that purpose.

Delivery

In mathematics, science, and engineering, specialized symbolic notations and graphical elements are used to represent concepts, relationships, processes, problems, solutions, and other information. Unfortunately, current WWW browsers offer little or no support for specialized notations and graphical elements. Consequently, mathematicians, scientists, and engineers normally convert nonstandard elements into GIF files for display in their HTML pages. The limitations of this approach arise because the contents of GIFs may not be searched, indexed, or copied into other applications for reuse. For instance, a complex mathematical formula may not be copied from an HTML page and pasted into a mathematical application for evaluation. Scientific papers may not be searched for use of a particular mathematical representation. And so on.

Significant progress toward a solution to this problem is being made by the World Wide Web Consortium (W3C, 1999). W3C is developing a WWW-based mathematics mark-up language, MathML. When implemented in the next generation of WWW browsers, MathML will facilitate the encoding of mathematical material suitable for teaching and scientific communication at all levels. It will also facilitate conversion to and from other mathematical formats, both presentational and semantic. For instance, Figure 4 shows a MathML generated matrix equation. Each object in the equation is a searchable, active HTML element and may be used as a link to other HTML objects and pages. In this case, the variable *e* is highlighted when the mouse passes over it.

$$\begin{pmatrix} 1 & 0 & e \\ 0 & 1 & f \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{pmatrix} x+e \\ y+f \\ 1 \end{pmatrix}$$

Figure 4: MathML Generated Matrix Equation

Output formats supported by MathML will include graphical displays, speech synthesizers, input to computer algebra systems, math layout languages such as TeX, plain text displays, and a variety of print media, including Braille. Recently, *Geometry Technologies, Inc.* (1999) and *ICESoft AS* (1999) jointly announced the release of a WWW browser with full native MathML support, *ICE Browser*. This collaboration involves *Geometry Technologies' WebEQ* editing and display tools and *ICESoft AS'* Java-enabled WWW browser.

A related problem is that of application sharing over the WWW. In application sharing, two or more users have joint control over an application running on only one of their computers. In teaching remote students the use of specialized applications such as modeling and simulation tools, instructors need the same freedom of demonstration enjoyed by teachers and students seated beside one another at a single computer terminal or by a teacher demonstrating an application to a class using a projection system. While a number of products offer partial solutions to this problem, no comprehensive approach exists that overcomes all of the cross-platform issues, affordability issues, limits on the number of simultaneous users, and other problems.

Readers interested in experimenting with application sharing are referred to *NetMeeting 3.0*, a free download from MicroSoft (1999). Two or more remote users may simultaneously share a single application using this tool. All users must have NetMeeting running in a Windows environment on networked computers. If the network connection is fast, both the audio and video connections are excellent. If the network connection is slow, the white board should be used for verbal communication rather than audio. One shortcoming is that animations do not share well, as the refreshing of the remote users screen becomes overwhelming. On the other hand, *NetMeeting* provides a simple means for sharing many other sorts of applications.

For organizing course content, managing communications and student accounts, and other standard issues in distance learning, I prefer *WebCT* (1999a). This integrated suite of tools has been tested on a number of university campuses with thousands of students (WebCT, 1999b). Interested persons may examine demonstration courses or create their own temporary course for free (WebCT, 1999c). WebCT itself is a free download and licensing fees per student are remarkably low, approximately $2 per student per course.

Using tools such as *WebCT*, *WebEQ*, and *NetMeeting*, significant progress is possible in the design, development, and delivery of low-cost WWW-based mathematics, science, and engineering courses and programs. Because the flow of information and ideas in such courses may be recorded for later use, they provide a powerful research environment in which to study teaching and learning in distance education. For instance, if distance education students are assigned to small groups, one may ask whether

- Synchronous (chats) or asynchronous (messages) are more productive environments for addressing various tasks
- Performance on group tasks is related to performance on individual tasks
- Different patterns of communication are more productive when negotiating meaning, formulating questions and answers, presenting findings, and so on
- Males approach group communication differently than females
- Patterns of communication evolve during the course or remain stable

Recommendation 3. A monograph on delivery systems in distance education for mathematics, science, and engineering

- Commissioned by AACE;
- Focused on the identification of needs, evolving technologies, and research opportunities.

Conclusion

This paper has examined three critical issues in the development of distance education courses and programs for mathematics, science, and engineering: Partnerships, content, and delivery. Until powerful partnerships are forged involving the principal stakeholders in distance education, systemic solutions to current problems and limitations cannot be developed. A national effort is needed to focus the attention of government, education, and the private sector on this issue. Only a call for participation for the highest level will induce these stakeholders to take the first step in the creation of such partnerships. For that reason, I believe the National Research Council should undertake this responsibility.

With regard to reform of mathematics, science, and engineering education, I believe that AACE should lead in an effort to define our goals with respect the use of information technologies. In this, we should seek the assistance of NCTM, NSTA, AMS, AAAS, and other interested organizations. But I think AACE is the natural locus of expertise to structure the inquiry in a manner meaningful to end users in the educational community.

Finally, concerning the development of a clear set of goals and needs relative to the delivery of distance education, I believe that AACE is the natural organizing agency. Working with the W3C, the Internet Society, IEEE, the high performance computing community, and other interested organizations, AACE can structure the investigation in a manner meaningful to the distance education community.

If we find a way to do these things, we, as educational researchers and teachers, will have a hand in the development of partnerships, curricula, and delivery systems that will define our professional opportunities for years to come. If we do not take the leadership in this endeavor, somebody else will who has other goals, other needs, other motivations. This is a time for boldness. Do we have a choice?

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Full Papers

George Lucas, Web-based Astronomy, and Teacher Belief Systems

James C. Adams
Chetek High School
Chetek, WI 54728 USA
Jcadams@citizens-tel.net

Dr. Robert E. Hollon
University of Wisconsin - Eau Claire
272 Brewer Hall, Eau Claire, WI 54701 USA
Hollonre@uwec.edu

Abstract. The Internet provides an excellent resource for students, teachers, and others to explore current science. In particular, it provides a vehicle for developing technology-rich courses that provide students with great autonomy in selecting and carrying out learning. Course development is a very complex endeavor linking subject matter, developmentally appropriate learning processes, available resources, technology, time, and assessment techniques. Less obvious, but of equal importance, is the interaction of teacher beliefs and design decisions. Development proceeds in a context of implicit and explicit beliefs about the nature of science, learning, and curriculum. Astronomy provided the context for illustrating the ways that one teacher's beliefs about science, learning, and curriculum were embedded in the development of a web-based high school course.

Introduction

Technologies are being introduced into schools at ever-increasing rates. Collectively, they have the potential to transform learning in ways that parallel the changes brought about by the printing press. However, teachers' existing beliefs and models of teaching are often inconsistent with the opportunities afforded by those technologies (NCATE, 1998). Making successful use of new technologies requires that teaching - and thus learning - practices be reexamined in light of research in the cognitive sciences and research on professional knowledge development if the potential is to be realized. In particular, blending the information-processing capacities of new technologies with current constructivist views yields a guide for establishing rich learning experiences that foster meaningful understanding (Perkins, 1992). Further, practices for preparing teachers need to change. Current teacher education practices tend to socialize beginners into a world of contradictions: Effective practices are described but not modeled; technologies are plentiful in one setting but absent in another; innovation is encouraged but risks are not allowed.

In this paper, we examine the ways that one teacher's beliefs about subject matter, learning, and curriculum were evidenced in the design and implementation of a technology-rich high school science course. The teacher, a former systems and NASA aerospace engineer with twenty years classroom teaching experience, is a recognized leader in science education in the state of Wisconsin. He serves as a technology coordinator and staff developer in his school district and works with the University of Wisconsin - Eau Claire science teacher education program.

Web-based Astronomy as the Context for Exploring Beliefs about Science, Learning, and Curriculum

The Internet provides an excellent resource for students, teachers, and others to explore current science. It is also a platform for learning where students can be guided through a process of learning in ways more tailored to their learning styles and interests. Jim Adams, a science teacher at Chetek High School, Chetek Wisconsin, is exploring the use of the Internet as a learning tool. Mr. Adams designed a web-based astronomy course designed to be completed independently by high school students. The students have all the resources necessary to complete the course available through a class Internet site. Students can access descriptions of class expectations, learning tasks, assessments, suggested schedules, and links to astronomy sites that will help them with various tasks. The course has operated for three 9-week terms and was featured on Wisconsin Public Television's Teaching through Technology program. The Internet address for the site is

www.win.bright.net/~jcadams (click on "Astronomy at Chetek High School")

The development of an astronomy course for high school students is a very complex endeavor linking subject matter, developmentally appropriate learning processes, available resources, technology, time, and assessment

techniques. The current astronomy course includes eleven tasks ranging from constructing a definition of astronomy to understanding the structure and scale of the solar system to illustrating the history and mythology of Astronomy to completing an independent project. Students complete the tasks - structured as projects - in any order they wish using support materials from the Internet, classroom, and the teacher, as they deem appropriate. Each task is scaffolded with introductory material, hints for getting started, and assessment criteria. In addition to the astronomy learning resources, the course web site provides expectations for classroom conduct, suggestions for managing time and effort, and grading information.

A typical day in Mr. Adams' class might find a group of students using the web sites embedded in the course to develop a comparison of astronomy while others are chatting about the images found at a NASA site. Still other students are discussing a project with Mr. Adams as an assessment of ideas about newly discovered objects in the solar system. Some students may not be visibly doing anything related to the course goals - it is their responsibility to manage time and effort (with occasional gentle guidance from the teacher...)

The Reflective Process

Mr. Adams serves as a supervising teacher and staff developer as well as a classroom teacher. Although our primary questions concerned the ways that the Chetek Astronomy course reflected Mr. Adams's beliefs about science, learning, and curriculum, we were also interested in the ways that examining course development might help teachers more carefully reflect on their own developing pedagogical knowledge (Shulman, 1986). We used the course materials and design as a setting for probing the underlying beliefs held by Mr. Adams and how those beliefs were evidenced - or not - in the experiences and materials available to students. We worked with the following guiding questions:

> "What are your fundamental beliefs about science?"
>
> "How does your own background in science and engineering influence what your believe about teaching
>
> "How is your belief system reflected in the Astronomy class you designed?"
>
> "How could reflecting on your belief system help pre-service teachers and methods teachers?"

These were deep questions and required considerable thought and a high level of honesty to answer. Examining ones beliefs about science and science teaching is like getting into the brain and viewing the past. Since the course already existed, we "worked backwards" using the course materials and tasks as evidence of Mr. Adams's beliefs (thus the reference to George Lucas in the title). We were guided by Schon's (1983) notions of knowledge-in-action and "design as a reflective conversation with the situation." In this case, the situation was the structure and function of the web-based astronomy course.

The reflective process included several cycles of posing assertions about science, learning, and curriculum followed by examination of the course materials for ways that the assertions were - or were not evidenced in the materials. We shared assertions via email, regular meetings, and impromptu discussions. As the reflective process unfolded, we elected to "go public" and developed two regional presentations about the course and the underlying beliefs embedded in it. These too served as vehicles for extending the reflective process and making implicit ideas more public and accessible. We developed outlines and Power Point presentations that acted as vehicles for classifying and synthesizing belief statements into groups. The presentations themselves thus became intermediate evidence. As new groupings emerged, we reexamined the course materials to identify points where students' learning

Mr. Adams' Beliefs

The conversations and analysis of course materials resulted in a clustered set of assertions that were organized into the following categories: (a) The nature of science, (b) Science as a vehicle for other learning, (c) What is science learning, and (e) Whose science curriculum is important. Each set of assertions is summarized below.

The Nature of Science

Mr. Adams' beliefs about the nature of science have been a part of his belief system since early childhood. However, it is mainly since becoming a teacher and teaching science that he has been able to think deeply about and express them in terms of science education.

Science is a part of our everyday life. Science is all around us. It is difficult to imagine living is this world without observing, experiencing, or using science principles in some way. The air we breath, vehicles we commute with, products we buy, the medicines we take, the entertainment we partake in, and the tools we use to be productive citizens all involve science in one way or another. It is difficult for me, as a teacher, to imagine anything we are involved with in our daily lives that does not include some form of science.

Science integrates many disciplines. Science is an excellent vehicle for learning. It involves technical reading, writing, speaking, and thinking. It involves mathematics from simple math to complex calculus. It requires students to research information using critical thinking skills such as evaluating resources, and learning the logic of something. It involves historical thinking because we have learned so much from our past. It often requires students to construct apparatus for experiments requiring the use of shop tools. It involves literature, particularly in the form of science fiction. If there were an "all around" subject in which all core disciplines (math, science, social studies, and English) can be integrated into project oriented learning, science would be it.

Futuristic science really interests students. If you want to catch the interest of students get them involved in what their future might be like. They enjoy projecting ahead and imagining what life will be like for them twenty or more years from now. They like to think about space travel, futuristic automobiles, trains, and boats, what life might be like on a different planet, or what computers might be doing for them in the distant future. Students seem to accept easily the challenge of projecting ahead and feeling a part of "designing" their future.

Science can "hook" the interest of students – if they can tinker at an early age. Often I find students, particularly younger students, who find a deep interest in some area of science because they have "tinkered" with it. Students who often go into the engineering fields do so because as a child they played with Tinker Toys, Erector Sets, Lego Blocks, or science kits they were given as a gift. It is even more valuable for young students if they can "play" with an adult with similar interests who can mentor them and enrich their interest in science.

There is much science in the things students are "into." Students are interested in many different things. They are interested in cars, tractors, animals, cooking, making clothes, music, electronic gadgets, gardening, health, and other things too numerous to list here. The science involved in automobiles is an example. A quick list includes the mechanics involved in the drive train and engine, the physics involved in transferring power from the engine to the pavement, the chemistry in fuels, plastics, and lubricants, the human reactions and responses to the act of driving, and the electronics involved in ignition systems, radios and stereos, and modern GPS (Geo-Positioning Systems). The key is that educators must find the interest of the learner and take advantage of it in the learning process. When learning is relevant to the learner, it is more likely that understanding will occur.

Science is a Vehicle for other Learning

Language/Communications. The study of the science of something involves a great amount of language arts and communications skills. When students are interested in learning about some scientific principle, object, or process, they readily become involved in using or learning research skills. These research skills involve library research, Internet research, and possibly searching for local or community resources. This research involves organization skills. Students learn to organize their notes, thoughts, and other information into form that helps them make sense out of it. Once students have collected their information and/or data, they need to communicate their findings to others. This is where writing and speaking skills are used. The science interest becomes the vehicle for writing and speaking.

The science being studied by students should have value to someone. It may be of value to the student, the school, the local community, or the scientific community. When there is value, there must be communication. If the information is not communicated in a clear manner, there is no value to it. Written and oral communication is an

excellent vehicle for student evaluation also. Such evaluation is performance based and authentic. It allows students to demonstrate their understanding of the information and concepts learned.

Critical thinking. Science offers students many opportunities to apply critical thinking. Through experimentation, research, and experience they learn to compare and contrast, consider other points of view, recognize valid and invalid resources, and understand the logic of things. When students examine their own beliefs about science, they often realize that what they believe is not always right. The science of things often defies what students believe they know. Some students believe that water will boil better with the burner on high and the hotter the burner the hotter the water in the pot. They will continue to believe this until through critical thinking and scientific experimentation they prove to themselves that it is not true. The Internet is a wonderful tool for students. However, it is also populated with WEB sites that are simply opinions. Use of the Internet offers students an excellent opportunity to evaluate information for its authenticity.

Science Learning

Students must construct their own meaning and understanding of science. Each day students experience science. It may be gravity, fishing and hunting, driving a car, baby sitting, or listening to music. They have their own concepts of how things work in the world and if their concept is incorrect, it will remain incorrect until they can construct their own knowledge and change their beliefs based upon scientific principles.

Whose Science Curriculum is Important?

Much of the science we teach is too specific and not relevant. Science curriculum needs to be based upon student's interests. So much of what is taught in secondary curriculums is so specific and detailed that students loose interest very easily. They need more choice in what they learn. Our curriculum might not be so fixed and rigid. Our students learn more like a person using the Internet. The idea of links which allow the Internet user to move about within a subject area at will is more in tune to how we all learn. Learning is not always sequential.

Much of the "pure sciences" are uninteresting to many students. Many students have little or no interest in the "pure sciences" we are teaching. They see little or no connection to what we are asking them to learn. We need to connect the sciences to some of the mysterious things students wonder about. They are fascinated with things like traveling at the speed of light, life on other planets, unexplained things, magic, sports, etc. Students also like to tackle health issues as long as we educators are not preaching to them – they would rather find out for themselves. The type of science they want to do is constructing models, raising gardens, doing nature photography, observing wildlife, or experiencing physics in an automobile. In short, they will learn almost any science if they can relate it to their experiences. In short, we need to concern ourselves with the question "What science do STUDENTS want to

Discussion

The descriptions above highlight essential aspects of Mr. Adams' beliefs about science, learning, and curriculum. Developing the language to describe the underlying thoughts provided him with a new way of analyzing his own teaching and other professional activities:

> "The idea of reflecting on my own teaching and beliefs about science and the teaching of science opened my eyes to why it is so difficult to reform the current education system. Most teachers teach the way they were taught. Because of such reflection, I can say that I began to understand how I learned for understanding. This helped me change the process I use with my students. The reflective process is time consuming and I feel is helped by being able to "talk it though" with another teacher or professor. The most difficult aspect is finding time to create new and relevant learning environments for learners."

Thus, we were successful in achieving the first goal - describing ways that Mr. Adams's beliefs were evidenced in the design of the astronomy course. Teaching future teachers to help learners understand the interactions among their ideas about science, curriculum, and learning is a challenge. Teachers need to know how science is learned, how to integrate subject matter, how to work with veteran teachers, how to work with leadership groups, and as mentioned above how to use technology. They have little time to think about or dialog about new ways to help students learn. Learning, to many, is a result of studying and passing a test on certain knowledge imparted from the teacher to the student (in a rather passive manner); not a result of the learner constructing his/her knowledge from experience. That is their belief system.

Examining the ways that an experienced teacher draws on technology to create rich learning environments has significant implications for preservice teacher education. One example lies in the use of tools to establish structure with Internet resources. When teachers become familiar with HTML languages, web page design tools, and strategies for organizing potential course materials, they are empowered to set up new ways of learning for their students. The process (and conceptualization) of lesson design may need to shift radically to incorporate such tools as everyday parts of the beginning teacher's professional repertoire.

Science content in teacher education programs may have to change. With the advent of the Internet, computer simulations (mathematical and experimental), CD-ROM's, and other multimedia systems, teachers need to become familiar with such tools so they can be used in the learning process – both the teachers learning process and the student's learning process. Common practice in teacher education programs should include modeling with computer spreadsheets, using various science software programs, making tables with word processors, and graphing equations with software. It is easy for one to see how math, technical communications, and social studies are integrated in a relevant way through science when technology is used as a tool for learning. Teachers will, in all likelihood, be changing their roles in the learning process as students become more familiar with technology.

Perhaps one of the most valuable things ALL science teachers can learn is how to think about their own teaching. The reflective process is an excellent way to improve one's teaching and beliefs about science and teaching science. Without a continuous reflective process teaching will become stagnant. The process is like doing action research inside your brain. The most difficult aspect is finding time to create new and relevant learning environments based upon the reflection process. That's another issue in the road to educational reform!

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ESSTEP
The Earth and Space Science Technological Education Project

Bryan L. Aivazian - Wyoming Center for Problem Based Learning, Casper, Wyoming, USA (bryana@trib.com)

Ed Geary - Earth Science Insights, Boulder, Colorado, USA (egeary@uswest.net)

Holly Devaul - The Geological Society of America, Boulder, Colorado, USA (hdevaul@geosociety.org)

Abstract: The Earth and Space Science Technological Education Project (ESSTEP) is a professional development program for secondary and college faculty. This program addresses the growing need to provide students with the critical academic and personal skills necessary for successful technical careers in the earth, space and environmental sciences. ESSTEP has provided educators with the skills to infuse global positioning system, geographic information systems and image processing into their classrooms. As a result of their ESSTEP experiences, educators are enhancing student learning, promoting science and technology careers, and catalyzing the development of new courses and materials.

Introduction

The Earth and Space Science Technological Education Project (ESSTEP) is a professional development program for secondary and college faculty. This program, which began in 1997, was developed to address the growing need to provide students with the critical academic and personal skills necessary for successful technical careers in the earth, space and environmental sciences. ESSTEP has provided educators with the skills to infuse global positioning system, geographic information systems, and image processing into their classrooms. As a result of their ESSTEP experiences, educators are enhancing student learning, promoting science and technology careers, and catalyzing the development of new courses and materials.

The ESSTEP professional development program is a collaborative between the Geological Society of America, Cypress College and the Space Science Institute, with support from the National Science Foundation. ESSTEP was designed to meet faculty needs by providing extended time for skills development and planning, on-going support over a two-year period, and substantial opportunities for peer collaboration.

Each year two sets of cohort groups were trained at three different sites throughout the country. To date, the ESSTEP program has reached nearly 130 secondary and college faculty. During a two-week initial workshop in the first year, and a one-week follow-up workshop the second year, participants were exposed to

- hands-on experience in state-of-the-art data acquisition, manipulation, and presentation technologies for the sciences, geography and mathematics

- innovative strategies for using technology in classrooms and laboratories
- improved access to a wide-variety of technology-based education resources
- assistance in obtaining internship opportunities in earth and space science technology fields
- training in implementing professional development sessions for colleagues.

The ESSTEP program was crafted to provide faculty with the opportunity to develop their own technology and teaching skills to create more dynamic, learner-centered curricula. Back in the classroom, ESSTEP faculty involve students in hands-on investigations of science, interwoven with appropriate technology tools in both the field and the lab. In addition, the National Technology Education Standards, currently under development as part of the Technology for All Americans project, views technology education as a process for dynamic problem-solving, and as a means to demonstrate scientific principles. ESSTEP supports this by exploring the role technology can play as a tool for more effective teaching, doing and understanding science.

A 1996 survey of university faculty and scientists in government and private industry revealed that a variety of skills, including communication skills, scientific content knowledge, mathematics, analytical thinking, and computer skills were fundamental to students' successful pursuit of careers in science and technology. These skills mesh well with the National Science Education Standards, which apply to all sciences, as well as the Curriculum and Evaluation Standards for School Mathematics and the National Geography Standards. Helping educators develop ways to better meet these standards was central to the overall goal of this program.

Global Positioning System (GPS)

ESSTEP has provided participants with several levels of instruction into the appropriate use of GPS in a school setting. Many teachers are finding that simply just using a GSP receiver as a tool for locating points around their school is an excellent way to explore the concepts of latitude and longitude. Used in conjunction with a local USGS topographic map, participants learn how to mark a point in the field, then later find it on a paper map. Additionally, participants learned how to:

- mark a point in the field, then later find it on a paper map
- enter locational coordinates manually into the GPS receiver
- create their own orienteering routes and use them in the field
- apply a differential correction to a location to reduce its level of error
- electronically download data from GPS receivers into a computer for post acquisition processing, plotting, or mapping

Geographic Information Systems (GIS)

Over the last decade, GIS has grown to be one of the most important tools available to city and land use planners. Bringing the conceptual knowledge of, and practical use of, this application to the field of education is critical; both because of its importance in industry and government, but

also because it represents a very effective tool for teaching students to think critically about resource use and land management.

This workshop used the application ArcView, developed by the Environmental Research Systems Institute (ESRI). Over a three-day period, GIS instruction focused on the following areas of performance:

- scale, labeling features, map projections
- visualizing data (changing colors, symbols, and classes of data)
- querying (asking questions of data)
- creating custom charts and layouts
- locating and accessing sources of existing GIS
- creating new data and incorporating it into existing projects.

The primary goal of this instruction was to get the participants to the point where they could introduce this technology into their classrooms at an entry level of operation. That is, to enable students to take existing data sets and use them to answer complex questions regarding the relationships between spatially referenced attributes. However, some teachers were comfortable enough to create their own data. Usually this was accomplished by creating spatial points obtained through the importing of GPS collected points and linking those with some attribute associated with each point.

Image Processing (IP)

Another important part of the technology instruction for this workshop focused on image processing. Software for this portion of the workshop was NIH Image for the Mac, and Scion Image for the PC. Drawing upon an instructional package developed by the Center for Image Processing Education (CIPE: Tucson, AZ) the participants were given three full days of hands-on instruction in this area.

The rationale for this part of the workshop was to make participants aware of what digital images are, how they can be manipulated, their power as visualization tools for representing data, and how they can be subject to a variety of analytical techniques. In addition to using the imagery provided for them on the CIPE workshop CD, participants also learned how to generate their own digital images through a variety of methods. These included the use of digital cameras, flatbed scanners, downloading of imagery from the world-wide web, and even the creation of images from text-based files of numerical data that have been arranged in a rectangular matrix.

Participants also learned to use some of the tools of this application to:

- scale an image to take fast and accurate measurements of distance and area
- calibrate the density of an image (its level of brightness) to a measured value
- make three-dimensional representations of an image
- project multiple images in sequence as an animation

The level of IP instruction was geared towards giving participants the basic knowledge necessary to introduce IP into science, math and social studies course at any secondary grade level. Instruction was also directed at helping all participants get to the point where they could take the basic principles learned and direct them to towards the creation of activities that were directly applicable to relevant issues within the subjects that they taught. Learning how to treat the application as a suite of tools that are useful for scientific inquiry, rather than as a set of "canned" activities, was a strong goal for the workshop participants.

Local Implementation

One of the most important parts of this program was the requirement that participants come as members of a team. Geographically proximal teams were composed of 2-5 teachers from a variety of science, math and social studies backgrounds from both college and pre-college institutions. By working together, each professional brought a unique perspective as to how the various technologies could be utilized in their local school situations. Team members also provide support for each other and access to additional local resources.

To make sure that workshop instruction eventually resulted in enhancements in student learning, all workshop participants with given ample time to talk together within their teams, and to develop specific ideas for each team's unique local circumstances and interests. Assistance was provided in such areas as:

1. **How to use specific technologies** - Which applications would best suit the needs of a particular scientific or geographic investigation. Making sure that the specific options within a technology are understood operationally so as to use them effectively in the instructional program.
2. **Where to find or create data** - Locating where useful available data may be found, and learning how to get data into a form that the chosen application could use.
3. **How to effectively use technology in a teaching/classroom setting** - Technology in a classroom situation often requires modifications as to how students interact with each other and the teacher. Teachers may find that their questioning strategies may need to altered, as well as their methods of assessment. Efforts were made by workshop leaders to share past experiences and best practices with workshop participants so as to make the introduction of these technologies into the classroom as smooth as possible.

One additional method to ensure that local implementation took place was to have each of the participants commit to returning for a follow-up week one year after their initial training. The requirement that each group had to share what they were able to do with technology in their classrooms provided a strong incentive to creative interesting and innovative projects. During each follow-up "reunion" we were continuously amazed with the variety of ways that the ESSTEP training resulted in exciting student projects that linked students to innovative ways to apply technological tools to their analysis and understanding of the world in which they live (from local to global perspectives).

Conclusions

Initial indications from our external evaluation reports have indicated positive impacts on student learning, interest and motivation for all types of students, including those with special needs. This finding is closely aligned with our original goals, providing support and evidence that the ESSTEP model is an effective means to bring change in both teaching and learning.

A key finding of the evaluation of ESSTEP's professional development model is that it provides valuable skills and knowledge to faculty interested in incorporating technology into science, math and geography instruction. With adequate training, time and support we have shown that teachers are capable of adopting cutting edge technologies to a variety of classroom settings. This program has also demonstrated the necessary degree of flexibility to address the training and support for a variety of teams, each with their own unique needs.

Thus far, the main impacts of ESSTEP are that it has:

- deepened teachers' involvement in a variety of responsibilities and activities related to technology and science education at their schools and colleges
- increased awareness and knowledge of a variety of technologies and their applications to earth and space science instruction
- increased knowledge and skills in geoscience content
- served as a catalyst for faculty developing technology-rich curriculum and implementing it in their classrooms
- encouraged and supported teachers to work with administrators and others at their schools and colleges to upgrade equipment, purchase software, and broaden the use of technology in the science curriculum and other subject areas.
- introduced faculty to resources and information on new science teaching methods.

Specific factors which have made this program successful include:

- Working in multigrade and interdisciplinary teams
- Providing substantial practice and exploration time during each phase of technology transfer
- Providing time for team concept building while in the group setting (with technical support and reinforcement)
- Working to help teachers achieve what they want to do within the constraints of their own teaching situations
- Sharing example of how the technology can be used effectively in the classroom, as opposed to just showing people what the technology can do
- Continued communication and support (technical & moral) during the initial local implementation of technological applications
- Creation of an extended professional support group, linked physically by the Internet, and emotionally by their common experience and shared ideals
- Reporting of activities conducted at the one-year reunion

A Manipulative World For Learning Addition Of Numbers

Yavuz Akpinar,
Dep. of Comp. & Inst. Tech. Ed.
Bogazici University, Istanbul, Turkey
akpinar@boun.edu.tr

Abstract: Technological developments provided types of tools to be employed in teaching different subject matters and allowed to make some problematic subjects easier. This paper critically outlines the major trends of the employment of computer based learning packages and argues for environments in which the domain tasks can be proceduralised. The design considerations of a procedural environment, BALANCER for learning addition, is described, implementation studies and a small informative evaluation on the interface are also explained. The interface facilities of the system were found interesting and helpful, so is interpreted promising. The paper concludes with some suggestions for more comprehensive evaluation studies.

Introduction

Recent advancements in the field of information and communication technologies enabled learning environments to process, store, retrieve and transmit information in multi-modes as sound, text, graphics and video clips. However, a learning environment has to be interactive in the sense that a learner can browse and navigate through it, search for information, experiment knowledge patterns, investigate procedures, and reply to questions by means of input devices such as a mouse, keyboard or voice command system. Well-structured environments with manipulation devices also allow to manipulate computer representations of knowledge, to solve problems, to respond to challenging tasks and to create representations. Interactive environments are now able to engage students in meaningful learning activities including collaborative learning with others nearby or at a distance. Therefore, the facilities of computers have aroused the design and implementation of a variety of learning softwares.

Early instructional software packages were in tutorial mode (Taylor, 1969) in which the material, tasks and feedback comments were pre-stored and the student must study under the program control. Those tutorials allowed the student to answer questions or undertake tasks within extremely directed styles (Akpinar and Hartley, 1996). Hence the introduction of even prescribed and directed programs can cause a shift towards greater learner and teacher involvement in instruction, even though the programs were not particularly designed to encourage to understand error and diagnostic feedback underpinning concepts of the domain.

As computer technology and computational methodologies improved, artificial intelligence techniques have resulted in the development of tutorial software packages containing domain knowledge in a form that allows them to generate task materials and respond students' different questions (O'Shea and Self, 1983). These intelligent tutoring systems (ITS) can therefore give greater interactive support to learners, however, they tend to be considerably specialised and have been implemented as proof of concept rather than as institutional packages which are employed in everyday teaching. Also, as Newman et al (1989) point out, ITSs, though sophisticated, are far from taking adequate account of the social context of learning.

LOGO project, (Papert, 1980) deeply influenced by artificial intelligence concepts and methodologies, provides students with a computer language to reveal, exploit and extend their knowledge in a principled way, for example in Turtle Geometry. However there are contradictory research findings about the effectiveness of LOGO. For example, Harel (1990) reports from empirical research data that LOGO activities were helpful to the children to develop fraction knowledge and problem solving. On the contrary, Vasu and Tyler (1997) found that the LOGO activities were not succesful over developing problem solving but at developing "spatial thinking". In practise, LOGO is seen as a collaborative activity for small group of children, despite the fact that the LOGO language was not designed from this perspective (Pea, 1987).

Interactive Multi-Mode Representations and Screen Design

Other forms of computer assisted learning receive similar criticisms. For example, computer based simulations involve the dynamic representations of process, incorporating to varying degrees the possibility of intervention, as interactivity, on the user's part (Dowling, 1997). Simulation programs are designed to encourage investigation as students form and test hypothesis about the underlying model. But nevertheless, this again requires careful preparation so that learners have an adequate conceptual framework on which to base and modify their hypotheses (Bork, 1984) and simulation programs are not usually designed to deliver this support. In classroom environments the programs are often used by small groups of students, and as evidenced by Vanlehn (1987) that these student interactions and explanations lead to learning benefits. However, Hartley et al (1991) showed that unless such discourse reached the student's causal beliefs, conceptual change could not be guaranteed. The evaluation studies of simulation and qualitative modelling programs (Draper et al, 1991) illustrated that a teacher is needed to engineer such interchanges and the designers must consider myriad modes of use classroom supports and the changing styles of teaching/learning that might occur.

Increasing complexity of learning environments and the instructional technology allowed to design complex systems based upon a non-linear organization of the information within multiple formats. Visually enriching environments as multimedia and hypermedia are reported to have the potential to motivate learning, to improve understanding and to achieve the highest rates of retention (Levin, 1987). However, research (Kozma, 1991) has shown that simply providing

multiple symbol systems for representation of subject matters, for promoting conceptual understanding of a knowledge domain and for enabling multi-sensory experiences does not enhance comprehension and knowledge acquisition. Empirical research has also demonstrated (Clark and Craik, 1992) that assumptions based on integrative effects of representational codes of single media on enhancing learning effectiveness fall short with regard to the conditions necessary for making the characteristics of external representations effective for the construction of individual mental representations. Scanlon and O'Shea (1988) suggesting instructional consequences from their results, concluded that instruction should be developed to provide constraints and to facilitate orderly moves from one inference process, representation or knowledge source to another.

Interaction is the major difference between traditional instruction and computer based instruction. Incorporating strategies that cause the learner to code, organize, integrate, elaborate on or transfer information is imminent for instructional programs (Orr et al, 1994; Hannafin, 1989). But all those cognitive activities are heavily depend upon screen design or interface of the instructional software. Well-designed screens should allow for maximum learning from the materials while providing the learner with appropriate control of the learning process. Effective interface has to maintain motivation and be feedback rich (i.e. the result of each action should be clearly visible and interpretable). As well, attention can be controlled by only making operators appropriate to the task available on the screen, and placing the animation phases of the processes under the active control of the users (Carroll and Rosson, 1987; Shneiderman, 1992). Recently the direct manipulation (DM) interfaces (Dix et al, 1993) allow the users to directly interact with the screen objects and operators with the interventions signalled through the mouse-pointer. It is the manipulatable interfaces of computer proceduralisation of a mathematical subject matter, namely the addition, where early primary school children pose many problems that this study focuses upon.

Children's Learning of Addition

During pre-school years, children's use of language to represent numerical information and relationships becomes increasingly important, they must learn their culture's number words, map these number words onto their existing number knowledge, and then learn the many ways in which number words can be used in quantitative situations, such as counting or measurement (Fuson, 1988). The development of basic number skills spans a 6-year period for most children, ranging from the ages of 2 to 8 years. (Fuson, 1991; Piaget, 1965). In this period, children memorise the number words, understand that each word represents a different quantity and develop their counting skills. These skills are used in many different contexts such as for measurements or for arithmetic.

Informal mathematics involves active construction, not only passive absorption of information. Children develop and apply informal mathematics because it is personally meaningful, interesting and useful to them. But informal mathematics has its limitations, child's mental addition, for example, is restricted to small numbers (Baroody and Ginsburg, 1986). Understanding cannot be imposed upon children. It evolves as they actively try to make sense of the world. Meaningful learning occurs when children intellectually and emotionally engaged in activities. As well, it occurs when they encounter novel situations that excite their natural curiosity. As cognitive research indicates that, with any mathematical content, learners progress developmentally from concrete to abstract thinking (Davis, 1984; Dockrell and McShane, 1993), they must be given the opportunity to assimilate school mathematics. Mathematical symbols, computational algorithms and procedures can make sense to children if it is connected to their existing, personal, counting based knowledge of mathematics. However, a gap between formal instructions and a child's existing knowledge prevents assimilation (Hiebert, 1984). It can make school taught skills and concepts seen foreign and difficult to children.

Addition domain represents the first attempt that schools make to teach what might be recognised as formal mathematics, This means learning to symbolically represent a problem situation, operate on the symbols and interpret the results. However, when first learning to solve addition problems, children rely heavily upon the use of manipulatives. As the child gains experiences and maturity, the favoured strategy shifts to finger counting (Carpenter and Moses, 1984). The use of manipulatives serves mainly two purposes: First, the sets of objects represent the numbers to be counted. The meaning of the abstract number, say 3 of an addition problem of 4+3, is literally represented by the objects. Second, referring to the objects during counting helps the child to keep track of the counting, that is, the child knows to stop once the last object is tagged with a number word. For most children, the shift from finger to verbal counting is gradual, and children don't have to be taught these different ways of solving simple addition problems but rather discover for themselves the most efficient procedure (Groen and Resnick, 1977; Sieglerd and Jenkins, 1989). Further, learning to solve multi-column problems (e.g. 23+19) involves developing not only efficient problem solving strategies but also an understanding of place value and how to carry or trade. When solving these problems, children initially rely upon the knowledge acquired for simple addition problems. Strategies for solving more complex problems include counting and decomposition, or regrouping, as well as the formally taught column-wise procedure (Ginsburg, 1989). However the most difficult process in complex addition involves carrying. According to Gearry (1994), two factors appear to make carrying difficult for children and some adults: First, carrying often comprises manipulating numbers mentally. In the problem of 37+48, the child must first add 7 and 8. Then he must mentally note that a carriage has taken place and retain this notation in working memory, whilst writing the units-column answer. Here it is possible to forget the carriage. Second, skilled trading involves an understanding of place value where the child needs to comprehend that the "1" traded from the units to the tens column actually represent "10" not "1", failure to understand this contributes to children's trading errors well documented in the literature (Ashlock, 1990; Fuson and Briars, 1990; Hiebert, 1987, Romberg and Collis, 1987).

To overcome children's difficulties within addition and to prevent errors and misconceptions from developing, Brown and Vanlehn (1980) suggest using illustrations. Lowell (1982) also suggested that because logical mathematical

experience is abstracted from one's actions and not from the materials themselves, structural apparatus of all kinds on which the child performs cognitive actions can play a useful role in understanding of the operation of addition. This argument was later supported by Collins and Brown (1988) and Thompson (1992) suggesting that through the structured procedure capturing systems which offer simple devices, perceptually reflective learning on concrete items can be achieved. Through the students' manipulation and inspection, aspects of the device structure can then be explicitly represented, annotated and become the subject of didactic discussion. Hence computer medium with embedded interactive cognitive tools (Kaput, 1991) can be focus of the design, aiding learning by making internal processes more public and available for examination and reflection.

Procedural Learning Environments

It is crucial to consider the interface design issues for systems with interactive manipulatives and proceduralisation tools, before considering the architecture of a procedural learning environment for primary school children's learning of addition. To develop conceptual understanding of the domain through operations, a software system has to service the learner with operational facilities to undertake tasks. The interface design principles to be adopted were taken from Shneiderman (1983, 1992). His recommendations were for a) continuous representation and display of objects and actions of interest, b) physical actions (e.g. mouse clicking, icon dragging) instead of language syntax to achieve changes in the object world, and c) rapid and incremental operations whose impact on the objects of interest is immediately visible. Moreover, the interface design should follow the extended principles expressed by Hutchins et al (1985). Although this study is not focused on human-computer interactions, it is necessary to make careful efforts to follow and interpret established guidelines for designing a procedural learning environment (PLE), the BALANCER. See Figure 1 for an architecture of the PLE.

A variety of teaching and learning approaches should be supported by learning environments in order to aid the user in proceduralising his/her interaction with the system and eventually be less prone to errors. The environment should regulate the control between the student and the system, accommodate real-life tasks and their solution methods which are rich in feedback and provide interactive illustrations supporting conceptual understanding, learner controlled inspections and problem solving. On the basis of a firm conceptual understanding the student's actions, as part of a procedure, are to be evaluated and reacted by the computer program to provide feedback about the effects the action would have in the real world. The student then takes successive action and each time explores more information. Further, because developing a firm conceptual understanding of addition domain depends heavily upon the constructive work with mathematical objects in a mathematical community and because the students need building materials, tools, patterns and sound work habits to learn operational relationships, the functional components of such "procedural environment mainly consist of the followings: (i) A concrete object space, the base for quantification, in order to represent the domain. (ii) A student-environment interaction language by which the student can operate an object world in ways that show the effects of their actions and that connect to representations of the object space and its relations at higher levels of abstraction. (iii) A curriculum management office (CMO) (inspired from Draper's lesson office, 1991) to specify and manage the task curriculum and record student performances for further use. (iv) User-system interfaces which are needed for students to apply the interaction language and manipulate the object world, and for teachers to specify and customise types of curriculum tasks for the curriculum management office.

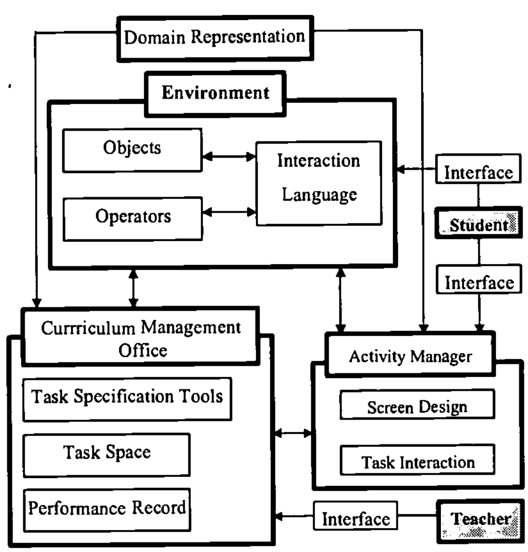

Figure 1: An architecture of the PLE

The conceptual and procedural knowledge summarising the curriculum to provide a domain representation (as semantic networks for the designer) is an essential requirement for the designer, because the objects, their attributes and

relationships between the attributes are determined by the domain representation. It will also clarify the operations the student can perform on the objects and the operators within the learning environment. The student-system interaction language will enable students to work on the object space and ideally allow them to develop their procedural or explanatory models of the world at higher levels of abstraction. This, in turn, informs the task space that represents the curriculum the teacher plans to place before the learner. The user-system language benefits from teaching experience in the domain as it requires an awareness of the conceptions and alternative conceptions the learners might employ and which the PLE should influence, correct and extend. The user-system language becomes a tool for thought and a means of knowledge interchange between the learner and the PLE. To aid the efficiency of these interchanges and to facilitate modes of working with the language is enacted through an interface where the display screen becomes the "workdesk" for the student.

The task manager is able to display the appropriate task which is selected in pre-specified sequence or adaptively by taking performance records into consideration. It will also manage the actual interactions with the learner. A task specification basically includes instructions and material for the learner, the arithmetical objects and environment facilities to be used by the learner. Any additional feedback and concluding comments to be supplied will also be contained in the task specification part. The system-learner interface allows students to undertake the tasks (via the interaction language) and to see the consequences of their actions and decisions. Thus, through the CMO tasks specifications, the teacher can follow a directed or an exploratory approach and also adjust the environment for individual or co-operative working.

Features of The Balancer PLE

To implement the design issues outlined, a proceduralisation environment was designed for school children's addition which is a problematic domain causing learning difficulties. The addition domain is the one where different type of instruction is possible, varying illustrations, both dynamic and static, may be employed and include proceduralisation of explanations, practice and problem solving. Therefore, the BALANCER procedural learning environment should have the following features to support the approaches to instruction of addition within the framework of the above system components: (a) Interactive mathematical, linkable objects and operators which are visual and can be directly manipulated by students. (b) Mechanisms to check the validity of students' methods, and to provide feedback on the appropriateness of their actions in relation to the presented task. (c) Be able to move its presentation (representation) modes from concrete to symbolic as the learners gain in competence, hence a seamless transition from objects to quantification is enabled. The equivalence between concrete representation (objects) and symbolic (representation) must be explicit to support the link. (d) Permit experimentation with concepts and procedures in ways that relate to the pupils' experience, thus supporting guided discovery as well as more directed methods of instruction. (e) The learning to be contextualised and procedural via the types of tasks that are specified within the CMO. (f) An operator that will enforce to employ "carriage" principle in operating numbers in a way that helps to explore the complex numbers addition strategy.

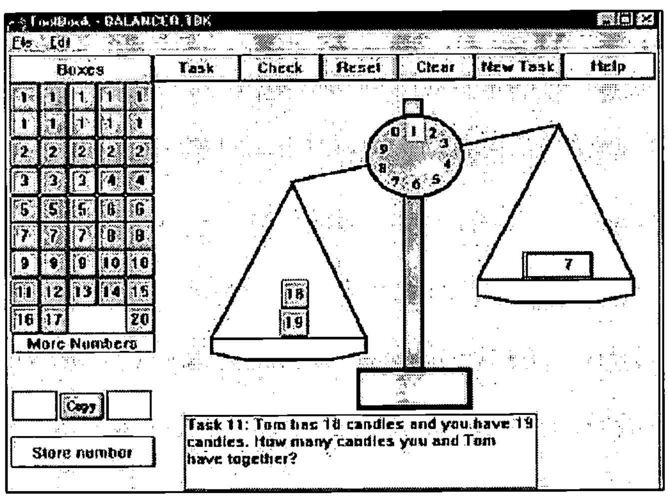

Figure 2: A window of the BALANCER

The Design and Implementation of The Balancer

Before designing the above specification of the BALANCER, an informative investigation with five teachers was undertaken to obtain their opinion on the use of materials for teaching addition (both one digit and two digits numbers). They confirmed the subject, particularly adding two or more digit numbers where carriage is needed, is difficult for children, and suggested that pupils will benefit from interactive proceduralisation of the computerised balance. Following their suggestions, a semantic network of the addition domain was prepared, it demonstrated the relations between concepts and operations within addition and aided the design. As children's operations of numbers is initially based upon concrete materials, manipulatives and counting of these materials, it was decided that an object should represent the concrete state of the number "1" and be from daily life, i.e. a box. The object will later be tagged with the number as 1. The weight of an

object, say, 1 gram for 1, will also reflect the number and the operator, a hand-scale or a balance will process the objects with regard to their weight, hence tagged number. The manipulatable object could be combined with other countable objects in the scale and be represented as in the pictorial and symbolic forms.

With the help of the task space, the operator, a balance, will allow pupils to investigate the addition procedure in different activities (e.g. counting objects on the pans of the scale, comparing set of objects and balancing the sets will be undertaken). A sequence of activities may be as follows: 1. balance the scale by using the pictorial boxes, empty boxes, being equal in weight, 2. balance the scale by using the pictorial boxes tagged with numbers, 3. balance the scale by using the boxes with numbers, carriage is involved.

The metaphor of a BALANCER was designed and developed with the learner being able to directly manipulate boxes through an operator. The performance of the operator is under learner control with each phase of the procedure shown visually first and later becoming and linking to symbolic representation. The combination of the boxes through the operator provides opportunity for pupils to investigate the comparison of sizes of the weight of the objects, the counting in relation to the weight, hence numbers, and the equivalence of the two added boxes on one pan and as its sum on the second pan. See Figure 2 for a snapshot of the BALANCER.

For the system to monitor and evaluate the operations accurately, the BALANCER carries out its own manipulations formally, and provides a mapping between the weight as concrete representation and symbolic representations so that the system can aid the more formal development of student's understanding in a seamless way. For instance, when adding 18 and 19, the student drags boxes with tags of 18 and 19 into the left pan of the scale. The scale is then unbalanced to the left, and a slot (box) on the right pan into which the student is to enter number appears. The student can either enter the correct number directly to balance the scale or add 8 and 9 first, enter 7 and mark the number "1" in the knob component of the balance to indicate that "1" is to be carried. Next, he adds 1 to 1, and the carriage is automatically added. Finally the correct result is produced and the scale is balanced. Note that depending on the size of the numbers in the pans, if there is inequality, the scale exhibits this by unbalancing the pans. If an incorrect answer is given, the learner is asked to try again, with the unbalanced scale remaining as a hint. The box representing the sum could also be moved out of the pan for further use or reference. So it becomes part of the object space in the work environment of the system. That may then allow co-operative activities for children. The teacher can tailor tasks which introduce the preliminaries of adding and which encourages to deal with large numbers. When the carriage is needed, the operator through its knob helps the learner to determine an appropriate carriage.

The Curriculum Management Office

The task specification is accomplished in the environment through the office which permits the task content, the specification of the representational form of the objects (empty boxes, tagged boxes each representing "1", boxes with different numbers tagged) and the sequence of tasks to be ordered in a curriculum. Answers are also specified (as checks for the system) and the teacher can provide comments and overall task feedback. Only the teacher through mouse-pointing can access task authoring pages (one different page for each task) of the CMO.

The CMO passes the sequence of curriculum tasks to the activity (task) manager of learning environment that controls the interactions with students and keep records of their progress. The office can accommodate prescriptive tasks (as practice examples) or more open-ended exploratory assignments. Further, the interface, through its mouse-driven direct manipulation, provides the learner with close control of the system components, and all these activities have clear effects.

The BALANCER was implemented in Asymetrix ToolBook™ on IBM PC computers. It is an object-oriented authoring environment providing versatile design tools to assist rapid prototyping which are especially useful for building graphical systems. The objects are buttons with appropriate scripts instructing the system to place the objects (boxes) on the pans (which are fields and graphics) and execute other control messages. Similarly, the task authoring part for the teachers have fill-in forms (fields) and iconised buttons to convey messages. These screen objects are held on pages that also have a supplementary pull-down menu for editing, resetting, getting new task, checking and asking for help.

Pilot Evaluation Studies and Suggestions for Further Work

The prototype software was tested through a small formative study. The pilot study was conducted with four second year elementary school students (aged 8, 8, 7.8 and 7.10, two girls and two boys) to test the interface features of the program, and to ensure that the students were able to use the system's interactive tools to work out the problem tasks given in social contexts, word problems. The amount of pre-training time to learn the features of the system was also to be estimated. The students took part of the study in an empty room of the school where the researcher was present. A brief introductory session introduced the children what the system components are and how they are manipulated. Four problem tasks were presented within a directive worksheet as well as on the screen. Although the students were chosen among the ones having difficulties in carrying out addition operations, they did not have assistance to understand the tasks, all four students had no difficulties in manipulating or understanding the mouse-driven interface (it took 7-10 minutes for the students to become familiar with the system). The children were extremely intrigued in balancing the scale for addition tasks, and their progress through all the tasks was much quicker than expected. The students were also able to provide satisfactory answers to the tasks.

The evaluation study showed that the students did not have any difficulties with the interface and the approach was interesting and well received. However, the testing of the software with target students in the real classroom environment with wider task regimes is needed to examine the value of the procedural approach. How effective are different task

regimes in helping the acquisition of addition operation? This type of evaluation study should ascertain how such tasks are managed in the classroom and what worksheet and other supports teachers consider necessary. Further, evaluation studies with paired students should be arranged to examine in detail how children use the software and how they discuss the tasks and tasks sequences in the environment. Studies with teachers should also examine what role the teacher should adopt and the type of discourse that results.

To conclude, it was clear that the developments in interface design should extend the educational ambitions of computer based learning which continuously faces with new techniques. Procedural environments with their flexibility and mixed initiative modes of learning seem a promising innovation, particularly when their design methodology can be formalised and supported through evaluation studies that embrace both teachers and students.

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Motion Games and Thinker Tools: Using Prior Simulations to Promote Learning about Motion

Thomas Andre,
Iowa State University
tandre@iastate.edu

Charlotte Hasselhuhn
Katherine Kreiter
William Baldwin
Catherine Leo
Todd Miller
Andrew Mroch
Alyssa Duschen
Brook Werner
Joseph P. Akpan
Iowa State University

Abstract: This presentation demonstrated computer software that helps students better understand Newton's first law. Two studies of effectiveness of the software were reported. The first found that males benefited from use of a fanciful version of the software. but females did not. The male oriented scenario used in the simulation and the lower interest and prior experience of females in physics may have made more difficult for females to transfer the computer experience to the first law concepts taught in the chapter. A second study, using software that more explicitly related itself to the chapter, found that both male and females students profited from prior use of the simulation. They developed and demonstrated a better conceptual understanding of the implications of the first law. The results suggest that, contrary to much current practice, simulations may be more effective instructional tools if used prior to more direct instruction.

Introduction

This paper demonstrated computer simulation software designed to help students better understand Newton's first law and reported two studies that examined the effectiveness of the software.. Helping students learn about the first law is important because many students have prior misconceptions or alternative conceptions[1] about motion. Such alternative conceptions interfere with the students' ability to construct understanding of newly presented theory (Wandersee, Mintzes, and Novak 1994).

Computer simulations potentially offer students opportunities to explore physical or biological situations that may be impossible, too expensive, difficult, or time-consuming to accomplish with actual laboratory or real-life experiences (e.g. frictionless environments). Even if real-life exploration is feasible, such experimentation can be supplemented by simulations that offer students the opportunity to explore a wider range of variables more rapidly. Such simulated experiences potentially can be used to confront alternative conceptions, produce disequilibration and, with appropriate scaffolded instruction, lead students to a new accommodation (Piaget 1983)

Despite this potential for the use of simulations, empirical results examining the impact of simulations in science education have been mixed (Akpan 1998). One potential way of resolving differences in existing research is to examine the ways simulations have been used in existing experiments. Typically, simulations have been used as surrogates for laboratory experiments and, like most laboratory experiments, have followed didactic instruction on the topic. However, several theoretical perspectives suggest simulations may be more effective if used prior to formal instruction. For example, Piagetian theory argues that knowledge is constructed through action. Actions leading to disconfirmation of expectation produce disequilibrium and the learner may construct or accommodate new mental structures to resolve the disequilibrium (Piaget 1954). Bruner (1966) adapted Piagetian theory into the idea that learning requires experiences at an enactive level before iconic and symbolic experiences can become meaningful. An enactive level requires participartory experiences with the domain of interest. An iconic level

involves graphical representations of experiences in the domain of interest. A symbolic level involves representation in an abstract symbol system. Klausmeier and Allen (1978) argued that conceptual development proceeds through a series of four stages of understanding. In the earliest stage, a label is attached to particular concrete experiences. Later stages lead to the development of a formal symbolic understanding. Using Tulving's (1972) concepts of episodic and semantic memory, Andre (1986) suggested that creating imagery based representations of experience in episodic memory was necessary in order to provide an experiential base that would allow symbolic representations in semantic memory to have meaning. Similarly, Paivio's (1986)dual coding theory suggests that creation of imagery based representations along with symbolic representations facilitates understanding. The important point is this. *Multiple theoretical perspectives argue that the learners need to have non-symbolic experiences within the domain of interest in order to be able to map symbolic expressions onto perceived reality and to give such symbolic expressions meaning.*

Thomas and Hooper (1991) articulated an instructional model that incorporated these theoretical insights. They proposed that simulations could be used instructionally in one of five roles. Only the first role is relevant in the present context. The first role, experiencing, involved the prior use of simulations to help provide an experiential base that would set the "cognitive or affective stage for future learning" (p. 499). Thus, these theoretical perspectives suggest that experiential simulations used prior to didactic symbolic instruction should facilitate students' construction of meaningful understanding about science concepts, principles, and schemata.

Hooper (1986) and Brant. Hooper, and Sugrue (1991) tested the Thomas and Hooper (1991) experiencing model. In studies involving students in college level computer science and animal science classes, they confirmed that using simulations before, as compared to after, lectures led to improved learning. Use of the simulation after instruction did not improve learning as compared to control groups that did not receive the simulation.

White and her colleagues (1984, 1987) developed a set of simulations called Thinker Tools. Thinker Tools provided a simulated environment that operated in a manner consistent with the first law. Sixth grades students who experienced Thinker Tools outperformed high school physics students who had just completed a unit on mechanics on a test of conceptual understanding of the first law. The sixth graders had not received any formal instruction on mechanics. Frederickson, White, and Gutwill (1999) showed that leading students through a graduated series of electricity simulations led to the development of dynamic mental models that facilitated understanding of electricity concepts.

Study 1.

The prior research had not separated cognitive and motivational explanations of exploratory simulations. Use of a simulation before instruction might be fun or arousing. Students with higher arousal or motivation might learn more from the didactic instruction that followed. We assessed this possibility in the first study. We developed a computer simulation similar to Thinker Tools that ran on Apple II computers and contrasted it with the use of a computer game involving a non-Newtonian motion (variants of Pac-Man and Snakebyte). The game or simulation were used either before or after students read a textbook chapter on motion. A control group received no computer experience. If the effect of the prior use of a simulation were primarily motivational, then the game and computer simulation groups should show similar improvements in performance over the control groups or computer experience after instruction groups. The Motion Games simulation allowed the student to apply "impulse" forces to a simulated spaceship. The impulse force mimicked a short duration force applied to the object that would produce a given increase in the velocity of the object. The simulation context made the students "spaceship captains-in-training" and gave them progressively more complex missions to accomplish. The controls allowed the force to be applied horizontally left or right or vertically up or down. Thus, control of the ship forced students to apply intuitively vector combinations of force to achieve goals. Accomplishing the missions thus led students to experience and intuitively apprehend how the first law controls motion. In Frederiksen et al.'s (1999) terminology, the simulation experience would allow students to construct a dynamic mental model of motion.

Volunteer college students were randomly assigned to the conditions and completed a pretest, interest and prior experience inventories, and a background questionnaire before reading the text or completing the computer experiences. Subsequent to reading and the computer experiences, the students completed a posttest focused on conceptual understanding of Newton's first law. Male college students who used the simulation before reading the chapter performed better than both males who used the simulation after reading and male students who did not used the computer games or did not received a computer experience. This pattern of results suggests that simulations used before instruction have primarily a cognitive, and not a motivational effect.

That conclusion was tempered, however, because no significant effects were found for female students. As is typical (Kahle and Meece 1994), females, as compared to the males, reported less interest in and experience with physics and also scored lower on the pretest. In addition, the space captain scenario that may have been more male than female oriented and did not explicitly relate itself to the chapter on motion. The lower prior interest and experience and the perhaps more male-oriented scenario may have made it harder for females to create meaning by relating the physics presented in the chapter to their simulation experience. Students often find it hard to transfer between two learning experiences if they do not recognize a connection between the experiences (Gick & Holyoak 1980; Pressley & McCormick 1995).

Study 2.

We explored this interpretation in the second study by using a simulation that more explicitly related itself to the physics of motion. A Macintosh version of Thinker Tools is now available. It is less fanciful than our motion simulation and more explicitly focuses attention on critical variables in understanding motion. In the second study, we compared the effects of use of Thinker Tools to a non-Newtonian computer game used prior to reading a chapter on motion on male and female students' conceptual understanding of Newtonian principles. We hypothesized that this more focused motion simulation would lead to improved performance for both males and females.

The participants were 24 male and 29 female college volunteers. Again the participants first completed background, interest and experience questionnaires and a pretest. They also completed verbal ability, mathematical calculation, and spatial ability tests. The students were randomly assigned to complete either a series of activities from the Thinker Tools simulation the computer game before reading a short chapter dealing with the physics of motion. Two days after studying the chapter, the students completed the posttest on conceptual understanding of the principles of motion.

The results revealed significant main effects for both condition and gender. While males did better than females, the theoretically and practically important result was that both male and female students receiving the Thinker Tools simulation did significantly better than did students receiving the non-Newtonian computer games as a prior experience.

Discussion

The major purpose of these studies was to examine if use of a simulation that challenged misconceptions about motion as a prior exploratory experience before students read a chapter on the principles of motion would facilitate learning. Prior research in other subject matter areas had shown benefits of simulations used as prior exploratory experiences. In our first study, use of a fanciful simulation that illustrated Newtonian motion facilitated learning for males. In our second study, use of a less fanciful simulation that explicitly related the simulation to motion helped both males and females learn more from a chapter on motion. We argue that the greater prior knowledge and experience of males in the first study would have made it easier for them to connect the simulation and the chapter. In the second study, the instruction led all students to connect the simulation and the chapter. It is well known that transfer between tasks may not occur unless students perceive a connection or are explicitly shown the connections between the tasks (Gick and Holyoke 1980; Pressley and McCormick 1995). Thus, we argue that use of exploratory simulations prior to students' formal study of scientific concepts will facilitate learning. However, the facilitation will occur only if students are led to see the connections between the experiences in the simulation and the scientific concepts they formally study.

In the M/SET presentation, we demonstrated the software and report the results of these two studies. The software is available free from the Web. For the Mission Newton "spaceship captain in training" software that runs on MSDOS/ Windows computers, see http://www.public.iastate.edu/~tandre. For the Thinker Tools software, see http://thinkertools.berkeley.edu/tt.

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[1] While many authors make theoretical distinctions between the term alternative conceptions and misconception, these distinctions are not relevant to the present study. Regardless of ones theoretical preference for these terms, thephcnomena that students have conceptions about motions that conflict with those of the culture of physicists is well established.

Dynamic and Parameterised Animation of Computer Science Topics

Andreas Ausserhofer
Institute for Software Technology
Technical University of Graz
Austria
ausserhofer@ist.tu-graz.ac.at

Abstract: The purpose of this paper is to introduce an animation module *CSAnim* as extension to the S.E.A.L. web-based education system [Ausserhofer, 1999a]. The main application of CSAnim is the generation and the display of a dynamically processed graphical visualisation of computer-science topics based upon user-input. The introduction will set the focus to the problem in general whereas the problem-analysis will show, why animation techniques - which have found to be a successful extension to traditional teaching methods - are not sufficient enough. A new approach is presented as solution to this and the integration into an existing education system is shown. The paper ends with future aspects and possible applications.

Introduction

Teaching computer science and computing is a challenging task. The reasons for the difficulty and the problems in teaching the science of computing are various, one of which is truly remarkable. Among the fact, that a primary goal is the teaching of theoretical subjects with the requirement of a well built mathematical background - it is clear that the teaching of practical programming skills is also of vital interest. The fast development of technology and the rapid change of programming languages make this task even more difficult.

Web-based education systems have been developed and introduced to support the teaching and learning of computer science topics and computing - nevertheless - many years of experience have shown us, that students still have serious problems in learning and understanding certain elementary mathematics- and computer-science topics.

The purpose of this paper is to outline such topics and to introduce an improving methodology for the teaching and learning process. Animation and visualisation techniques are the basis for the solution approach presented within this paper. The paper starts with a problem analysis and presentation of the solution approach and it ends with the presentation of the characteristics of the new methodology along with its implementation and its integration into an existing teaching and learning environment.

Problem Analysis and Solution Approach

Experience over years shows us, that independent from the teaching methodology applied to, independent from the presentation media used for and finally independent from the practical examples chosen to explain – there are subjects which are still hardly understood and barely learned by the students due to their complexity and difficulty.

An information inquiry proved that it is mainly topics related to computer science processes which are found difficult to understand, two of which are listed as examples:

Evaluation Strategies of Expressions: Students typically find it difficult to understand the process of expression evaluation, namely the difference between *Call-by-Name*, *Call-by-Value* and *Lazy-Evaluation*.
Recursive Function Calls: Students hardly know and barely learn how a recursive function call is performed and what really happens at each recursive step. They have problems in isolating the base case and the definition of the inductive step.

A major share of people is visually centred, i.e. cognitive recognition is amplified through visual impressions. Information presented mainly in visual form (pictures, graphs, video sequences, ...) is easier understood and faster integrated. This is only one reason why graphical visualisation and animation techniques have been successfully experimented with – not for educational purposes only.

A survey on animation and graphical visualisation tools shows that

- there exists a large number of animation tools, specifically designed and implemented for various purposes except the animation and visualisation of computer science subjects as described before, and that
- most of the existing approaches cannot be adapted and re-used in order to meet our requirements due to their very architecture and design.

Both perspectives have to be taken at a closer look. Nearly all of the present existing animation and visualisation systems can be classified in either one of two categories:

1. Predefined Examples: Animation tools referring to this type implement more or less predefined examples with little or no possibility to interact and/or parameterise. The animation sequence can be *consumed* like a movie or a comic strip, started, stopped and replayed on user request. User input is limited to setting/changing parameters or to flow control. Most often these tools are technically brilliant, with excellent animations, hiding the implementation inside.

2. Predefined Animation Tool: Representatives of this category are characterised by an implemented framework or software library which can be used in order to create and build animations. Users of these tools have to design and implement the software to model their problem of interest and have to integrate the animation tool into it. They further have to specify how to create the animation sequence by choosing from the command set of the animation library.

Both approaches are unsatisfactory within the scope of this work. Creating animations based upon the first technique is neither new nor very difficult. But it lacks the architecture to be applied to most or all of the representative examples of the problem domain. An example for every problem to be graphically visualised would have to be implemented, with little or no interaction for the user.

The application of the second approach is even worse. Students have problems in understanding a process which is hidden inside computer architecture. The animation technique would force them to first model the problem by means of a software solution and then integrate the animation tool in order to visualise the solution. This is a contradiction by itself, students cannot model problems of which they have no understanding of.

In order to meet the requirements of successful animation in teaching computer science and programming topics, three prerequisites have to be defined:

1. Animation and graphical visualisation has to be individual, i.e. it has to be built from the particular problem entered by the user.
2. The animation program must take the user-input for the animation *"as-is"*, i.e. the user shall be able to enter the problem in a way he is used to argue about it. No special syntax shall be defined.
3. The user shall be set free from all questions of how to build the animation sequence out of his input data. The animation sequence must be built dynamically and parameterised.

Dynamic and Parameterised Animation - an Example

Example Definition

The *"evaluation process of expressions"* is one problem which turns out to be difficult and which is hardly understood by first year students, no matter which educational system is used for presentation. The purpose of this section is to introduce the example itself and to further use it as explaining example for animation.

Given a function definition and a value expression, denoting the recursive function call as follows:

$$f(x) = 2 * x + 4 \tag{1}$$
$$g = f(f(f(3))) \tag{2}$$

The purpose of (most) computer systems is to evaluate value expression. Independent from the strategy which is used to calculate the value, the result for this example should be g = 52.

Computer scientists are not only interested in delivering correct results but also have to deal with finding effective ways for doing so. Different strategies for evaluating expressions open different opportunities with individual advantages and disadvantages. Three main strategies for evaluating expressions are well-known and have to be understood by computer-science students.

Call by Value: The value x of inner-most function is calculated, the result is then supplied to the function body of the value definition again (Fig.1).

$$\begin{array}{llll} f(f(f(3))) \rightarrow f(f(2*3+4)) = f(f(10)) & f(x) = 2*x+4 & x = 3 \\ \rightarrow f(2*10+4) \quad = f(24) & f(x) = 2*x+4 & x = 10 \\ \rightarrow 2*24+4 \quad = 52 & f(x) = 2*x+4 & x = 24 \end{array}$$

Figure 1: Call by Value Evaluation

Call by Name (Normal Order): The value x is immediately substituted into the body of f of the value definition. The value of the resulting expression is recursively evaluated (Fig.2).

$$\begin{array}{llll} f(f(f(3))) & \rightarrow 2*f(f(3))+4 & f(x) = 2*x+4 & x = f(f(3)) \\ & \rightarrow 2*(2*f(3)+4)+4 & f(x) = 2*x+4 & x = f(3) \\ & \rightarrow 2*(2*(2*3+4)+4)+4 & f(x) = 2*x+4 & x = 3 \\ & \rightarrow 2*(2*10+4)+4 & f(x) = 2*x+4 & \\ & \rightarrow 2*24+4 & f(x) = 2*x+4 & \\ & \rightarrow 52 & & \end{array}$$

Figure 2: Call by Value Name Evaluation

Call by Need (Lazy Evaluation): Value x is immediately substituted into the body of f of the value definition (as before), but each argument is evaluated at most once, when it is needed.

System Architecture

The Animation module for dynamic and parameterised graphical visualisation (*CSAnim*) is integrated into a web-based education system called S.E.A.L. [Ausserhofer, 1999a]. S.E.A.L. is built in client/server architecture and primarily used to support teaching and learning of computer-science and programming. Teachers use S.E.A.L. to present their lecture notes and to show/execute programming examples; students use S.E.A.L. for learning purposes and training skills from remote.

CSAnim is an integrated server module to S.E.A.L.. It receives its input from remote users through the WWW. Input is entered into a S.E.A.L. front-end (JEdit) and sent to the system over the WWW. The results are re-displayed at the client site by means of the X-protocol technology. Fig. 3 presents the general system architecture along with the interface definition.

The system architecture follows the principle introduced with the algorithm animation system *XTango* [Stasko, 1992]. Therein, the animation model is separated from the interpretation of it. The animation

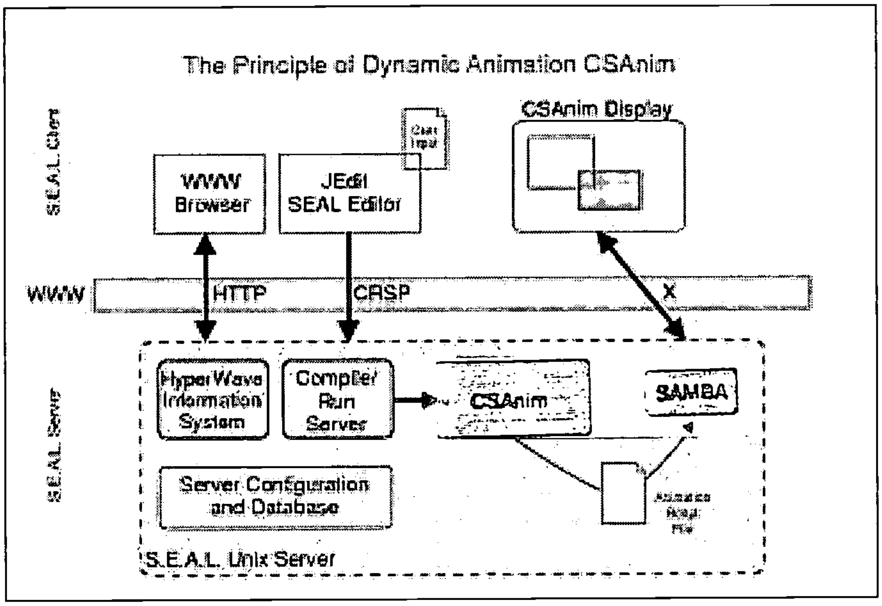

Figure 3: S.E.A.L. System Architecture

realised in here is of the same principle – the *CSAnim* module is responsible for building the animation model, whereas a third-party animation interpreting software handles the presentation of the animation.

Animation Model: *CSAnim* consists of an animation generator which is designed and implemented in the Java programming language. Two rather recent developed tools have been used for supporting purposes. JFLEX [Klein, 1998] is used to carry out the lexical analysis of the user input. CUP [Hudson, 1998] is being included in order to define the accepted grammar for the problem specification and to build the parse tree from the user input. The *CSAnim* module implements an abstraction layer to the animation command language which is understood by the subsequent animation interpreting software.

Model Interpreter: The interpretation of the animation module is done using the *Samba* animation interpreter [Stasko, 1995]. *SAMBA* was originally designed for the algorithm animation package *XTango*, representing the interpretation module. S.E.A.L. is the result of a research project where one objective was not to work on a too broad research frontier, thus re-using well-established system parts where possible. *Samba* is not perfectly well suited for our application but works sufficient for the prototype version.

Dynamic Animation of Evaluation Strategies

It is almost impossible to describe a dynamic animation process in textual form - at least - it seems not very useful. Thus the purpose of this section is to describe the principle of how the dynamic animation is generated within the S.E.A.L. education system and to present an application example. The principle of dynamic animation of evaluation strategies can be seen from the system architecture (Fig. 3).

User Input Users access the web-based education system by means of any ordinary Java enabled web-browser software. By authenticating themselves to the education environment they can load and open a S.E.A.L. editor environment. This environment us used to enter all information which shall be processed by the system.

Information, concerning the problem statement of an expression definition is entered using the notation of the SML programming language syntax [Milner et al., 1997]. This language is currently used in our basic

computer science lectures, unless the system is able to handle any notation as long as the syntax can be defined formally.

The problem statement of an expression of which the evaluation shall be explained and graphically visualised consists of a function definition and a referring expression value statement (see input below).

```
fun f(x) = 2 * x + 4;
val g = f(f(f(3)));
```

Data Processing The input statement is submitted to the education system server by simply pushing a submit button from the referring menu. The data, together with administrative information necessary, is then sent to the S.E.A.L. server through the Internet using a native *CRS protocol*.

Creation and Presentation of the Animation Sequence The S.E.A.L. communication server handles the expression statement to the *CSAnim* program module. This program parses the input and generates the desired animation sequence out of it. The result is a simple ASCII file containing animation commands which can be understood and processed by the animation interpreting module *SAMBA*. *SAMBA* is started by the S.E.A.L. system, parsing and processing the animation control commands and displaying the animation at the client side using the standardised `X Protocol`.

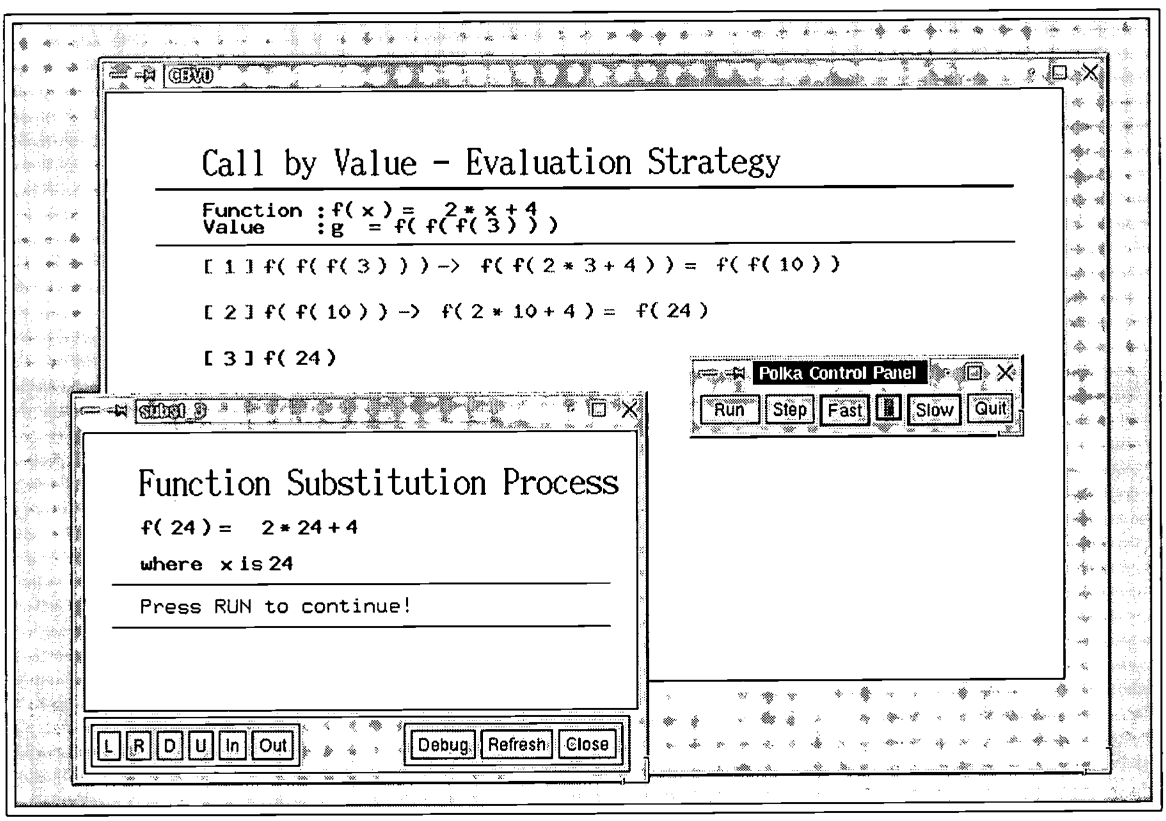

Figure 4: CSAnim Example Animation

Fig. 4 shows the presentation of a sample animation of an evaluation process for expressions following the *Call_by_Value* principle.

Evaluation Process: The large window in the back shows the evaluation process in a step by step manner. Each line represents one evaluation step. The actual step is highlighted whereas previous steps are grey-shaded.
Substitution Process: Each substitution step is graphically visualised (see lower left window). In this view, the substitution of the value x=24 into the function expression $f(x) = 2 * x + 4$ is animated.
Control Panel: The user can interact with the animation by means of the control panel (small window in the mid right), i.e. pause or continue the animation sequence and change the presentation speed.

Thus users receive animation sequences directly based upon their input statements without the need for dealing with the building and processing activities of the graphical visualisation themselves.

Conclusion

By means of dynamic animation, which is based upon the problem individually entered by the student - a major improvement with respect to the learning and understanding of traditionally difficult problems is made. Dynamic animation combines the advantages of graphical visualisation in general with the individuality of personal teacher education.

Future Work

S.E.A.L. is in prototype state - and will be developed further. By now, the system is mainly used for teaching computer science and computing [Ausserhofer, 1999b]. The architecture is far more general, thus it is possible to extend the functionality very easily. We consider to extend the system for other fields and subjects, namely electrical engineering, mathematics or computer graphics. It is even possible to adapt the system to fit the needs for corporate education programs and *training on the job* purposes.

By now - the system is being tested in real live situations and will be evaluated by the end of the year 1999. *SAMBA* was originally designed for algorithm animation. Further-on it would be interesting to implement a native S.E.A.L. animation parsing program in order to extend the functionality with respect to user interaction.

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Development of an Effective Multimedia/WWW Training Model for Faculty

Patricia Backer
Department of Technology, San Jose State University, USA
pabacker@email.sjsu.edu

Miriam Saltmarch
Department of Nutrition and Food Science, San Jose State University, USA
saltmarc@email.sjsu.edu

Abstract: This paper describes the results of three summers of teacher training initiatives in multimedia and the Web for the classroom as well as a trainer of trainers model currently being undertaken for faculty at San Jose State University based upon the results of the summer workshops. An original objective of the summer workshops was directed at providing faculty who could function as trainers of other faculty. Moving from the year one model (training faculty to utilize a wide range of multimedia equipment and tools to build complete projects) to the year three model (training faculty in specific applications) changed the extent to which faculty could act as trainers of other faculty at their school sites. The current model focuses on empowering faculty to complete technology-based projects for their university classrooms and become trainers of other faculty in their academic units, within the realistic constraints imposed in a teaching-centered university.

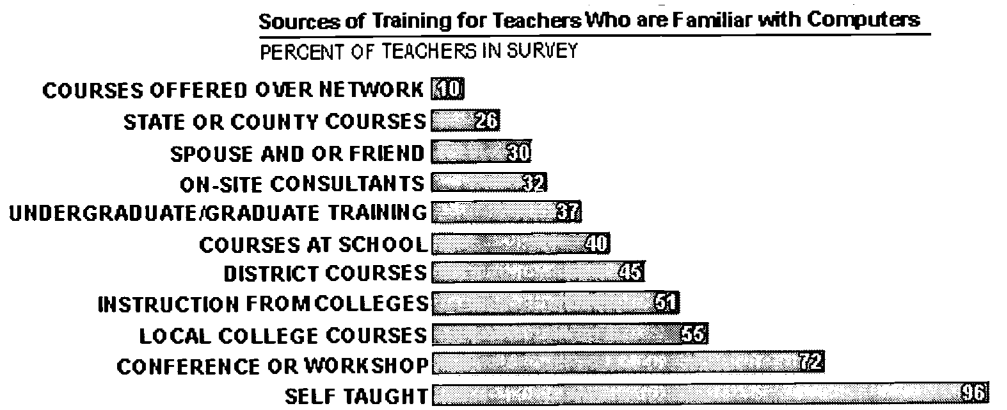
Introduction

The constant theme of the past five years has been increasing the use of technology, particularly computer-based ones, in education. Many articles and white papers accumulate to create this message with "a new insistence that teachers must become technologically literate" (Ely, Blair, Lichvar, Tyksinski, & Martinez 1996, p. 3).

> "Information technologies can so enhance classroom communications and resources that, when properly applied, they can transform conventional pedagogical paradigms and create new and powerful contexts for learning and teaching. Connected classrooms potentially offer open-ended, dynamic, discovery-oriented learning experiences. The more advanced the classroom use of telecommunications is, the greater the potential to change the learning environment, the teacher's role in the classroom, the flow of information to students and overall classroom dynamics; each can evolve to form more natural and much richer learning processes." (Berenfeld 1996).

In concert with this call for technological literacy is the increased use of multimedia and the WWW in everyday society. These two forces serve to create an overpowering impetus for instructors to utilize technology in their classrooms.

However, along with this call to arms is the reality that, in general, college instructors are generally unprepared to integrate technology into their classrooms. There is a small (but growing) cohort of early adopters of technology in universities but the majority of professors are either non-users or just beginning to explore multimedia and the World Wide Web in the classrooms. One of the major reasons for this dichotomy is that technical support for university instructors is inadequate. In 1995, the National Academy of Sciences and National Academy of Engineering completed a report on the use of technology in education entitled **Re-Inventing Schools: the Technology is Now.**



Source: Table obtained from **Re-Inventing Schools: the Technology is Now.** Available: http://search.nap.edu/html/techgap/navigate.cgi

Statistics shown in this report contain indicate the trend in technology training for teachers. The table above (from this report) shows the sources of training for teachers. When teachers were asked what the source of their training was (for those familiar with computers) 96% of the teachers surveyed indicated that they had been self taught; 72% indicated that conferences or workshops were sources of training, while only 45% indicated that they received much of their training from their school district and even less (40%) suggested that their training came from courses within the school.

Although the report, **Re-Inventing Schools: the Technology is Now**, focused on K-12 faculty, the situation is no different among faculty from institutions of higher education. Over the past few years, the number of university-level courses with components utilizing multimedia and the WWW has exploded. However, a persistent problem still remains: how do you transfer the use of these technologies to "mainstream" faculty?

Much of the existing training that has been developed is focused on the "innovators or early adopters" of technology. A standard strategy of presenting the technology itself and teaching people how to use the technology is most appealing and appropriate to faculty interested in technology, the "innovators." However, mainstream faculty have different motivations and reasons for adopting technology as compared to "early adopters." "Early adopters" and innovators are "techies" who are willing to explore and play with new technologies (Geoghagen 1994). According to Freeman, Brimley, and Rosen (1999), mainstream faculty are more likely "to show interest in a new technology if it is easy to use and does not require a major change in the skills they already possess."

Most universities have established teaching and/or training initiatives related to multimedia and the WWW. Many of these initiatives have evolved from training center models—where faculty sign up for pre-established "workshops" to learn a new skill. The most successful attempts to equip faculty with the skills and knowledge, as well as equipment to create multimedia based learning materials, have occurred where there is a institution-wide effort; as demonstrated at Pennsylvania State University with Project Empower Noel and Brannon (1997), with the STARS program at Wake Forest (Brown 1999) and outlined in the TESSI Project adopted by the Ministry of Education in British Columbia (Woodrow et al. 1997). Unfortunately, not all higher education institutions or educational agencies have arrived at this juncture.

Project Description

This paper builds upon previous work by Backer and Saltmarch (1999) and describes the results of three consecutive summers of teacher training initiatives in multimedia and the Web for the classroom. Sponsored by MASTEP, an

NSF funded collaborative to improve mathematics and science teacher education in the greater San Francisco Bay Area.

Summary of First year workshop

The structure for the first-year training consisted of two one-week "basic" workshops and two three-week "advanced" workshops. Workshop participation in the "basic" workshop ranged from 15 to 25 attendees. Attendance in the "advanced" workshops was much lower and ranged from 4 to 10 daily. The "basic" workshops were very structured and introductory in nature while the "advanced" workshops were project-oriented and open-ended in format. The participants who entered the advanced workshops with a clear project idea were most able to take advantage of the instructional materials presented during the advanced workshops and were also closest in their performance and outcome expectations to those of the workshop instructors. Approximately one-third of the faculty attending the "basic" workshops were mainstream faculty while, in the "advanced" workshops, all attendees were "early adopters."

Many participants in the "basic" workshops were not aware of the state of multimedia technology prior to the workshops. They would have benefited by having more time to be "brought into the technology" using an approach similar to that developed at Pennsylvania State University through the Project Empower program (Noel & Brannon 1997). In our training sessions, as was noted by Oliver and Lake (1997), using technology seemed to hinder learning when technical problems arose.

Many of the participants in the "advanced" workshops also had trouble devoting enough time and energy to the workshops since they were not compensated in monetary terms nor were they assigned college or continuing education credit for attending the workshops except for the K-12 teachers. The higher education instructors from the state and community colleges were taking time from personal projects and other work projects in order to attend the workshops at cost to them. Because of these factors, attendance and attrition during the advanced workshops was a problem during the latter part of the workshop where participants did not receive formal instruction but were expected to work on individual projects. Some higher education instructors looked forward to release time during the next academic year to continue the multimedia projects developed during the summer workshops and these participants were more motivated to complete their projects.

Summary of second year workshop

June Higher Education Workshop

In all, fourteen faculty (from local Community Colleges and San Jose State) participated in the June 1998 workshop. Based upon feedback from the first year, we changed the workshop structure to four one-week sessions rather than the one-week "basic", three-week "advanced" model of Year 1. The topics for the one-week sessions were: Week 1 Pedagogy, Week 2 Desktop Multimedia, Week 3 Using the WWW, and Week 4 Special projects. Workshop participation in the one-week workshops ranged from 4-10 attendees. Most of the workshop attendees in the June Workshop were again "early adopters."

The attendees of this workshop differed in many respects from the workshops of the previous year. Most of the faculty entered this session with highly defined, preconceived ideas of what they wanted to do. Sometimes, this led to a conflict between teacher and student expectations; incidentally, *this situation was not reflected in the teaching evaluations that were excellent.* In many ways, students were resistant to any suggestion or teaching that did not fit into their paradigm regardless of the need of their design. For example, to engineering faculty members attended the June workshop with the goal of designing course Web pages. These faculty members refused to participate in any tutorials or class discussions, or learn any software, that was not directly related to their task at hand. Although this goal seems acceptable, this resistance precipitated the re-teaching of many concepts and software throughout the four weeks.

July K-12 Workshop

The July workshop session was structured differently than the June workshop in some respects. This

session was again divided into four weeks. However, the fourth week had a different focus (the first three weeks of this workshop paralleled the content of the same weeks in the June workshop). The attendees of this workshop were all K - 12 teachers who had been selected to receive equipment and software through a proposal competition run by MASTEP. All of the workshop attendees in the July Workshop were again "early adopters."

The teachers, by their own admission, expected that the workshops would follow a "chalk and talk" format. At first, the teachers were dismayed that they had to actively learn and produce tangible products. However, compliance to teacher expectations and motivation was high. Also, the students in this section were graded on the quality and appropriateness of their outcomes.

Summary of third year workshops

After reviewing participant feedback from both years, a consistent thread emerged. The workshop time commitment was too great for most faculty. In addition, the researchers were concerned about extending this training to mainstream faculty rather than just serving the pool of "early adopters." It was decided to move to a topic-specific training model with short one to four day training sessions. Additionally, over the three year period, specific workshop instruction had been transformed from an open-ended, project focus emphasis into a specific topic tutorial-based, structured environment. The attendees and other faculty drove this transformation, which began in year 2 and was fully evident in year 3, interested in the workshops. To meet a trainer of trainer's objective, each topic specific workshops required that a mini project be completed after initial tutorials. Participants, who were predominantly mainstream faculty, were very satisfied with this format.

Summary of Current Training Model for SJSU Faculty

An original objective of these workshops within the MASTEP Collaborative was directed at providing faculty who could function as trainers of other faculty. Moving from the year one model (training faculty to utilize a wide range of multimedia equipment and tools to build complete projects) to the year three model (training faculty in specific applications) changed the extent to which faculty could act as trainers of other faculty at their home school sites. Since complete multimedia or WWW projects normally require the use of various applications and equipment, faculty would have to attend a series of topic specific workshops and then attend a separate series of project based workshops to assemble a complete desktop or WWW project. The intention of this model is to meet the time constraints of mainstream faculty and yet provide the necessary training and project management skills necessary to develop a fully realized desktop or WWW project.

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The Collaboratory Project's Science Fair Repository

Richard Barone
The Collaboratory Project
Northwestern University
United States
ibrich@nwu.edu

Ann Blythe
Alan B. Shepard Junior High School
United States
ablythe@mail.dps109.lake.k12.il.us

Beatrise Revelins
Charles J. Caruso Junior High School
United States
BRevelins@aol.com

Abstract: Northwestern University and Deerfield School District 109 in Illinois are collaborating on a project that seeks to encourage cross-district collaboration and the sharing of resources between teachers and students via the internet. The setting for this initiative is the annual school science fair with its broad scientific scope and need for community involvement. Northwestern's Collaboratory Project has developed an internet application that is being piloted in classes at both junior high schools in District 109. The results thus far have been encouraging and are reported here by a member of the development team and the two teachers adopting this technology.

Background

The expertise of a university development team gives K-12 teachers the framework they need to bring technology quickly and expertly into their classrooms.

The Leaning Model: A science fair project is a long-term, engaged-learning activity for middle and high school students. In some school districts science fair projects are required, promoting the concept that not just the scientifically gifted student can gain from the experience of learning science by doing science. In these districts it is felt that everyone should have the opportunity to apply the scientific method firsthand. In many other school districts throughout the country participation in a science fair is optional but still considered a valued learning experience.

The Collaboratory Project (http://collaboratory.nunet.net): The Collaboratory Project is a Northwestern University initiative funded by Ameritech Corporation. Its charter is to establish a network-based collaborative environment to support education in the greater Chicago area. Collaboratory Project Communities are network initiatives that enable people and organizations with common interests to collaborate on projects and share ideas, information, and resources. The Collaboratory Project's most recent collaborative community is "The Repository" which is being piloted in Chicago area schools this fall as a science fair resource.

The Repository: The Repository is a resource for sharing projects on the web. Repository managers define the goals of their repository collection, control the available categories, and monitor contributions. Users can search repositories by category or keyword, propose new categories, and make contributions from a standard web browser.

Motivations

> I do not want to ask students to participate in a science fair only to see them next on the day of the fair. The lines of communication need to be open all the time.

Getting Started: In the planning stage of the project teachers interviewed pointed to *project selection* as a major predictor of success in science fairs. If students like what they are doing they are motivated to carry out a three-month engaged-learning activity, but students and teachers agree that one of the hardest things about participating in a science fair is getting started, that is, deciding what to do.

Many students are eager to do science fair projects when they are first introduced. They welcome the idea of being in charge of the design of an experiment and the gathering of data. But, before any of this occurs, they must choose a topic. This is extremely difficult for many students. There is such an array of ideas - how does one choose a topic? Unfortunately many students decide not to participate because they are struggling to do the very first step - choosing a topic or idea.

Sharing Resources: In Illinois, science fair projects are judged by volunteers from the community who have expertise in one or more of the categories of participation. Judges are parents, teachers from out-of-district schools, local officials and representatives from local industry. Projects are scored on various criteria including a written, visual and oral presentation; display of knowledge gained; command of the scientific method and creativity. Projects with the highest scores advance to a regional science fair.

To judge a regional science fair, the precursor of the state fair, is to experience a vast difference in the quality of projects between districts. Indeed one might suspect that different standards had been used, although guidelines are clearly defined by the state. Whatever the reason for the poor quality of some projects that were judged winners at local fairs, their authors experience a reality check at the regionals. This might be considered a good learning experience for them but did they have to wait for the regional competition to see what their peers in other districts were doing? Could communication with their peers have turned their efforts into a more positive experience at the regional fair?

This suggests a need for districts to collaborate on this and like common objectives and further implies the potential benefit to education in general at the greater community level. The Science Fair Repository was conceived with the conviction that the internet held a solution to this problem and could effectively provide a way for school districts to share two resources they all possess regardless of budget: knowledge and ideas. Peer feedback between districts can only help reinforce student knowledge of standards and comprehension of the scientific method. One attribute shared by participants from all districts is effort. They all work hard on their projects and it is likely that many students will be better rewarded for their efforts if they have the benefit of inter-district collaboration.

In April 1999 The Collaboratory Project introduced a prototype of the *Science Fair Repository* to a group of local K-12 science teachers formally initiating a pilot program with the goal of addressing the problems described here.

The Science Fair Repository

> There was the temptation to call this "Project Paradox" for it has as its focus the needs of the individual learner and as its goal access for the masses.

Vision: *The Science Fair Repository* is the first incarnation of The Collaboratory Project's repository community. Its vision is that of a large continually updated collection of science fair project abstracts organized by scientific category and searchable by author, date, category and keyword. Abstracts are submitted to categories by registered teachers and students from around the country. An abstract is accepted or denied by the

manager of the category of submission. A "category manager" is a teacher with expertise in the science fair category that is being moderated. Once activated, accepted, the abstract is visible to anyone with a web browser.

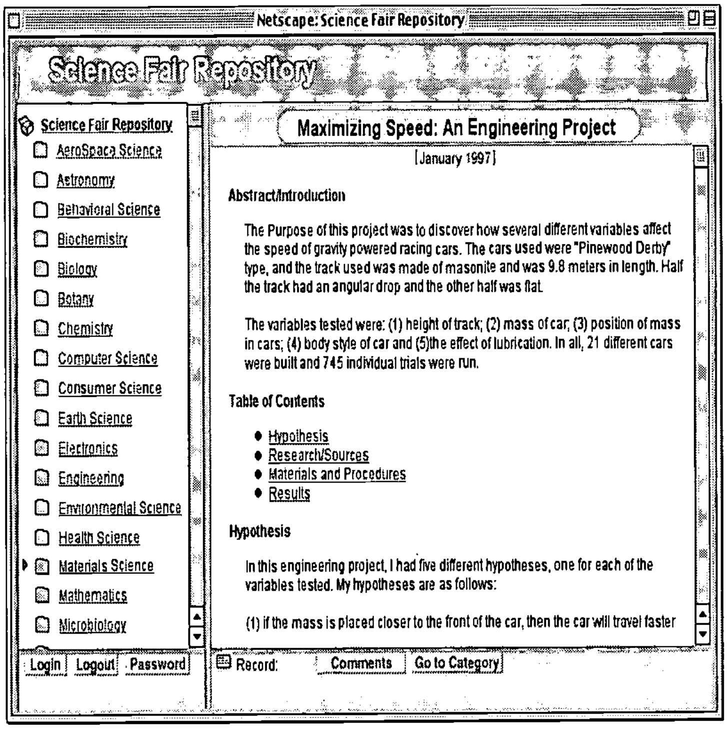

Figure 1: A general view of the Science Fair Repository. Category choices appear in the left column with login functions for students and teachers with accounts at the bottom. The abstract is viewed in the right column. Comments directed to individual abstracts are initiated below the abstract view area. (Categories and project sections for the pilot follow the guidelines of the *Illinois Junior Academy of Sciences*.)

The Abstract: This is more than a simple overview of the project but less than a complete project paper. It includes sections for: the author's name, date of submission, an introduction/overview, acknowledgments, the hypothesis, research with sources, materials and procedures, and references. Conspicuously missing are sections for "results" and "conclusions". They have been omitted on recommendation of focus group teachers. Virtually every teacher interviewed expressed some degree of concern for plagiarism. Most seemed satisfied with this solution. A *results section* with a short "teaser" was generally thought to be an acceptable alternative, perhaps even engaging for an interested student. This is one area that will be watched closely during this year's testing.

Seeding: Before the vision of the Science Fair Repository can be realized it must be populated with a functional number of real projects. The core of teachers consulted during last year's development cycle has been asked to input, or have the student authors input, abstracts of projects from recent state science fairs. The goal is to have several good examples for each science category so that the Science Fair Repository can be demonstrated at this year's regional and state fairs in order to generate a significant number of account applications from science teachers statewide.

It is intended that the Science Fair Repository will be sufficiently populated by the fall semester of 2000 to be a useful resource for any science student or science teacher with an internet connection. It will expose students in search of a "good fit" science fair topic to real projects, written and presented by their peers and predecessors, in all represented categories. This will address the issue of student motivation by providing participants with a better idea of what they might "like to do". The Science Fair Repository is expected to continually grow and update itself as the number of contributors increases, making it a richer resource as time passes.

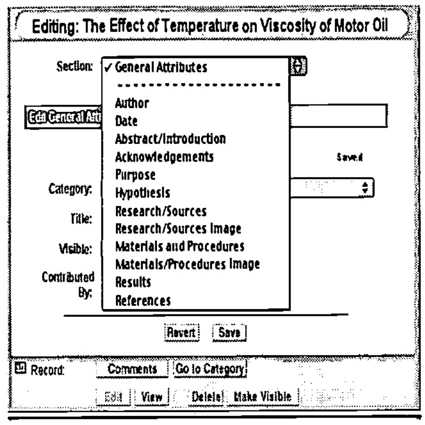

Figure 2: A data entry view for the Science Fair Repository.

Variations of the Science Fair Repository

Give a teacher a good idea and the teacher will return the favor.

The Science Fair Repository was developed as a science fair resource and a project development tool but the later function was not scheduled for testing this year. However , both pilot teachers saw this potential and asked to employ the tool for this purpose, each with somewhat different requirements for their individual programs. The remainder of this document will explore the benefits they expect to derive from the Science Fair Repository and will be reported primarily from their points-of-view.

Pilot A, Shepard: Experiments For Everyone

> At Shepard Junior High School, science fair projects are required of all 7th graders. Ann Blythe teaches four 7th grade science classes there and all of her students are using the Science Fair Repository to record and report their projects as they progress. Each student has been given a semi-private account, visible only to the student and the teacher. This gives Ann the ability to monitor the progress of each student and by using the built-in "comments feature" she can make private on-line suggestions for individual projects.

When I was initially approached to become involved with The Collaboratory Project, I viewed this as a vehicle to show how middle school students can achieve success in doing a science fair project: one that really involves a student, applies the principles of the scientific method, and requires the use of critical thinking/problem solving skills. Furthermore, my students would have the opportunity to publish their exemplar projects on the web and read the projects of others. I believe that this type of design will assist students in finding quality ideas in all fields of science, allow students to work at their own pace, and enable a teacher to work more on a one-to-one level with students.

This project fulfills the needs of both students and teachers. Both parties can roam the site in search of ideas, receive self-instruction on the components of a project, along with examples of what that component "looks" like. For teachers unfamiliar with how to teach the science fair project process, this site can be the "how-to" in preparing their students. The design allows for students and teachers to view how a project flows, keeps information in one central area and provides the ability to edit work. Most importantly, it encourages ongoing teacher-student communication via a comment field. The teacher can also monitor quality control in determining what actually is an acceptable project for the Science Fair Repository.

My students showed a level of enthusiasm for both working on their project via the web, and viewing their school name at the Collaboratory site along with pride in knowing some of Shepard's projects would be viewed by the world. My students come prepared when they know we will be in the computer lab and many have

worked ahead using the site. For students who are unsure of how to design a component, they can easily reference an example or use the menu for extra help. I view this as an universal self-help skill.

As for my school, it is thrilling to be involved on a project in a pilot role. This is a real "science fair experiment" in itself with 100 student subjects to provide reliability in the test results. I am experiencing the same feelings, learning, and technology obstacles as do my students in this process. This project has benefited both my students and myself. I now have a more urgent need for the latest technology and the vehicle for which to incorporate it into the curriculum. Our state goals do reflect the ongoing need and use of technology, and I know we will meet that standard on all levels.

Overall, this type of project benefits not only students, teachers and the school, but also the community. Where else can they go and view what students are producing at their schools, to see how students use technology, and how to arrive at a finished product that undergoes numerous revisions, and mostly importantly, understand what students have learned through problem solving?

Pilot B, Caruso: The Regional Track

> At Caruso Junior High School, the other middle school in the district, science fairs are handled quite differently. Here the local school science fair is optional but for students who are motivated to go to the next level there is a special **Regional Track Program**. Beatrise Revelins is the coordinator of this program and is piloting a science fair repository that has been tailored specifically for it.

I see the Science Fair Repository as a great resource of ideas, helping students get through the difficult initial stage of choosing a topic. Students will no longer have to rely on books that list vague topics such as plants and the sun, water pollution, computers, etc. Instead they will see interesting, challenging, and successful science fair projects while gaining insight into what makes a project a winner. Teachers will no longer have to struggle in finding lists of topics that will interest their students.

I joined this pilot program for three reasons. First, I saw this program helping me establish another means of communications with my students. Experiments are long-term projects that need constant input. I do not want to ask students to participate in a science fair only to see them next on the day of the fair. The lines of communication need to be open all the time. Our school has established a great program for students interested in going to a regional science fair. Here the lines of communication have been established fairly well. These students are seeing the need for more teacher input. Problems arise, equipment is needed, and charts need to be reviewed. Constant input is a must for this type of a high level project to become a success. The Science Fair Repository allows these students and teachers to communicate as never before. My second reason for joining this pilot program is simple. We would like to bring more students into the science fair and give them individual attention. The students who decide to do the "Regular Track" (local fair only) are also in need of more input from their teachers. Because this is not a mandatory project, these projects are done outside of school. Many students do fine work alone, but more and more are seeking guidance from the teachers. I see this project opening the lines of communication to all science fair participants. Everyone receives input and assistance. The third reason why I was willing to participate in this pilot program is because I feel we as a school need to bring more technology into the classroom. Technology in the class seems to be years behind the rest of the world. I want my students to be using today's technology for their projects now. This eliminates paperwork and helps students stay more on track.

Our "Regional Track Program" is very strong. This project will bring it up to date. We can eliminate paperwork (project update forms), which can be difficult to keep track of depending on how many students are involved. Teacher feedback is now quicker and the organization of the project is more visible. Our district needs to meet technology goals within the curriculum. This project is a very powerful tool that will allow us to bring today's technology into the classroom.

One of the most exciting aspects of this project is giving the students an opportunity for another audience to see their work. I believe that by showcasing these exemplary projects many people benefit. As students work on their projects they know that this will be on the web for others to see. Their audience has been broadened. In my

classroom I have mentioned numerous times how scientists strive to publish their findings as soon as they can. They know that feedback from their colleagues is priceless. They also seek recognition for a job well done. This project gives students that real-life feeling. Students, the young scientists, have completed an experiment and are now given the opportunity for their peers and others to see their work and give them feedback. Future science fair participants also benefit. In the Science Fair Repository they will find true experiments that work. Both parties gain so much. It truly becomes more than a "science fair project for my science class." It is an experience that is documented for the world to see.

Summary

The Science Fair Repository offers K-12 science educators a collaborative tool with a short learning curve for teachers and students. As a resource it offers a solution for the common problem of choosing a science fair project. As a organizational tool it can provide improved student-teacher communication throughout the course of a long project. In the later application, students can work privately on their projects until completion when the teacher can make it viewable to the class and immediate community. This does not replace the poster, paper and oral presentations but will provide access to the project for peers, teachers, parents and science fair judges long before the actual day of the fair. It promises to divert much of the confusion brought on by papers left at home and relieve much of the time constraints placed on judging.

The topic of a web-based science fair, or cyberfair, arises whenever the Science Fair Repository prototype is shown to a group teachers. The Collaboratory Project is not addressing that concept or even suggesting it to partner schools at this stage in development. The primary goal, at present, is to deal with the issues expressed in this document. Yet it is apparent that the Science Fair Repository may be a first step in this direction for some schools. Indeed, in terms of deploying the written portion of a project in web format it is already there. As teachers use the Science Fair Repository they will discover new ways to use and improve the product. In particular it may provide an opportunity for Mathematics and Computer Science teachers to consider on-line options for science fair projects in their fields, which are generally not well represented in local and regional fairs. The Collaboratory Project will consider the on-line science fair option when and if this occurs.

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"A Tour Before": Interpretations of a Science Gallery & the Interactive Videoconference Which Preceded It

Timothy Barshinger
Department of Curriculum and Instruction
Purdue University
United States
tbarshinger@w2com.com

Abstract: This study examined how elementary children and their classroom teacher interpreted a visit to a museum's science gallery and the videoconferencing link that preceded it. The interactive "virtual tour" was meant to serve as an advance organizer for the children. This interpretive, non-comparative project specifically involved four fifth grade "key informants" and their teacher. Data were gathered through interviews, observations, artifacts, and researcher reflections. Individual informant data was analyzed for common patterns and compared cross case for synthesis into key themes about the nature of the experiences. Data analysis revealed that the students' learning styles and peer group structure had an impact on the nature of their investigations during the on-site visit. Also noted was how the videoconference was a successful advance organizer. Students were able to create mental organizers, such as mental maps and interest agendas, following the link which helped direct and focus their exploration during the museum visit.

Introduction

Science museums and other informal science centers such as zoos, aquaria, and environmental centers have increased in popularity with teachers because they provide opportunities that extend beyond the traditional static museum. These types of environments provide direct, interactive experiences with relevant materials that enhance students' curiosity and wonderment about science (Falk, Koran, & Dierking, 1986). Bitgood, Serrell, and Thompson (1994) note the advantages that informal learning environments have over the traditional classroom. These sites are often able to meld affective and cognitive learning experiences as academic enrichment occurs via recreational interactions. Additionally, "time-on-task", while usually short, episodic and more intense than a traditional classroom, is controlled by the learner. Thus, participants are more apt to pursue those exhibits which possess science content that is relevant and meaningful to them. With this growing utilization of informal environments, the assumption would be that the canon of research supporting their use has increased as well. However, Schauble and Bartlett (1997) concluded in their search for research-based museum designs that there is an incredible discrepancy between research on museums as an actual learning context compared to studies on exhibit evaluations within the museum. They also note that even though there are many current sub-fields organized around school learning, such as educational psychology and instructional psychology, there is currently no sub-field that is generating the constructs and methodologies associated with informal learning.

Whereas research on galleries designed with appropriate pedagogy is limited, there is a significant amount of information on the behaviors children exhibit while attending informal science settings. In particular, the behavioral reactions to setting orientation and novelty influence has been examined extensively. This has led some researchers to be concerned that the novelty, or excitement of a field trip, may interfere with task-directed learning. Children spend more energy orienting themselves with the environment than trying to understand the scientific concept being presented (Falk, 1983a). In fact, some studies suggest that extreme novelty could even lead to less exploration and fear (Falk & Balling, 1982; Falk, Martin & Balling, 1978; Martin, Falk, & Balling, 1981). Researchers have conducted investigations to determine if purposeful, novelty reducing procedures such as

advanced organizers, or pre-visit, post-visit and on-site visit materials affect students' conceptual learning. Falk (1983b) researched whether orienting materials could be useful in producing more successful learning of museum information. These orienting materials include: logistical layouts and agendas given pre-visit, information panels placed anterior to museum exhibits, teacher pre-visit discussions, cognitive preparation materials related to the exhibits, and slide-tape presentations given pre-visit.

This last form of novelty reduction provided the catalyst for this study. Kubota and Olstad (1991) introduced a pre-visit novelty reducing treatment via a slide tape presentation of the logistics and highlights of the science center. Their positive outcomes suggest that two-way audio-visual interactive learning technology could produce similar results. However, few projects investigate applications at the high school level and virtually none exist for the middle or elementary school (Evjemo, Eidsvik, & Danielsen, 1995).

The Study

Objectives

The purpose of this research study was to examine how children and their classroom teacher interpreted a visit to the ScienceWorks Gallery of The Children's Museum of Indianapolis, and the videoconference pre-visit "tour" of the gallery which preceded it. This two-way distance link was broadcasted and received via a statewide fiberoptic, videoconferencing network. The "Virtual Tour" was meant to serve as an advance organizer for children so that they could better focus on the concepts being presented by museum exhibits. Specifically, the study addressed the following questions:

1. What are children's interpretations of their experience in a novel science museum setting and the distance link which preceded it?
2. What is the classroom teacher's interpretation of those children's experiences?
3. How do the children's and teacher's interpretation of this experience compare?

Design & Procedures

This interpretive study involved four fifth grade children and their classroom teacher as key informants. Data was gathered throughout three phases of the study and included interviews with the key informants, observations, field notes and artifacts, and researcher reflections. These data sources are highlighted in Table 1. The study followed a phenomenological theoretical tradition. According to Patton (1990), the central question of phenomenological research is "What is the structure and essence of experience of this phenomenon for these people?" (p. 88). The research questions for this study addressed that inquiry as the participants interpreted the experience of their interaction with technology and with the museum environment.

Interviews were utilized as the primary data source. An interview was conducted with each key informant following the initial observations but prior to the distance link. A second interview occurs immediately following the distance link but prior to the museum visit. The third and final interview sessions occured following the experience at the museum.

The key informants and their classmates were formally observed prior to the visit. This experience helped provide general background knowledge on the dynamics of the class, the students, and the teacher. Tracking of the key informants was utilized during the actual visit to the museum; assistants recorded information such as the path of movement throughout the gallery, exhibits that were explored ("attraction"), amount of time spent at those exhibits ("holding power"), interaction with other visitors or classmates, and comments made related to the exhibit.

The data obtained from tracking were used as one type of field notes. Other field notes included artifacts produced by the key informants during interviews. As part of the second interview, the student informants created a graphic organizer of the exhibit areas they remembered most vividly. This organizer served as a probing mechanism during interview questioning and discussion. A second artifact that was produced during the third interview was a color coded "level of interaction" map which each key informant used as a type of self evaluation. Each child was given a map of the ScienceWorks Gallery and was asked to color code the exhibit areas according to their perception of their level of interaction. This organizer provided a focus piece for discussions related to favorite exhibits and science content learned at those exhibits. The tracking records were used in conjunction with

these maps as they provided a basis for comparison when consistencies and inconsistencies were pointed out to the students.

Personal reflections that followed observations, interviews, the distance link, and the museum visit were also recorded. Reflections were defined as interpretations of why students behaved in a particular manner, why students responded to various interview questions, what parts of the study went well, and difficulties experienced during the study.

Project Phases and Data Types

	DATA TYPE			
	Observations	*Key Informant Interviews*	*Field Notes and Artifacts*	*Researcher Reflections*
Phase 1: Background Development	• before and after first interview	• during full day observation	N/A	• following full day observation and first interviews
	Pre-visit "tour" of ScienceWorks via videoconferencing technology			
Phase 2: Live, Interactive Video "Tour"	• during pre-visit tour	• 1 day following pre-visit tour	• graphic organizer of memoriable exhibit areas (2nd interview)	• following pre-visit tour and second interview
	On-site visit of ScienceWorks (2days following second interviews)			
Phase 3: Museum Experience	• during on-site visit	• 4 days following on-site visit	• tracking reports • Level of Interaction maps (3rd interview)	• following on-site visit and third interview

Table 1: The three phases of the study and the type of data collected during each of those phases.

Data Analysis

Each student informant interview set was initially examined for patterns in interpretations. These patterns were compared with other related data such as artifacts, observations, and researcher reflection. Such comparisons were used to either support the patterns or highlight inconsistencies. The teachers interviews were not analyzed as an individual set but were used as a means for comparison of the student's interpretation with her interpretation of those students' experiences. To develop a more comprehensive understanding of the nature of the videoconference link and museum experiences, and to provide an anchor for implications, a cross case analysis was implemented. This procedure compared the individual interpretation patterns of each of the four student informants. From this comparison, a set of key themes specific to five domain areas was determined. These themes were examined in relation to the research question, hence, providing the conclusions and implications.

Findings

Derin as an Example

While all four students and teacher informant data were examined for the analysis of the study, the following section highlights those interpretations provided by Derin, one of the four student informants. He was the most verbal of the four students and hence, provided the richest set of data. Following the Derin interpretation is a summary of key points noted from the cross-case analysis.

Derin approached many of his endeavors in a purposeful and somewhat systematic manner, a trait confirmed by his teacher who stated, "Knowing him [Derin] as a student, he's very detailed in writing and sequential" (Interview, 11/18/97).. His ability to make logical connections across learning domains was clearly evident. He was capable of establishing relationships and reinforcements between and among his school and home environments. In addition to approaching his school science purposefully and systematically, Derin engaged in his museum experience in a similar manner. His exploration of the gallery was initiated by a self-orienting session. When asked what he did as he first entered ScienceWorks, he replied, "Well, I looked around to see where everything was, just to see...well, if the pond's over there, then the crane's over there. And the pond's right there,

and then the ball machine's right there. So I kind of worked my way around and then I went to the pond, and then to the crane, and then to ...the pond...er, the river, then to the crane, then to the pond "(Interview, 11/18/97).

For Derin, the video medium provided a bridge between the museum and his school. He implied that the technology provided almost a seamless connection to the gallery. When ask for a general reaction to his first videoconference experience, Derin stated, "I thought is was kind of cool how you could see the person at the same time as they were talking. It was like watching someone on TV, but they could see you too. So that was neat" (Interview, 11/12/97). He compared it to the actual physical context of our interview setting stating, "It's [the video link] like standing right next to someone and talking to them, like this" (Interview, 11/12/97). He also noted that this interaction allowed him to view the connection as a dynamic, synchronous medium (whereas some of the other informants noted how they would slip into a "passive viewing mode"). Derin concluded that these technological characteristics provided a unique venue for exposing his class to the ScienceWorks Gallery. According to him, a film strip of the gallery or a museum facilitator visiting them on site both have merit, but he would prefer the video link, noting, "I'd probably rather do a distance link so they could show you what it really looks like" (Interview, 11/12/97).

After the museum visit, Derin was asked to compare the experience in the gallery with the expectation he had developed following the broadcast. His response demonstrated his belief that the link was a valuable tool for enhancing his experience. He noted, "It [the museum visit] was better than I thought. Cause, I was thinking we'd just go through and go to a few different things. But it was really, really neat to be able to be there and do all the stuff we seen on TV" (Interview, 11/18/97).

Such reflections would support the canon of research that recognizes the cognitive and affective benefits of advance organizers and pre-visit experiences. Additionally, when Derin was asked to compare his explorations of other galleries located in The Children's Museum, he highlighted the orientation which had taken place. "It [a visit to another gallery] was not as good as this one because I actually knew what would be good and what to do with my time. Cause the other ones, I just had to explore around" (Interview, 11/18/97). For Derin, the distance link provided him an opportunity to create a mental map of the gallery.

Cross Case Findings

The following is a summary cross-case analysis generated from the interpretation of all informant interviews and supplemental data. Many of the patterns noted in the Derin data are evident in this analysis. Patterns were noted in five domains: Exploration and Interview Style; Science Understandings; Museum Experience Interpretation; Videoconference Experience Interpretation and; Relationship of Videoconference Experience to the Museum Visit.

1. Exploration & Interview Style:The examination of the various data set has reinforced a realization that in order to properly evaluate and interpret the information, the personal context each student possesses must be taken into account. What type of communicator are they? How do they approach their explorations? What types of social structures influenced their reactions and behaviors? Such factors had a significant impact on the interpretations of their experience as well as how they chose to verbalize them. Two of the students were very articulate in their interpretations, while two were quite apprehensive during the interview settings.

2. Science Understanding: All four student informants believed that their manipulative opportunities in ScienceWorks was in some way related to underlying scientific phenomena and concepts. Their proclivity to reach those understandings varied. Two of the informants were very capable on drawing upon connections between the science they experienced at home, school, and the museum environment. For instance, Derin was particularly apt at noting the relationships of science concepts observed in his personal life with those he learned about in science class. Some student informants enhanced their explanations by integrating science "jargon". Finally, this experience provided an opportunity for all the students to rethink, reinforce, or refine their current conceptual framework related to the host of topics presented via ScienceWorks.

3. Museum Experience Interpretation: The success of a gallery such as ScienceWorks is mostly due to its ability to eschew the traditional static display in exchange for a more active approach that incorporates multi-sensory manipulations. Each informant made frequent references to ScienceWorks and other field experiences that provided opportunities for engaging experiences. Conversely, as the data noted, static displays which offered little opportunity for involvement or simply required a visual or auditory observation did not fare as well as those that

encouraged touching, moving, or hands-on investigating. Hence, environments that provide relevant, multi-sensory experiences are viewed as exciting and inviting places because the encourage active kinesthetic explorations.

4. Videoconference Experience Interpretation: The use of a new technology for the first time instilled a sense of excitement for the students. All informants viewed the videoconference link as an enjoyable experience. Adjectives such as "neat", "fun", and "cool" were frequently used to describe its nature. Throughout their reflections on the video link though, the students tended to separate the audio and video constructs, highlighting the uniqueness or importance of each. Not surprisingly, the visual capabilities of this technology seemed to initially draw the most discussion. All the students were familiar with synchronous voice communications through the use of the telephone. However, each of them noted that the opportunity to have a visual attached to that audio was a different experience. This uniqueness stemmed from the realization that the same time they were receiving an audio/video signal, they were also sending their own signal to the remote site. The television was no longer a passive conduit. Ironically, while a primary goal of this study was to orient the students to the ScienceWorks Gallery, another inherent form of orientation needed to first occur. The students needed to make themselves comfortable in the presence of the technology. The teacher described her interpretation of how the students were not always actively aware that this was a two- way medium. She recalled, "I think they forgot that [they were able to be seen]. A few of them too, with their mouths, they blurted here or there. Or you would see them suddenly think 'Oh my gosh, oh yeah, we're being listened to or watched' and then they would put their hands over their mouth" (Interview, 11/12/97). This statement demonstrated The teacher's recognition that students went through a period of adapting to the technology before they were able to move on. The students provided insight as to some of the features of the technology that were useful in focusing attention beyond the novelty of the experience. For instance one student noted that the Picture In Picture of the outgoing transmission aided the awareness of what the remote site was actually viewing. The opportunity to ask and answer questions also provided a means of making the technology a less intrusive focus of the broadcast.

5. Relationship of Videoconference Experience to the Museum Visit: The video link provided students with an insight into the simulated environment presented by ScienceWorks by enabling them to create mental organizers. Two specific organizers were gleaned from these patterns: a logistical or spatial awareness of where the exhibit components were in relation to each other (a mental map), and a interest organizer that enabled the students to determine the order or hierarchy for which they would explore that environment (a mental interest agenda). Many of the students created combination or conglomerate of the two with the main function, as one informant creatively iterated, to keep from "going nuts about it". As previously noted, Derin provided a useful example of how a mental logistical map was helpful for him. He explained how, upon stepping into the gallery, he initiated a self-orientation session that helped put the various gallery pieces in a spatial layout. As the students were aware of their logistical placement, they also utilized the second mental organizer, the interest agenda. Derin was forthright in stating how the opportunity to view the gallery prior to actually visiting it enabled him to plan his explorations around those exhibits that piqued his interest the most. The teacher shared how the students' reactions to the video link provoked a change in their focus for the trip. She compared it to previous ventures when student interest revolved around secondary attributes of the visit, such as travel and food. Finally, the teacher summarized the manner in which both mental pre-organizers come together to ultimately benefit the students' experiences. She reflected, "[The video link] just set the tone for the whole trip... It really let them know, 'Oh, we know where were going this Friday. We know what the agenda is. We know what we want to see when we get there.' It really mapped it out well in their mind" (Interview, 11/18/97).

Discussion

Conclusions

Even though the goal of this study was to examine the notion of novelty and the role of an advanced organizer within an informal science setting, one of the limitations was that it also had an inherent second form of novelty, the actual use of the interactive audio/visual technology. Since this form of communication is just emerging in the education arena, it is something with which most children and their teachers are not familiar. The use of the communication system could have inadvertently influenced the behavior of the children when they were exposed to a technology in which "they talk to the TV and it talks back." Students may have focused on the novelty of this phenomenon, which could serve as a distraction from the content presented in the distance link

experience. The interpretation of the data takes into account that the students and the teacher may not have been responding to the information presented in the link as much as to the workings of the technology.

Review of student and teacher interviews suggest that the technology was effective in orienting the students to the gallery environment. Such findings would support the core body of research that iterates any type of advanced organizer will have some positive cognitive and/or affective outcomes. One of the key informant's comments regarding the type of media used as the advanced organizer provided an interesting finding on the nature of such interactive media. All interviewees felt the opportunity to interact with the museum facilitator (who led the "Virtual Tour") added to the excitement of the link and the subsequent trip. When asked to compare the distance link with a video-taped tour of the gallery, all informants emphasized that the ability to ask questions and speak with the tour guide "on the spot" made the distance link more motivating. These same reflections were shared by the teacher who also believed that this was one of her most successful field trips. She felt this is so because many of the students came prepared with a plan of action for their visit.

Implications

The results and conclusions of this project will help provide a better understanding of how children think and learn in informal science settings. It will also help extend previous studies done on novelty reducing preparation in informal learning environments. Additionally, this particular project can serve as on one of the few studies that examine the outcomes of using distance learning technology in a classroom and in an informal science setting.

The conclusions drawn from the project will have implications for the educational establishment's current push toward the integration of advanced technology in the classroom. It will provide a basis for further studies that implement distance learning technology. It will also provide information for schools and museums that are just beginning to equip their buildings with distance learning technology.

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Gaining Confidence in Mathematics: Instructional Technology for Girls

Carole R. Beal
Department of Psychology
Cbeal @psych.umass.edu

Beverly P. Woolf, Joseph Beck, Ivon Arroyo, Klaus Schultz, David M. Hart
Center for Computer-Based Instructional Technology
Computer Science Department
{bev, beck, ivon, schultz, dhart}@cs.umass.edu

University of Massachusetts
Amherst, MA 01003

Abstract: AnimalWatch is a mathematics tutor with enhanced adaptive feedback precisely tailored to girls' instructional needs. Three evaluation studies with fifth grade students support our hypothesis that adaptive feedback is beneficial to girls' math confidence. We have also had high levels of teacher participation including classroom activities, after-school presentations and summer workshops. This paper describes features of the tutor, evaluation studies, work with classroom teachers and dissemination activities.

1. Increasing Girls' Self-Confidence in Mathematics

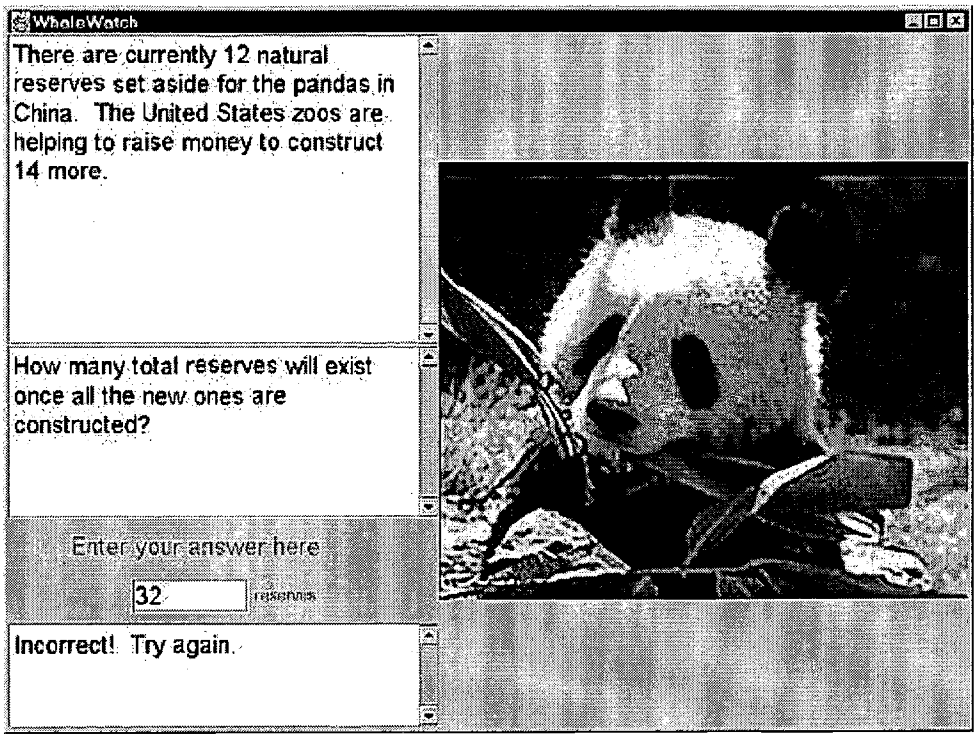
A major factor contributing to women's lower participation in science, engineering and mathematics careers is that, beginning in junior high school, many girls begin to doubt their ability to learn mathematics (Beal, 1994; Beller & Gafni, 1996). As a result, girls are typically more likely than boys to progress no further in mathematics than eighth grade algebra, and are subsequently under-prepared for many science and math-intensive majors and programs at the university and graduate school levels.

This project focuses on development of an intelligent tutor to provide effective, confidence-enhancing mathematics instruction for girls in late elementary school (Hart et al., 1999). The guiding hypothesis is that mathematics instruction in the United States can be completely transformed through the use of instructional technology so as to be much more appealing to girls, and in turn, enhance girls' interest in and preparation for math and science careers.

In contrast to most educational software which is designed primarily with the male user in mind, AnimalWatch provides supportive, adaptive and effective math instruction tailored to girls' interests and needs. AnimalWatch accomplishes this via its "student model," a module that draws on cutting edge techniques in artificial intelligence to create a representation of each student's math understanding. The student model is continually updated as the student works on math problems and is used to 1) generate appropriately difficult problems and 2) to respond to the student's errors with customized help and feedback tailored to her or his needs. AnimalWatch also engages girls' interest in math by blending mathematics with environmental biology, the science subject that is of highest interest to female students.

AnimalWatch has been developed with the collaboration of local schools 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. 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.).

When a student has trouble solving a problem, AnimalWatch initiates a tutoring interaction with customized hints and guidance that helps the student work through the problem. Similar problems involving the same

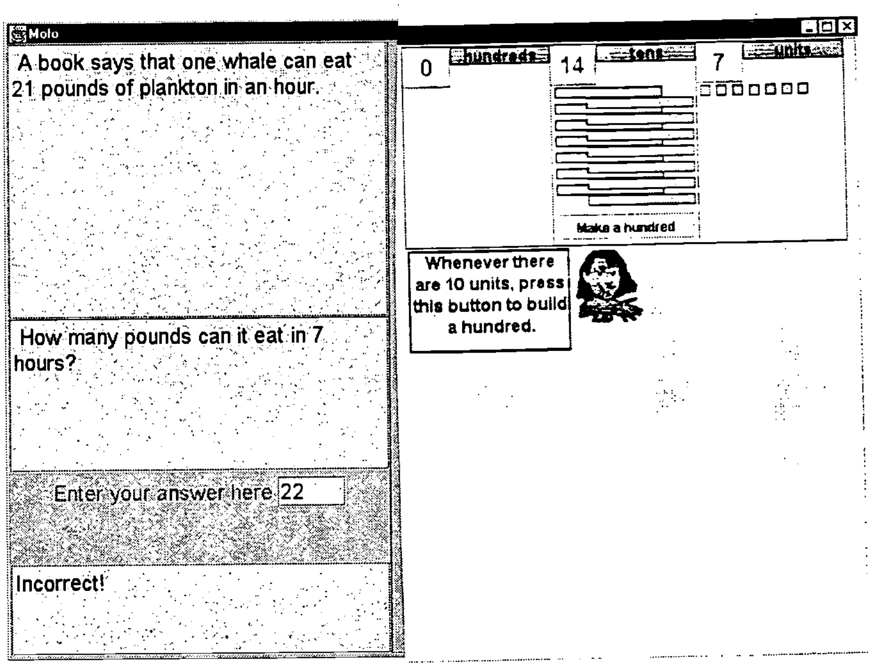


subskills are given until the student can successfully work the problems. AnimalWatch maintains an accurate assessment of the student's strengths and weaknesses. Online self-assessment surveys conducted as students work with AnimalWatch have showed that the tutor generates a more accurate assessment of each student's abilities than the students themselves (Beck et al., 1997).

Figure 1: Example of addition problem in AnimalWatch

AnimalWatch uses Artificial Intelligence techniques for problem generation, hint selection and student modeling (Stern et al., 1999). Multimedia is used judiciously to engage the student by animating key concepts and providing interactive manipulables based on those used by classroom teachers.

Figure 2: Example of a hint on a simple multiplication problem



2. Features for Girls in AnimalWatch

When the student logs on, he or she enters an environmental biology storyline in which math problems are presented within distinct contexts that unfold as the narrative progresses. Students can select an endangered species, such as the Right Whale or the Giant Panda, which includes an initial story context. The student is invited to join an environmental monitoring team and engagesin activities to prepare for the trip.

For example, in the case of the Giant Panda, problems involve research at the library about the Panda's habitat, reading about the birth of a new Panda at the San Diego Zoo, estimates of the expenses associated with a trip to China, and analyses of the rate of decline of the Panda population over time, etc. The student model estimates when the student is ready to move on to the next environment (e.g., whale-watching vessel; mountain terrain trip, etc.). Each math problem includes graphics tailored to the problem, e.g., a map of Cape Cod bay showing the migration route of the Right Whale for a problem in which students calculate the fractional progress of a pod over the course of a week's travel. The third context involves a return to the research "base" and preparation of a report about the species' status.

Hints and instruction screens appear when the student has made a problem solving error (example shown in Figure 2). Hints and adaptive feedback have been shown to be especially important to girls, whereas boys retained their confidence in math even when working with a drill and practice version of the system that simply presented problems and responded to student errors with the message, "Try again." This gender difference in response to different types of feedback is consistent with the theoretical framework: Detailed and immediate help provides a critical role for lower-confidence students, many of whom are female, who are quick to assume that they do not have the ability to understand difficult concepts.

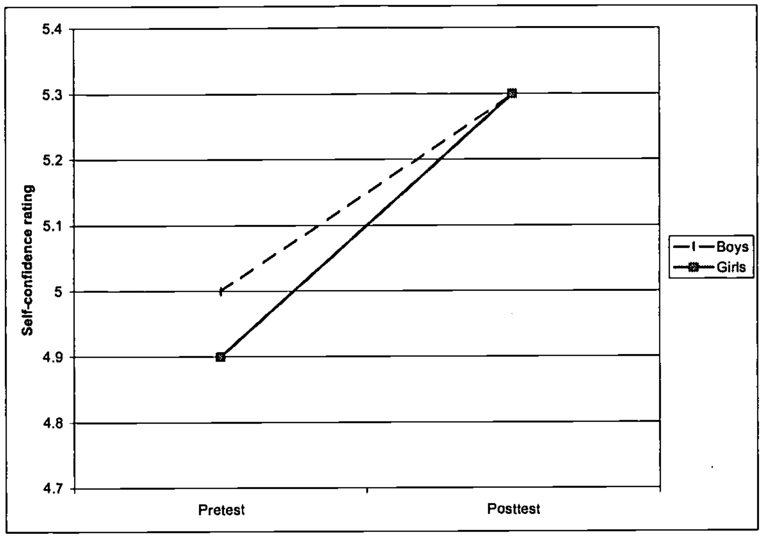
The intelligent student model is continually updated based on the student's ongoing performance. Math problems in AnimalWatch are not "canned" or pre-stored. Rather, hundreds of problem templates are used to generate novel problems "on the fly." AnimalWatch currently includes mathematics operations that match those included in most fifth grade classrooms: whole number operations (multi-digit addition/subtraction, multiplicaton/division); introduction to fractions; addition and subtraction of like and unlike multi-digit fractions; reduction/simplification; mixed numbers; introduction to proportions/ratios; and interpretation of graphs, charts and maps. AnimalWatch has been implemented in the Java computer programming language inorder to be easily disseminated via CD-ROM or the Internet and easily used by most elementary schools.

3. Project Findings: Evaluation Studies with AnimalWatch

Results from three evaluation studies will be described. The first study focused on collaborative learning, and, consistent with students who worked individually, students who worked with a partner showed significant increases in math self concept (Berry, et al., submitted). The increase in math self confidence was observed for girls working with a male partner, as well as those working with another girl. In terms of math confidence and objective problem solving, these results indicate that girls do well with AnimalWatch even when working with a male partner.

The effectiveness on girls' and boys' performance of different types of adaptive feedback was measured in June 1999 with three classes of fifth graders. Preliminary evidence showed that highly adaptive feedback is especially important to girls: when students worked with a version of AnimalWatch with the adaptive feedback "turned off," girls were more negatively affected than boys. The goal was to identify specific hints and help that are most beneficial to girls, particularly those who are at different stages of cognitive development.

In this study, students worked with AnimalWatch for three sessions over the course of one week. AnimalWatch was adjusted to compare responses to different types of hints, such as those shown in Figure 4. When the student made a mistake, the system first provided messages with relatively little content, e.g., "Are you sure you are using the correct operation?" Low interactive text hints were used at first because nearly half of the errors entered are corrected by students on the next try after a simple prompt. If the student kept entering a wrong answer, the system presented a hint to guide the student in the whole problem-solving process. At this point, AnimalWatch selected randomly either hints that were highly conceptual (see Figure 2) or hints that were more



procedural in nature (see Figure 4). Hints also varied in the degree of interactivity required from the student: hints that were highly interactive were also highly structured and walked the student through the solution process in incremental steps (see examples in Figure 4). We hypothesized these would be more helpful to girls.

Figure 3: Change in Confidence of Girls and Boys

Data on math problem solving were automatically collected. Hint effectiveness was assessed by comparing the number of errors made on subsequent problems of the same type, the idea being that if a particular hint is helpful then the student should be able to to solve a similar problem with significantly fewer errors.

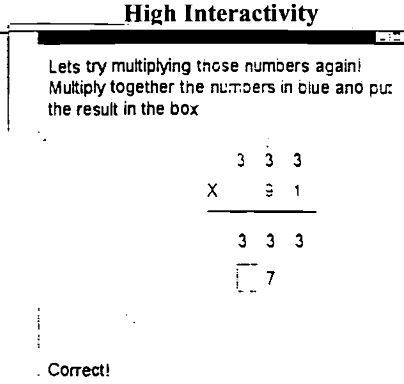
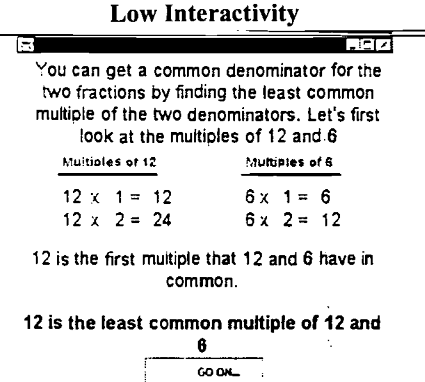
Symbolic/Procedural Hint High Interactivity	Symbolic/Procedural Hint Low Interactivity
	

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Figure 4: Examples of hints differing in interactivity

To evaluate girls' reactions to the different types of hints, ratings from a survey were analyzed, in relation to gender and cognitive development. In a pre-test session, students' cognitive developmental stage was assessed via a computer presented battery of Piagetian reasoning problems (Arroyo et al., 1999). Students also completed a survey about their AnimalWatch experience, including questions in which they were asked to rate the helpfulness of the different types of hints that they saw. The results indicated that, not surprisingly, both boys and girls of lower cognitive development needed more hints to solve the problems. However, there was a strong relation for girls between their cognitive developmental stage and their views of how helpful the different hints were. In addition, hints that were highly interactive (i.e., structured) were rated by girls as significantly more helpful than less interactive hints, and were more effective (i.e., were followed by fewer errors in subsequent problems), whereas there was no relation for boys, see Figure 5. Overall, the results indicated that not only is adaptive feedback especially important for girls, certain specific types of feedback are preferred by girls, whereas boys do not appear to show such consistent preferences.

Several evaluation studies showed significant improvements in attitudes towards math (confidence, value, liking) after students worked with AnimalWatch (Beck et al., 1999). The goal was to assess the effects of working with AnimalWatch on girls' math confidence. With regard to students' confidence in math, analyses of variance comparing the pre- and post-test data from the Academic Attitudes Questionnaire indicated that working with AnimalWatch led to significant increases in students' math self concept (Figure 3).

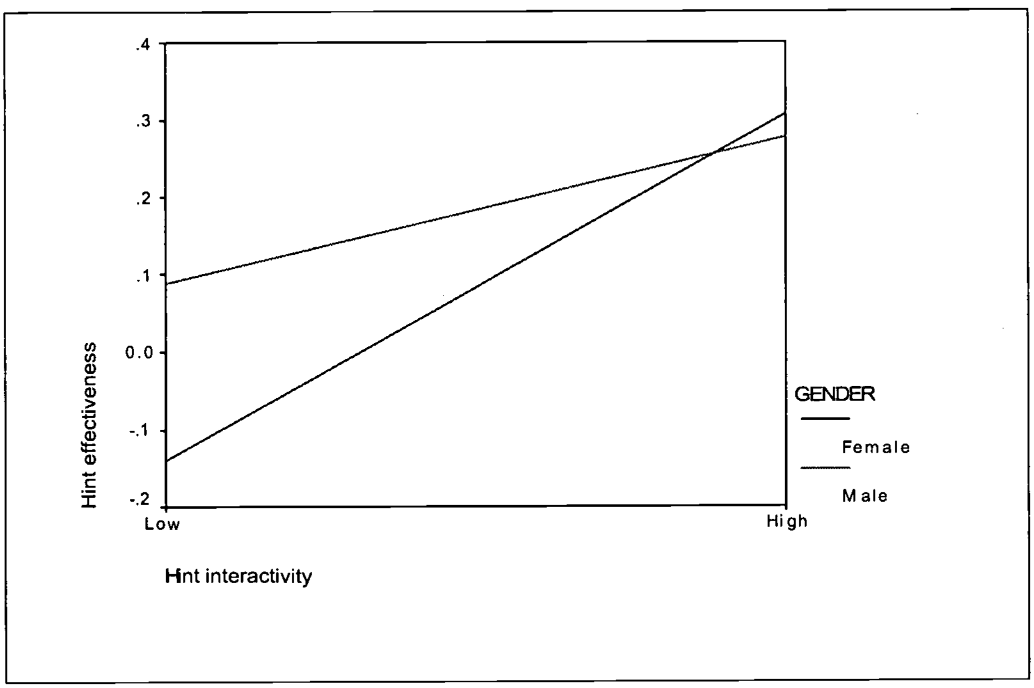

Figure 5: Gender differences in response to high and low interactive hints

Analyses of the AnimalWatch survey revealed that students generally rated their experience highly: Means range from 3.78 to 4.85 (on a 5 point scale) for questions such as "Would you like to use AnimalWatch again?," "When you made errors, did AnimalWatch give you enough help?," "Do you think the computer is a good way to learn math?." On the question, "Did you like working with AnimalWatch?," girls gave significantly higher ratings than boys (mean 4.50 for girls, 4.05 for boys).

4. Dissemination

Classroom teachers and teachers-in-training were involved in the design of AnimalWatch and in the evaluation studies. Workshops for the participating fifth grade teachers focused on gender equity in math and science, as did guest lectures to psychology, education and teacher training programs and three-hour workshops for student teachers.

AnimalWatch received high marks from the teachers, who rated it highly on such issues as appropriateness of math topics, sufficiency of help, ease of use, and fit to their curriculum. They also felt that working with AnimalWatch would help prepare girls for high stakes achievement tests such as the PSAT or the MCAS (a new state assessment test suite in Massachusetts), on which girls typically perform less well in math than boys. All the participating teachers volunteered their classrooms as sites for future evaluation studies.

Teachers responded very positively to AnimalWatch's ease of use and resilience (i.e., there is little that a student can do to "mess up" the computer and thus require teacher intervention). They were very pleased that it will run on any platform.

5. Current Research Issues

Our primary goal in the project is to help girls tackle increasingly challenging math learning while maintaining their confidence in their math ability. The critical mechanism is AnimalWatch's ability to immediately provide individualized adaptive feedback and to pace the difficulty of problems to avoid discouraging the student with repeated failures. In particular, we are now concerned with how rapidly AnimalWatch should "push" girls through the math curriculum. To address these issues, a mechanism that quickly and automatically estimates the optimal sequence and rate of problem presentation for each student is being evaluated. Another goal is to add an additional species, with background research and context construction. At the request of many teachers, we will add a user feature that would allow teachers to review the progress of individual students after each session with AnimalWatch.

An artificial intelligence learning mechanism that quickly and automatically estimates the optimal sequence and rate of problem presentation for each student is being evaluated. However, determining when a student is bogged down in problem solving is actually quite difficult, technically. First, the overall skill level of the student must be accounted for. If two students are given identical problems, the more skilled student will solve the problem more quickly than the less skilled student. Second, there are considerable individual differences in how quickly students work. For example, some students navigate the keyboard more quickly than others, some students have the multiplication tables memorized (more often, boys) while others prefer to use pencil and paper (more often, girls) etc. Any of these factors can impact the time required to solve a problem. Finally, the time required to solve a problem is a noisy variable. That is, if a student is given similar problems, he or she may take very different amounts of time to solve them. A small mistake at the beginning of the problem solving process can drastically impact the time required to solve a problem. All these issues are being investigated.

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Communication Between Problem Solving Groups in an On-line Geometry Course: Results and Lessons Learned

Brian Beaudrie
Department of Mathematics and Statistics
Northern Arizona University
United States
Brian.Beaudrie@nau.edu

David A. Thomas
Department of Mathematical Sciences
Montana State University
United States
dave@math.montana.edu

Abstract: The purpose of this study was to investigate the relationship between communication and achievement among cooperative learning groups performing problem-solving activities in a WWW-based Geometry for Teachers distance education course. This paper presents an overview of the preliminary findings of the study.

Introduction

As the American educational system enters into the 21st century it is undergoing an evolutionary change more rapid than any change in history. Technologies such as the Internet and World Wide Web (WWW), unknown by most a decade ago, are now regularly and increasingly used to meet the demands of an ever-changing educational populace. Most universities and colleges now offer courses via distance education, some offering entire degree programs completely delivered by distance education.

The reasons for its growth, particularly at the university level, reflect the evolution of higher education in general. According to the Virginia Commission on the University of the Twenty First Century, higher education is evolving as follows (Potter and Chickering, 1991):

- The college will be a network of resources, not a place.
- Offerings will give students a global, multicultural perspective.
- Widespread use of new technologies will improve the quality of instruction, increase contact between students and faculty, and reduce time, place, and space constraints.
- Living and learning will be more closely integrated outside the classroom.

These findings indicate the fundamental, evolutionary changes that are occurring in the form of electronically distributed distance education courses in colleges and universities across the country. Indeed, those universities, colleges, or departments that do not make this change may find themselves proceeding the way of all evolutionary nonconformists.

A major reason that some institutions of higher learning have resisted the change is the several questions they may have concerning this form of distance education. Although the use of the Internet/WWW to conduct courses has been growing rapidly for almost a decade, the study of the use of the Internet as a medium to conduct distance learning courses is still in its relative infancy. Several questions have been answered; however, several more still abound.

Interaction between students and between student and instructor has been shown to be an important factor in determining the success of students enrolled in distance learning classes. There are several studies that show this (Threlkeld & Brzoska, 1994; Coldeway, MacRury, and Spencer, 1980). However, the question of the quality of interaction - the intellectual level of the communication that is taking place - and how that effects the success of students academically is what this study attempts to answer.

Context

Math 527 Geometry for Teachers (http://www.math.montana.edu/~dave/m527/Sp99.htm) is a distance education course developed by David A. Thomas for K-12 mathematics teachers pursuing masters or doctoral degrees in mathematics education at Montana State University. The course surveys transformation, Euclidean, fractal, projective, and hyperbolic geometry using a variety of modeling technologies and texts by Smart (1998) and Thomas (1998) and is taught concurrently with an undergraduate on-campus course, Math 329. Students are divided into small working groups and assigned weekly tasks. Each task requires students to integrate and apply concepts and procedures encountered in assigned readings and exercises, make systematic observations using geometric models, write descriptive statements, formulate and test conjectures, and synthesize solutions to complex mathematical problems. Group communications take place in an Internet-based conferencing environment, *First Class Intranet Client.* Students use *FirstClass'* messaging and chat features to negotiate the content, language, and format of weekly reports. Equations, graphics, data files, and other elements of routine mathematical communication are attached to these messages and downloaded by group members as necessary.

Subjects

The subjects of this study were all the students who were enrolled in the Geometry for Teachers course offered at Montana State University for the 1999 Spring semester. There were a total of 18 students who enrolled and completed the course. Fourteen of the eighteen students enrolled in the Math 329 level of the course, four in the Math 527 level of the course. Of the fourteen students who enrolled in the undergraduate section of the course, all but one were on-campus students taking other courses at MSU during that semester. These students were typically secondary mathematics education majors, although since enrollment in the course is open to any student who meets the prerequisites, there were students in other fields as well as mathematics education. All four students enrolled in the graduate section of the course were off-campus students, teaching in middle schools and high schools in the United States.

The content of the course was identical. The course was not taught in the traditional lecture setting; instead, the course materials were delivered to the students via the Internet through the use of the World Wide Web. The students who enrolled in this class were typically secondary mathematics education majors

During the first week of the semester, the students were placed into four groups of four or five students each. One group would consist of the five off-campus students. The other three groups were created from the thirteen undergraduate students. The members of these three groups were chosen by matching on prior mathematical ability, with gender as a secondary matching variable. Prior mathematical ability was determined by the student's college grade point average in all mathematics courses that count towards earning a degree in secondary mathematics.

Description of Treatments

The study investigated the differences in the content and form of communications occurring among the members of the four groups as they worked on and discussed problems in an Internet-based, distance education format. The students engaged in a series of weekly small group, problem-solving activities in two electronic formats: an asynchronous bulletin board messaging system, and a synchronous chat room. Both formats were conducted using the *First Class Client* sofware, an Internet-based communications software used in all Web-based distance education courses taught at Montana State University.

The Geometry for Teachers course at Montana State University for spring semester 1999 was a fifteen week course. During the first three weeks, students were given activities to help familiarize themselves with the First Class Client software and other software that would be used throughout the entire course. After this, for eleven weeks, the students completed one activity per week working in their assigned groups. For the last week of the course, no group activity was assigned; instead the students used the time to complete a final project for the course and to prepare for the final test.

Each week all four groups would work on the same problem, using either the bulletin board or the chat room to conduct their communication. These environments were to be changed every two to three weeks, giving students a chance to familiarize themselves to both environments. The weekly group tasks were to be addressed

collaboratively, with each student contributing ideas, responding to ideas, proposing strategies and procedures, demonstrating possible solutions for the purposes of feedback, and summarizing and reporting the groups findings. A complete record of each group's deliberations was recorded in electronic form using First Class Client's messaging and chat tools. Substantive contributions to these deliberations that took place in face-to-face or phone conversations were to be referenced and reiterated in the electronic communications of that group.

Methods of Data Collection

Achievement was measured by the scores on all group activities, and by the scores on individual's midterm and final tests. For the group activities, each member of the group was given the same score providing he or she fully participated in the work. Since it is relatively impossible to differentiate achievement levels among individual class members through the use of the group activity scores, the midterm and final test scores were used for this purpose.

The intellectual content level of the communication was measured using the Interaction Analysis Model (IAM) for examining social construction of knowledge, developed by Gunawardena, Lowe, and Anderson (1997). The IAM was designed to measure the social construction of knowledge in computer conferencing. The designers of the instrument defined five distinct levels, called phases, of knowledge construction. They are (in hierarchical order):

1. Sharing/Comparing of Information;
2. The Discovery and Exploration of Dissonance or Inconsistency among Statements, Concepts, or Ideas;
3. Negotiation of Meaning/Co-construction of Knowledge;
4. Testing and Modification of Proposed Synthesis of Co-construction;
5. Agreement Statements/Application of Newly Constructed Meaning.

The authors also used the IAM to rate one entire message, rather than different sections of the message as belonging to different levels, as done earlier by Henri (1992). According to the creators of the IAM instrument, if a message was broken down into units of meaning and analyzed separately, the process by which arguments, hypotheses, and theories are advanced would be difficult if not impossible to describe. In conducting this research, messages were handled in a manner similar to the intent of the creators of the IAM instrument. Each message, whether it be from a bulletin board posting or in a chat, would receive one rating.

Computer attitudes were measured using the Computer Attitude Scale (CAS) developed by Loyd and Gressard (1984, 1987). The CAS is an instrument that measures attitudes towards learning about and using computers. The instrument provides scores on four different scales: Computer Anxiety, Computer Confidence, Computer Liking, and Computer Usefulness. Each subscale consists of ten items. Students respond to statements by selecting one of four responses ranging from strongly agree to strongly disagree. Some sample items from the CAS are statements such as "computers make me feel uncomfortable" or "I will use computers many ways in my life". Scores can range from a low of 10 to a high of 40. In general, the higher the score, the more positive the attitude towards computers. Alpha reliability coefficients calculated for each of the three subscales are very high, ranging from .87 to .91. The correlations between the subscales range from .69 to .84.

Finally, attitudes towards the course, the two treatments (asynchronous and synchronous communication) and other attitudes were measured with a survey instrument designed by the researcher in conjunction with the instructor of the course. The survey was designed to illicit responses both open ended, and using a Lykert scale for statistical comparisons.

Results

Note: Since the data is still being analyzed, many of the results are still pending; they should be ready by the time this paper is presented during the conference. However, there are some preliminary descriptive results of data analysis, which will be presented here:

Computer Attitude Scale

The results of the CAS, administered during the first few weeks of the course, showed that most students had a very positive attitude towards computers. Indeed, some students registered the highest score possible on the test. Only two students could be put into the category of having a neutral attitude towards computers. Those two students were also the only two students who were relatively new to computers, having experience with learning about or working with computers of less than six months. When examining the subscales, they were found to both have positive attitudes towards computer usefulness, and computer liking, with neutral attitudes on the computer confidence subscale. One of these two students also recorded a neutral attitude on the computer anxiety subscale. No students were found to have a negative attitude towards computers.

Messaging and the Interaction Analysis Model

During the semester, a total of 740 individual bulletin board messages were posted. Given that there were few messages sent during the first few week (when students were familiarizing themselves to the software), and few messages sent during the last week of the course (when students were studying for finals), the average of almost 50 messages a week is fairly impressive. Of these messages, 88 were sent by the instructor of the course, leaving a total of 652 total messages sent by the students.

The content of the course covered six different geometry topics. They were (with the number of weeks spent on each topic in parentheses): Transformational Geometry (2), Euclidean Geometry (3), Fractal Geometry (2), Inversion (1), Projective Geometry (2), and Hyperbolic Geometry (2). The total amount of messages posted for each topic area is given in Table 1. It can be seen that the number of messages varied from topic to topic; but the general trend in both student and instructor messages was a decline in the total amount of messages sent.

Topic	Total Messages	Instructor Messages	Student Messages
Transformational Geometry	194	27	167
Euclidean Geometry	197	21	176
Fractal Geometry	128	15	113
Inversion	37	2	35
Projective Geometry	101	10	91
Hyperbolic Geometry	83	13	70
Total:	740	88	652

Table 1: Number of Messages per topic

The number of messages also varied widely among the problem-solving groups. Each of the four groups was identified throughout the course by a color; Red, Blue, Green, or Yellow. The first three groups listed were the on-campus groups, with Yellow representing the off-campus group. The total messages posted by each group is shown in Table 2. Not surprisingly, the off campus group had a large percentage of the messages posted.

Group Name:	Total Messages	Percent of Total Messages
Red	33	5.06%
Green	184	28.22%
Blue	78	11.96%
Yellow	357	54.75%
Total	652	100%

Table 2: Number of Messages per group

Each of the 652 student messages was analyzed using the Interaction Analysis Model. A summary of the scoring for each message based on group affiliation is shown in Table 3 and Table 4. A rating of no score was given to messages that did not fit into any of the phase levels of the Interaction Analysis Model, such as personal messages. In general, both the number of messages and the percent of messages should be higher in the lower phases, and lower in the higher phases. This did occur in some instances, but the pattern didn't follow the predicted path entirely. Some theories regarding why this occurred are discussed in the next section.

Group	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	No Score	Total
Red	17	5	7	2	1	1	33

Blue	54	21	65	14	15	15	184
Green	31	4	17	1	16	9	78
Yellow	149	40	77	24	19	48	357
Total	251	70	166	41	51	73	652

Table 3: Number of messages for each phase level

Group	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	No Score	Total
Red	51.52	15.15	21.21	6.06	3.03	3.03	100
Blue	29.3	11.4	35.3	7.61	8.15	8.15	100
Green	39.7	5.13	21.8	1.28	20.5	11.5	100
Yellow	41.7	11.2	21.6	6.72	5.32	13.4	100

Table 4: Percent of Messages for each Phase Level

Statistical analyses of the data are currently underway, and will be presented in full at the 2000 M/SET conference.

Conclusions

As the course progressed, the total number of messages posted by the groups and the instructor tended to decline. This could be due to several factors. As the students became more familiar with the context of the course, with what was required for each activity and assignment, with the software they were using, and in general with each other, questions and statements of this nature decreased. This would also account for a majority of the decrease in instructor postings. Also, as the course progressed the students familiarized themselves with division of labor for the activities, and became better at asking and answering questions about the activities. Perhaps a third reason could be found in the medium itself. For most students, using *First Class Client* to conduct these group problem-solving activities was new, and probably fairly exciting. As that excitement wore off (and the daily grind of the semester set in) the urge to post would not be as strong.

The Yellow group - the group whose members were located off campus - had by far the most postings, more than the other three groups combined. This is not entirely surprising - since it was impossible for them to have any face-to-face contact of any kind, they needed to conduct all of their communication on-line. The other three groups, while working on the activities on-line still could, and did, take advantage of their situation and would meet to discuss the problems assigned for the class, including the group activities. To restrict them from doing so would have been an unnatural course of action. Hence, the postings from these groups were quite a bit less.

As tables 3 and 4 indicate, the most common phase was phase 1: Sharing and Comparing Information. This is to be expected; in order to solve most problems using a group effort, the knowledge of each member of the group will need to be shared among the group's members. Opinions about potential solutions (without any additions or deletions), another common posting, also fall into this category.

However, the strength of Phase 3 messages (Negotiation of Meaning/Co-construction of Knowledge) over Phase 2 messages (The Discovery and Exploration of Dissonance or Inconsistencies among Ideas, Concepts, or Statements) was surprising. For one group, the number of Phase 3 messages was higher than even Phase 1 messages. A partial explanation could be that the on-campus groups solved much of the dissonance by either talking to the instructor about the problem, or meeting with other group or class members to discuss the problem. Then, all they would post was the results of this discussion (the construction of knowledge) - not the steps it took them to arrive at the results. However, the completely off-campus group had similar results. This could be due to the use of the instrument by the researcher. However, it could also be a result of the nature of mathematics (and mathematicians). Unlike a more social, discussion based subject, where dissonance and exploration of ideas are brought to the surface and discussed, most of the dissonance in mathematics (for most mathematicians) occurs internally. Most mathematicians are not likely to discuss a problem unless they believe they have a potential solution to the problem. Thus, most of Phase 2 would occur within the mathematician's mind; he or she will then divulge what they think is a possible or partial solution, which would fall into the Phase 3 category. More studies would be necessary in order to answer this question fully.

This could also explain why there are more messages falling into the Phase 5 (Agreement Statements/Applications of Newly-Constructed Meaning) category than Phase 4 (Testing and Modification of

Proposed Synthesis or Co-Construction), although it should be noted that the difference is small. Rather than testing the proposed construction externally, mathematicians will test it internally, then pronounce it fit and apply it to the situation (Phase 5) or find errors in it, and revert back to a Phase 2 or Phase 3 situation.

It has been shown that communication is one of the keys to success in a distance learning course. But communication for its own sake - the solution is probably not as simple as that. The study of how groups communicate on-line, and what constitutes effective communication, holds the promise of discovering the best possible way to design and implement a web-based course.

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Global Warming – Should We Worry?
A Problem-based, Simulation, and Teamwork Approach To Teaching Integrated Science

Terry Kiser
Mathematics & Statistics
CSU, Chico
United States
tkiser@csuchico.edu

Jeffrey R. Bell
Biological Sciences
CSU, Chico
United States
jbell@csuchico.edu

Richard Flory
Geosciences
CSU, Chico
United States
rflory@csuchico.edu

Roger Lederer
Dean, College of Natural Sciences
CSU, Chico
United States
rlederer@csuchico.edu

Randy Miller
Chemistry
CSU, Chico
United States
rmiller@csuchico.edu

James Pushnik
Biological Sciences
CSU, Chico
United States
jpushnik@csuchico.edu

Abstract: For the past year, a team of six faculty from the College of Natural Sciences at California State University, Chico have been working on the NSF-funded development of integrated science materials employing a problem-based approach and infusing computer modeling and simulation with traditional laboratory experimentation. This paper will report on a one-semester course we have developed based on the theme: *Global Warming – Should We Worry?* The course covers topics such as: an introduction to climate change with web-based research, an introduction to computer modeling and simulation using the program Stella, and a series of modules, Solar Radiation and The Earth, $C0_2$ and The Ocean, and Photosynthesis and Respiration, where computer models are developed tied to pertinent laboratory experiments. The

course concludes with student teams taking on the task of representing various countries or regions of the world in a mock Kyoto accord.

Introduction

Three major issues in science education are the use of educational technology, problem-based learning, and the teaching of science in an integrated format. While the use of technology in the classroom has been growing rapidly and recognition of the effectiveness of active, problem-based formats is spreading, implementation at most campuses is still piecemeal. The third issue of employing an integrated format is gaining momentum and has received national attention from professional organizations and funding agencies for the past several years. Change, however, is difficult due to the entrenched structure of single discipline-based instruction.

California State University, Chico, is considered as a leader in the 23 campus California State University system in the implementation of educational technology. What we are in the process of doing now, with the assistance of a National Science Foundation grant through the Institutional Reform of Undergraduate Education program, is enhancing the entire basic core science curriculum with educational technology using a problem-solving, computer simulation, and integrated science approach. It is our aim that early in their education students will have the opportunity to see that the sciences have many commonalties, such as, the scientific method, a need for quantifiable and verifiable data, and the use of statistics and probability. Most importantly, all the sciences require a healthy skepticism tied to the process of critical thinking. Our goal is to have student teams investigate and model complex problems involving current scientific controversies of national importance chosen specifically to require knowledge and skills drawn from many different scientific fields.

Presently, a student, whether a science major or not, receives an introduction to college-level science by taking a basic science course in one discipline, be it chemistry, biology, physics, or geoscience. It is perhaps only after several courses and years that students begin to be able to integrate knowledge across the sciences and see a more authentic process of doing science. If they only take a couple of courses, they may never see the big picture. An integrated approach to science is needed and the best way to accomplish that is for faculty from different disciplines to work in teams. It is our hope that by paving the way with a substantial development of resources and through faculty training, we can invite more faculty to jump on board, promote a cross-discipline, team teaching approach and, thereby, revitalize the core science curriculum with the latest in educational technology and pedagogy.

A Problem-based, Integrated Science Curriculum

For the past year, a team of six faculty from the College of Natural Sciences at California State University, Chico have been working on the NSF-funded development of integrated science materials employing a problem-based approach and infusing computer modeling and simulation with traditional laboratory experimentation. One of our long-term goals is to develop a library of curricular "Modules" centered on interdisciplinary scientific issues, which could be packaged into semester and yearlong integrated general education science and critical thinking courses. The NSF grant, also, has helped to fund the remodeling of a classroom into a modern and effectively designed combination class/computer laboratory. In addition, we were able to purchase and construct science equipment, which will effectively promote our underlying teamwork and hands-on approach. This semester, we are conducting faculty workshops to highlight our accomplishments and train faculty in the use of our materials and the use of equipment in the newly remodeled room.

Currently, we have completed materials for a one-semester course based on the theme: *Global Warming – Should We Worry?* Global warming is an ideal "big" issue with plenty of national attention, relevant to the lives of our students, contains heavy doses of math and science drawn from numerous disciplines, and is steeped in debate over political and social side issues. Other topics under consideration and in various stages of development are origins & evolution, watersheds, wetlands, and pollution.

The section below briefly covers some of the pedagogy and student activities comprising our course on global warming.

Global Warming – Should We Worry?

In an attempt to incorporate the latest educational pedagogy and provide for effective student and program assessment, we have researched the literature on program development and course design. As described in (Wiggins & McTighe 1998), we developed our course through the following three steps. First, we identified our course objectives. Then, we addressed how we would know if students have met these objectives, which formed the basis for developing a series of rubrics as assessment tools. With these two important foundations in place, we began the process of developing the student activities. A brief overview of our course, beginning with course objectives, a course outline by topics, student assessment, and course evaluation, is given below.

Course Objectives

In switching from a content driven to a problem-based course, considerable thought went into identifying our goals and expectations. The following three objectives illustrate our emphasis on the process of doing science more than developing a storehouse of scientific facts.

1) Students can critically discuss contemporary scientific issues.
2) Students demonstrate proper use of scientific method.
3) Students can make informed decisions involving science and society.

Course Outline

I. Global Warming – What's The Big Deal?
This unit serves as an introduction to global warming with web-based research using a web site we created containing numerous links to interesting pro/con debates and various climate change organizations (the URL for this site is given at the end of the paper). The primary objectives in this unit are to introduce students to the issues that are part of the global warming controversy, to expose them to several different points of view about the controversy, and to learn how to critically evaluate a web site. The main student activity for this unit is a site review assignment where students will examine various web sites and then write a paper critically evaluating a web site of their choice.

II. An Introduction to Computer Modeling with Stella
The primary objectives in this unit are to introduce students to the computer modeling and simulation program Stella and to develop a "systems thinking" approach to the modeling process (a URL for downloading a free run-time version of this program is given at the end of the paper). Students will investigate simple systems, such as, population models and draining sinks, as they learn how to use the model creation tools, incorporate mathematical relations defining the interconnections between model components, and analyze and evaluate models through simulation. The unit will conclude with a modeling project where students will attempt to incorporate additional features in previously developed models.

III. Solar Radiation and the Earth
In this unit, students will begin creating a model for the global mean temperature of the surface of the earth. The focus will be on the flow of solar radiation and how it effects the temperature of the surface of the earth. It is expected that their model will evolve substantially as their understanding of these various science issues grows. There will be several opportunities to connect simulation activities using their computer models with traditional experimentation through experiments covering such topics as measuring the solar constant, discovering the Stefan-Boltzmann law, specific heat capacity measurements, and determining a planetary albedo. The unit will conclude with student teams giving oral reports over the development of their computer models and its evaluation along with design of experiments and data analysis.

IV. CO_2 and the Ocean

The main objective of this unit is to have students extend their previous model for the global mean temperature of the earth by incorporating the role of CO_2 in the atmospheric absorption and emission of radiation and the role of the ocean in the uptake of CO_2. One of the key activities in this unit will have students design an experiment for measuring the solubility of CO_2.

V. Photosynthesis and Respiration

In this unit, students will continue the process of extending their model by investigating how the atmosphere and biosphere are linked through photosynthesis and respiration. They will learn how these processes can be measured and be introduced to equipment for calculating CO_2 exchange rates. Some of the main experiments in this unit will be to investigate the influence of temperature, light, water, and atmospheric CO_2 on photosynthesis.

VI. Science & Society

The course will culminate with a mock-Kyoto accord meeting where student teams will represent various nations or regions of the world in coming to a consensus on identifying the dangerous issues of global warming and what to do about them. Students will then be responsible for writing a news article debriefing VIP's of the accord and defending their stance.

Student Assessment

In each of the units described above, there is one or two main activities involving a mix of individual and team papers, team oral reports, designing experiments, team reports on creating, testing, and evaluating models, and some traditional quizzes. For each of these main activities, we have identified our objectives and developed a grading rubric, which is given to the students at the beginning of the assignment so they will know right up front what is expected for various levels of assessment.

To illustrate the style of our assignments and rubrics, given below are abbreviated versions for the opening web site review assignment and the capstone Kyoto accord paper.

Web Site Review Assignment

For this assignment, you are to critically review a web site focused on the global warming controversy. Your review will be posted and used by the other students in the class as a resource for projects later in the semester, so it is important that you produce a review that will be useful to your fellow students. Links to some sample sites are given below, although, you are welcome to search for any other useful sites that might be out there. Reviews should include a summary of the material available at the site, an evaluation of the quality of the material (how much is there, how accurate is the site information, how useful will the site be, etc.). You should also evaluate the site for ease of use and discuss the biases of the authors of the site and any bias you find in the material available at the site. You should describe your point of view and any bias that you might have. This should all be written up in a concise and clear one page electronic paper and is due Feb. 1. The review is worth 10 points and will be evaluated for the following characteristic:

- Has a comprehensive description of what is available at this site
- Has an analysis of the quality and utility of the site
- Makes comparisons between this site and others and is able to evaluate this site's contribution to illuminating the issue of global warming
- Includes a clear description of the student's understanding of the global warming issue and the student's point of view on this issue
- Paper is clear, concise, and demonstrates critical thinking

Kyoto Protocol Paper

The Kyoto Protocol is an agreement among several countries to reduce the environmental contributors to global warming. Each country, developed or developing, has a unique set of factors to contend with, such as, its geographic location, natural resources, infrastructure, economy, political environment, present atmospheric conditions, and production of greenhouse gases. Every country will have to approach the solution to the problem of global warming in a different way. Your assignment is threefold:

1. Read the Kyoto Protocol.
2. Choose a country and, based on the pertinent characteristics of that country, develop amendments to the protocol that would be more favorable to you, but with the understanding that the goal remains to reduce greenhouse gas emissions. Pretend you are writing a report to debrief VIP's of your country of your stance on the issues of the Protocol and justifying your amendments.
3. Determine what your actions and timelines, as this country, would be to implement the protocol if none of your amendments were accepted and you followed the stipulations of the protocol.

Your paper will be assessed on the following:

- Able to thoroughly explain the meaning and significance of the Kyoto Protocol
- Understands thoroughly the terminology in and of the Protocol
- Demonstrates an understanding of the economics, stage of development, environmental issues, and political pressures of the countries involved
- Clearly articulates the represented country's unique needs, position, and characteristics
- Paper is clear, concise, and demonstrates critical thinking

Course Evaluation

This is an area still under development but the following are some ideas we have that directly relate to our course objectives.

- Critical discussion on scientific issues: We will make an initial versus final paper comparison. At the beginning of the course, a questionnaire/paper containing some directed questions will be given. This will be compared with a final summary report going into each student's portfolio to assess the growth in their ability to discuss the issues involved in global warming.

- Proper use of the scientific method: We will use a pre-post test comparison along with a beginning versus final design of experiment comparison.

- Making informed decisions on science and society: We will use a video tape of the Kyoto accord meeting and Kyoto Protocol paper to assess the decision making processes students incorporated in reaching their consensus.

We are currently consulting with in-house faculty whose area of expertise involves student and program assessment to add to and refine the components outlined above. Two other items we intend to include to aid in these areas are the use of portfolios and an attitudes survey.

Given below are some URL's for our global warming web site, providing a link to download some of our finished Stella models, and where to download a demo version of the Stella program to run theses models.

Our CSU, Chico web site on Global Warming

http://www.csuchico.edu/~jbell/GlobalWarming/

Information on Stella and free run-time versions

Stella Home page: http://www.hps-inc.com

Free run-time versions: http://www.hps-inc.com/products/stella/free_runtime/runtime.html

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Partners in Science: An Example of Collaboration, Mentorships, and Technology

Gary Bender
Office of Instructional Technology
Fairbanks North Star Borough School District
United States
gary@northstar.k12.ak.us

Abstract: This paper is a preliminary report discussing initial results of the five year *Partners in Science* project. *Partners in Science* is a project linking K-12 students and teachers with practicing university, industry and agency scientists using networked technology, with the aim of increasing the practice of authentic, project-based math and science. The project's goals are to:
1) Improve the student's understanding of science by designing and conducting their own research;
2) Effectively utilize technology as a part of the learning and teaching of science and mathematics;
3) Bring active scientists into the teaching and learning process, both in and out of the classroom.
Research data gathered from teachers, students, and scientists indicates that the project shows promise in each of the three areas.

The Planning Grant (1995-1997)

Partners in Science began as a planning grant in 1995. During this planning year, the project began to take on a structure, recruited a board of directors, hired a project administrator, selected a pilot school, and installed computers and peripherals. The emphasis of the project during that year was the application of networked technology for the improvement of math and science achievement in Fairbanks and remote village classrooms. The planning grant funded a project administrator and the technology hardware for the teachers. There were three sites: an elementary school in Fairbanks, a K-12 school in McGrath, Alaska, and an elementary school in Grayling, Alaska, as well as five home school students living in the Fairbanks North Star Borough.

In the fall of 1996, the project received a second year extension of the grant and added one new teacher to the project in Fairbanks. Staff development during the first two years (1995-1997) of the planning grant focused on technology. The grant funded computers, monitors, modems, color printers, scanners, video, and digital cameras for each site. It took most of the first year to order and install the hardware and equipment. Teachers needed a great deal of support just to use the hardware, but there were no trainers during that time. Initially, fifteen computers were set up at Pearl Creek Elementary School (PC) in the "Virtual Math Science Lab (VSM)," a separate room that was a good distance from the two Partners in Science classrooms. Accessibility was a significant issue. Teachers found it difficult to make time to get down to the computer lab on a regular basis. Frustration with the technology remained at a high level throughout the first year and one-half. Because of this, at the start of year two the VSM Lab became the Partners in Science office and all the computers were divided among the teachers and located in their classrooms. There were still problems, though, because connectivity to the Internet in the classrooms was not as good as the lab, so the machines kept freezing. E-mail was used only sporadically during the first years for pen-pal type communications with the Partner scientists. When students did use the Partners in Science listserv or e-mail to research a question,

the questions were of a level that students could have easily researched the questions themselves using the Internet or books. Scientist responses were direct replies to the questions. There was no attempt to initiate a dialogue and start the students thinking.

The Implementation Grant (1997-2000)

In February of 1997, the NSF funded the Partners in Science project as a research project for an additional three years. The charge was to research different models for integrating technology and collaborations with science, engineering, and math professionals into K-12 classrooms and home schooling. The primary goal was to further math and science learning in grades K-12 in the Fairbanks North Star Borough School District, Iditarod Area School District, and isolated home schoolers. The secondary goal for the project was to document the successes and the failures of our efforts to support math and science learning in K-12 classrooms in Alaska, so that they could be shared with other school districts interested in doing the same thing.

Additional teachers were selected, three from Fairbanks and a teacher from Shageluk School in the Iditarod Area School District. The project hired a half-time administrator in McGrath and a half-time secretary, and two trainers, one for technology and one for science and math. The additional staff provided the ability to intensify the focus on the project's goals in staff development, as well as the opportunity to look closer at the project's progress through formative and summative assessment.

Under the research grant, teachers were expected to receive at least seventy hours of staff development a year. The focus of that training began to evolve almost immediately from technology to a more integrated approach to staff development based on the needs of the teachers and the expanded goals of the project. Three tiers were identified to provide a platform for the evolving staff development needs. Tier I teachers were to receive basic staff development in technology and methodology, as well as a scientist partner. Tier II teachers were to have continued staff development and a partner, but staff development would include inquiry strategies and project learning. Tier III teachers received only fifty hours of instruction with the goal of becoming mentors. Teachers moved up the tiers only when they were ready. It was expected that some teachers would remain at Tier I all three years. While this sounded good on paper, the teachers never fit into these boxes. So, with the exception of scaling down staff development for Tier III schools after their third year, this plan was never implemented.

The project continued to evolve as teachers, staff, and scientists pursued a deeper understanding of teaching and learning. By the fall of 1997, the project had a four-fold focus for staff development. "Partners in Science is a project to link K –12 students and teachers to practicing university, industry, and agency scientists using networked technology, with the aim of increasing the practice of authentic, project-based math and science". The project had evolved from a focus on technology into a broader vision of support for math and science learning and teaching. To accomplish this new vision, staff development during the 1997-1999 included the following strategies:

1. Team-teaching lessons in the classroom with the teachers and scientists
2. Modeling lessons in the classrooms
3. Providing a three-day GLOBE (Global Learning Observations for the Benefit of the Environment)
4. Workshop Sharing resources (books, materials, equipment) to teachers on request

5. Other miscellaneous staff development opportunities on an individual basis

In the fall of 1997, the project experienced another significant change. The School District Curriculum Director contributed Eisenhower funds to support six additional teachers to attend the monthly staff development days. This doubled the number of teachers in attendance at the workdays.

Evaluation during the 1997-1998 school year continued with all the key elements from the implementation grant, and the following elements were added:

- A performance instrument
- A new attitude instrument
- Student, teacher, scientist, and trainer journals
- Teacher-made assessments
- Regular interviews with students, teachers, and scientists by the local evaluator
- Regular observations by the local evaluator.

The project schedule for 1998-1999 was very similar with a few important exceptions:

- The GLOBE course for teachers was moved to August
- The original external evaluator was replaced with a local evaluator
- Partners in Science staff flew to Iditarod schools three times to deliver staff development on site rather than flying the teachers in to Fairbanks
- Staff development was held one day per month and attendance was required.
- Science content courses (chemistry, ecology, physics) were offered to teachers in June

Staff development during the year was determined by a needs assessment given to the teachers in the fall. Teachers selected the following staff development items on which to focus for the year: Science content, Learning Cycle model, GLOBE, Process skills, and Technology.

Project Completion (1999-2000)

The Partners in Science project will continue through the end of the 1999-2000 school year. It is expected that new teachers will be added and goals and strategies will continue to evolve as students, teachers, scientists, and staff, continue to collaborate in an effort to better understand learning and teaching math and science. In order to support that process of understanding, qualitative and quantitative data will continue to be generated until the termination of the project. It is expected that exploring the evolving patterns and themes over a period of several years will contribute additional understanding about the project. During this final year we will be seeking strategies that will support the sustainability of the philosophy of the project in Fairbanks after the NSF funding ends.

Evaluation

The project's evaluation (thus far) is based upon quantitative and qualitative data gathered during the 1997-1998 and 1998-1999 school years (a third year 1999-2000 will be incorporated following the end of the 1999-2000 school year). Qualitative and quantitative data are being used because they proved complementary in supporting and extending our understanding of the complex teaching/learning process that is occurring in the Partners in Science classrooms. The principal questions addressed by this research are:

- How does the Partners in Science program support students, in project classrooms, to learn and apply science inquiry skills and key content concepts?
- What can count as evidence of student learning of these science inquiry skills and key content concepts?

The data taken as a whole suggests that the presence of the Partners in Science partner scientists, staff development, and technology provided by the project may have supported and extended learning in the project classroom by providing on-going support and introducing new content and methodologies that would not have otherwise been there. There was, however, considerable variation across the project classrooms as each partnership and classroom evolved uniquely while teachers, partner scientists and students constructed new ideas about science, teaching, and learning. This variation, itself, was an important factor in supporting and extending understanding of the Project, but made any sort of generalization inappropriate.

It was also hoped that the assessments would inform the project about the second focus question, what could count as evidence of learning in Project classrooms. For this purpose, teachers and staff conducted and collected a variety of assessments. The analysis of the data generated seemed to support the literature about the value of collecting assessment data through a variety of methods in order to provide all children with the opportunity of showing what they knew and could do (Gardner, 1993). Because teachers were encouraged to try a number of diagnostic, formative, and summative assessment methods, the study benefited from their successes and failures, as well as the triangulation across a variety of sources.

Assessment methods other than the Attitude Assessment seemed fairly consistent in helping inform the project about what and how the students were learning. It is important to note, however, that no method was universally effective for all students. Each assessment method worked in certain situations and with certain students, but not in others. It will be important for Partners teachers to consider this when designing their assessment plans in the future.

The process of data generation (assessment), itself, shaped and informed the project. Teachers gathered more formative assessment than they had previously in an effort to support the study. They also journaled regularly for the first time, reflecting on how they and their students were doing during the change process.

Qualitative Data

Qualitative data collection supported and extended the understandings that emerged during the study. In particular, it appeared that the variety of assessment methods and contexts across the project proved especially beneficial for understanding what students were learning in the complex and evolving classroom environments. Several methods proved especially valuable formatively and summatively across all participants and context, in particular interviews, journal entries, and teacher-designed assessments.

All interviews for this report were semi-structured in nature. The data generated from the interviews supported the large body of research suggesting that semi-structured interviews were valuable for developing an understanding of the interviewee's perspective. Interviews apparently provided an important opportunity to understand the thinking of students who could not or did not express their understandings fully in writing. In a number of cases, indications of concept development appeared in interviews and nowhere else. The exception to this was the middle school interviews, which will be discussed thoroughly in a following section. There was no obvious evidence of reflexivity (saying what interviewer wanted to hear). In fact, the honesty of participants during the interview process was influential in the evolution of the project.

Journal entries appeared to be equally valuable and outspoken. They were especially informative for children and adults who were comfortable expressing their ideas in written form. In several significant cases, however, student journal entries indicated little concept development while other non-written sources of data contradicted this by showing good concept development.

Teacher-designed assessments were the final important category of evidence of learning to emerge from the data. Like the semi-structured interviews, they had the flexibility to be able to focus on the big ideas, as well as unique understandings, in each unit.

Quantitative Data

Though the qualitative data generation and analysis processes provided the majority of important understandings, the quantitative data were important, because they provided an additional perspective and triangulation for the qualitative data. They also raised unanswered questions that will continue to be addressed through both qualitative and quantitative methods, particularly about the Attitude Assessment.

Performance Assessment

The data suggested that there were significant gains for the Partners in Science classrooms compared to the control classrooms. In addition to showing significant gains, the Performance Assessment provided considerable support to the qualitative data on how the project supported student learning of science process skills. It also supported the qualitative data in suggesting that there may be a relationship between the amount and quality of time partner scientists spent in their classrooms using process skills with students may have made a difference in how deeply students were able to understand and apply science process skills.

Summary:

As the project begins its final year, research data (1997-1999) gathered from teachers, students, and scientists indicates that the project is being successful in each of the three targeted areas: Improving the student's understanding of science by designing and conducting their own research; Effectively utilizing technology as a part of the learning and teaching of science and mathematics; Bringing active scientists into the teaching and learning process, both in and out of the classroom. Additional information including sample CD's, and brochures can be obtained from the Partners in Science web page (http://www.northstar.k12.ak.us/nsfpis/vsm.html). Details of the local evaluator's report can be found in the Partners in Science Quarterly Report to NSF (Stayrook 2000) and in Gordon (Gordon 2000).

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Some Psychological Aspects of Using Information Technologies in Teaching Linear Algebra

Mikhail M. Bouniaev
Math/Cs Department
Southern Utah University
United States
bouniaev@suu.edu

Abstract: Despite the indisputable advantages of using information technologies in teaching mathematics in general and linear algebra in particular certain problems related to technology-oriented education have become quite evident now. The presentation reviews and analyses efficiency and expediency of using information technologies at different stages of teaching linear algebra. Our research is based on the results of the experiment conducted during the last five years in teaching linear algebra with MATLAB and modern calculators. This paper is a follow up of an earlier article "Linear Algebra With MATLAB Package In Preservice Teacher Education" (Bouniaev, 1997).

Introduction. Basics of DMA Theory

Our analysis of using information technologies in teaching linear algebra is based on the theory of stage-by-stage development of mental actions (DMA theory) developed by the Russian school of psychology (Galperin 1960, Leontyev 1975, Talizina 1975) as applied by the author in teaching mathematics (Bouniaev 1991, Bouniaev 1996, Bouniaev &Connell 1996). Without going into a detailed description of this theory we will outline some of its basic concepts that are essential for this paper. We also assume that in a linear algebra course an instructor can use various technologies at different stages of instruction, such as modern calculators and software packages like MATLAB or Derive. So we are not going to specify what software or a calculator should be used in the course of instruction . In most cases this problem of choice may be solved by different means and depends on their availability. According to the DMA theory the major goal of instruction is developing mental actions with objects of the studied field. Finding a solution of a system of linear equations, proving that systems of vectors is linear independent (dependent), reducing matrices to the reduced row echelon form, finding eigenvalues or eigenvectors are examples of the actions to be developed in a college linear algebra course.

Instruction is viewed as organizing and controlling students' activities and hence organizing and controlling the process of development. Thus, instruction efficiency is determined to a great extent by a well developed system of control and management.

Analysis of component operations of any action shows that they perform different functions. A part of performing an action is taken up by some preliminary work, a preparation for an action in a certain sense. This preparatory part is called *orientation part of an action*. The performance itself is called *executive part* of an action. Analysis of an action and experiments carried out in this respect show that there also exists a *control part* which takes place after the executive part, when an individual compares the results achieved in the executive part of an action with the goals of an action and the draft plan of the execution planned in the orientation part.

As a rule, the performed actions consist of other, more primitive actions and in their turn can be part of other actions. Actions that are part of a given whole, are called operations. That is, operations are also actions; hence the term emphasizes only a hierarchical subordination among actions. The DMA theory specifies four independent characteristics of any action used to determine the level of development of an action. The first characteristic is a *form of action.* An action can be in a materialized (material), speech or mental form. The materialized form of action is connected with manual activities (manipulation, hand-on

activities, etc.); objects of action (or their models) are presented in a material form; results of action should be real transformations of these objects or of their models. For example, entering an equation into a graphic calculator could be considered as an action in materialized form.

There is no need to discuss the speech form of an action. It should be noted that according to the DMA, writing belongs to the same form, i.e. the speech form. If we consider an example of solving a system of linear equation then the speech form will mean *articulation* of the performed actions. There is no need for these objects to be present in the material form. For example, in the process of instruction a student may be asked to comment on all the operations of entering an equation into the calculator. The action can be an answer in the form of oral speech or a note in a workbook.

The mental form of action is the highest form of action development. An action in this form is imperceptible for one's associates and its results are recorded in an imperceptible for others form also. This form of action means that its objects are representations, notions and concepts. All operations are performed to oneself. The ability to perform a whole action in the mental form indicates that it has gone through all the stages of development and interiorization.

Structure of the actions to be developed in a linear algebra course

The primary goal of the first linear algebra course is introduction of basic concepts of the subject such as systems of linear equations and their solutions, the concept of a matrix, linear space and linear operator. Activities-oriented learning theories claim that development of concepts takes place through development of actions aimed at the objects that fall under these concepts as well as at the objects that fall under the concepts immediately connected with the developed one.

All actions can be referred to two categories: general logic actions and specific actions. The characteristic general logic action for a linear algebra course is that of recognition. For example recognize if a matrix in the reduced row echelon form is an augmented matrix of the inconsistent system of linear equations. Another example of a general logic action is an action of classification, for of matrices into subclasses of singular and nonsingular matrices. We will demonstrate that developing general actions is crucial in the course of linear algebra study.

Specific actions are basically inherent to a given subject field. For example, in linear algebra they are: reducing a matrix to the reduced row echelon form, matrix multiplication, finding determinant of a given matrix, etc. We will show that in developing basic concepts of linear algebra most specific actions can be performed with the help of technologies.

Let us consider the structural composition of some actions aimed at developing the basic concepts of a linear algebra course. Naturally, if we consider the development of the systems of linear equations concept, then the basic action to be developed is that of finding a solution of systems of linear equations. This action is not homogeneous, it consists of a sequence of certain operations.

Example1 Action of solving a system of linear equations.

- Operation 1. Recognizing the system as a linear system (general logic action).
- Operation 2. Recognizing variables, coefficients, constant terms (general logic action).
- Operation 3. Rewriting the system in the standard form (specific action).
- Operation 4. Finding a method of solution (general logic action).
- Operation 5. Creating a matrix **A** – augmented matrix of the system (specific action).
- Operation 6. Reducing matrix **A** to the reduced row echelon form (specific action).
- Operation 7. Making a conclusion based on the form of rref**A** (general logic action).
- Operation 8. Determining the method of solution that depends on the results of performing operation.
- Operation 9. Solving the system given in the reduced row echelon form.

In developing the concept of vector space an important role belongs to developing such actions as recognizing linear independent (dependent) system of vectors; determining whether this particular vector is a linear combination of vectors of the given system and recognizing the basis of a vector space. Let us consider the operational composition of these actions.

Example2 Action of recognition of linear independent (dependent) system of vectors.

Assume we have a system of vectors $\mathbf{a_1}=(a_{11}, \dots, a_{1m}),\dots, \mathbf{a_n}=(a_{n1}, \dots, a_{nm})$ in m-dimensial eucledian vector space $\mathbf{R}^m$. The problem is to determine whether this system is linear independent or dependent.

- Operation 1. Designing a master plan for solution (general logic action).
- Operation 2. Creating the system of linear equations $x_1\mathbf{a_1}^T+\dots+x_n\mathbf{a_n}^T = 0$ (specific action)
- Operation 3. Creating the matrix $\mathbf{A} = [\mathbf{a_1}^T \dots \mathbf{a_n}^T\ \mathbf{0}]$ (specific action).
- Operation 4. Reducing the matrix **A** to the reduced row echelon form (specific action).
- Operation 5. Making a conclusion based on the form of rref**A** (general logic action).

Example3 Action of representing a vector as a linear combination of the system of vectors.

Assume we have a system of vectors $\mathbf{a_1}=(a_{11}, \dots, a_{1m}),\dots, \mathbf{a_n}=(a_{n1}, \dots, a_{nm})$ and the vector $\mathbf{b}=(b_1, \dots, b_m)$ in m-dimensial eucledian vector space $\mathbf{R}^m$. The problem is to determine whether the vector **b** is a linear combination of vectors $\mathbf{a_i}$, i=1…n.

- Operation 1. Designing a master plan for solution (general logic action).
- Operation 2. Creating the system of linear equations $x_1\mathbf{a_1}^T+\dots+x_n\mathbf{a_n}^T = \mathbf{b}$ (specific action)
- Operation 3. Creating the matrix $\mathbf{A} = [\mathbf{a_1}^T \dots \mathbf{a_n}^T\ \mathbf{b}^T]$ (specific action).
- Operation 4. Reducing the matrix **A** to the reduced row echelon form (specific action).
- Operation 5. Making a conclusion based on the form of rref**A** (general logic action).

Example 4 Action of basis recognition.

Assume we have a system of vectors $\mathbf{a_1}=(a_{11}, \dots, a_{1m}),\dots, \mathbf{a_n}=(a_{n1}, \dots, a_{nm})$ in m-dimensional eucledian vector space $\mathbf{R}^m$. The problem is to determine whether this system is a basis for $\mathbf{R}^m$ or not.

- Operation 1. Designing a master plan for solution (general logic action).
- Operation 2-5 as in example 2.

Then we have to check whether any vector in $\mathbf{R}^m$ is a linear combination of vectors $\mathbf{a_1},\dots, \mathbf{a_n}$. It may be done in different ways. Usually we choose the method that assumes the use of technologies, but not symbolic computation systems. So the idea is to check whether the vectors of standard basis $\mathbf{e_1},\dots, \mathbf{e_n}$ are linear combinations of vectors $\mathbf{a_1},\dots, \mathbf{a_n}$. This problem can be substituted by the problem of determining whether n systems of linear equations are consistent or not. Fortunately all these systems have the same matrices of coefficients, so it makes sense to determine their consistency simultaneously.

- Operation 6. Creating the matrix $\mathbf{A} = [\mathbf{a_1}^T \dots \mathbf{a_n}^T \mathbf{e_1}^T \dots \mathbf{e_n}^T]$ (specific action).
- Operation 7. Reducing the matrix **A** to the reduced row echelon form (specific action).
- Operation 8. Making a conclusion based on the form of rref**A** (general logic action).

From the point of view of our analysis it is instructive to compare the operational composition of the action of the previous example with the action of finding a matrix that is inverse to the given one.

Example 5 Action of finding matrix inverse .

Assume we have matrix $\mathbf{A}== [\mathbf{a_1}^T \dots \mathbf{a_n}^T]$. The problem is to find its inverse.

- Operation 1. Designing a master plan for solution (general logic action).
- Operation 2. Creating the matrix $\mathbf{A} = [\mathbf{a_1}^T \dots \mathbf{a_n}^T \mathbf{e_1}^T \dots \mathbf{e_n}^T]$ (specific action).
- Operation 3. Reducing the matrix **A** to the reduced row echelon form (specific action).
- Operation 8. Making a conclusion based on the form of rref**A** (general logic action).

Developing Actions In A Linear Algebra Course

Comparison of the operational composition of actions of the above examples shows that actually the only "transformational" operation in all of these actions is that of reduction of the matrix to the reduced row echelon form. Analyzing the actions to be developed in a linear algebra course one may come to the conclusion that the majority of actions to be mastered by students in this course can be presented as a sequence of three absolutely identical operations. The first operation is construction of a certain matrix, second – reducing this matrix to the reduced row echelon form, the third is interpretation of results, i.e. comparison of the original matrix with the one in the reduced row echelon form.

It is easy to see that the above problems require practically identical treatment not due to the limited number of concepts we operate with in linear algebra but because these operations form only the executive part

of action. The executive part of action in many linear algebra problems comes down to construction of a matrix and its reduction to the reduced row echelon form.

In real life situation (not in class) that require performing any of the above described actions it would be natural to perform explicitly only the executive part of the action. An engineer or a mathematician would enter the matrix into the computer or the calculator and then push the button controlling "rref" command irrespective of the fact whether one is looking for the solution of the system of linear equations or proving that system of vectors is linearly independent. The situation is completely different in class since all students actions are not aimed necessarily at getting the right answer for the given problem but more at acquiring skills to solve problems of this category.

In the course of the experiment while studying the linear independence and the concept of basis in the experimental group we allowed the students to start the solution of problems right from the executive part of the action. Thus, for example, in developing the action of recognizing the linear independent system (example2) students were not required to start with the system of linear equations but with operations 2 –3 (entering the matrix in a computer or a calculator and finding its reduced row echelon form). In the control group the students were required to start with the system of linear equations and write down an explanation how this system is related to the problem in question. Thus the experimental group in the course of study was able to solve almost twice as many problems as the control group but 60% of the students experienced considerable difficulities substantiating their actions, and they also provided substantiation that could be related to a different class of problems. They could not extend the same idea to a similar class of problems.

While determining the fact that given vectors generate the entire space (example 4) the students of the experimental group were allowed to perform all operations (except 6 and 7) mentally. The students in the control group were required to write down all operations with detailed substitution. The day before we discussed these topics we found an excuse to remind the students how to find an inverse matrix, i.e. actually reviewed the operational composition of the action of example 5.

Proceeding from the assumption that the executive operations of example 4 (operations 6 and 7) and example 5 (operations 2 and 3) are absolutely identical the students from the experimental group came to the independent conclusion that actions of examples 4 and 5 are based on the same idea (which is a misconception). All the attempts to provoke students in the control group to come to the same conclusion failed. The control group students were fully aware of the fact that despite the superficial similarity of the execution parts of these actions their orientation parts are absolutely different and thus these actions cannot be similar.

According to the DMA theory, besides the form any action has another three independent characteristics:

- *degree of generalization;*
- *degree of completeness;*
- *degree of assimilation.*

Generalization of an action means the ability to determine and discriminate essential for performing an action properties as well as the ability to apply them to objects of different nature . For example, if the action of solving systems of equations is developed at a high enough level of generalization the student does not find it difficult to progress from solving the system of three equations with three unknowns to solving any system. It also does not matter how the unknowns are designated. The degree of completeness indicates whether all the operations that were to be performed in the process of performing an action have been actually completed. If the action is already developed, then the subject of the action (the student who performs it) practically does not discriminate operations from each other, i.e. the action takes place in the compressed form. If we assume that the previous learning was successful, then failure to perform an action (without any time limits) often indicates that a student can not present the action in operation-by-operation form when all the operations are present and are clearly identifiable. This indicates that performance of the action is not completed. The ability of the student to perform an action in the operation-by-operation mode giving justification for their performance shows that the action was developed at the sufficient degree of completeness.

Going back to discussing different approaches to organizing the learning process in the experimental and control groups we can come to the conclusion that in the experimental group the development of actions did not reach the required level of completeness which in its turn affected negatively the degree of generalization of the developed action. On the other hand, the degree of assimilation was higher in the

experimental group.

In the experimental group we had to spend additional time to develop the actions at the required level of generalization. For this purpose we created a class of exercises that we called inverse problems. The students were given only the executive part of the action of the problem to be solved. The task was to restore the full operational composition of the action.

This experiment as well as other experiments conducted in the course of teaching linear algebra with information technologies demonstrated that each part of the action should be singled out and developed separately. In the process of instruction the executive part of an action should be performed by a computer or a calculator.

The executive part usually is a specific action for the subject. The orientation part as a rule is a general logic action aimed at the objects of the studied field. The orientation part of an action includes intermediate goals, reducing a problem to the already familiar ones, selection of definitions and theorems related to the performed actions.Thus in the above examples the problem is reduced to determining the consistency of the sysem of linear equations. The expediency of this problem substitution is determined by the corresponding definitions and theorems.

In developing any new action in the course of linear algebra its orientation part should go through all the forms of development starting at least with written speech. For the above discussed examples 2-4 it means that at the initial stage of development a plan of action should be written down as well as all necessary theorems and definitions on which this plan is based. The system of linear equations should be presented in a written form. Only after completing all these actions a student can use a computer or a calculator to perform the corresponding operations. Thus major problems in teaching linear algebra arise not in developing specific actions of the course but in developing general logic actions aimed at the objects of the studied field.

The DMA theory presupposes *five stages in organization of instruction*. At the first stage the instructor presents new material. Taking into account a relatively abstract nature of the linear algebra course it is expedient in presenting a new material to illustrate it with practical problems and to create computer models of these problems. Thus in teaching the theme Least Squares Solutions it is worth starting with the discussion of linear regression and demonstration of vivid programs modeling linear regression. In teaching the projections it is hard to overestimate the value of visually enhanced programs illustrating the geometry of the performed actions. At the second stage the actions are developed in the materialized form. At this stage of instruction it is expedient to organize the work with blocks of texts and illustrations and move these blocks to different parts of the screen.

The third stage is development of actions in the external speech form. At this stage it is important for students to articulate their thoughts out loud and write down necessary comments. As experience showed at this stage traditional pencil and paper are hard to substitute. Group work is also very useful. Computers can be used for conducting different experiments requiring discussions with other students. And only the fourth and the fifth stages are developing actions in the form of internal speech and mental form.

In developing every new action the executive part can be delegated to a computer. Thus for example in developing an action of reducing matrix to the reduced row echelon form it is expedient to use programs like MATLAB m-file "RREF", providing executions of elementary row operations at students instructions. At further stages of instruction it is expedient to delegate this action fully to a computer or calculator. In finding eigenvectors and eigenvalues computers can solve the systems of linear equations and characteristic equations. At the same time development of the orientation part of this action should go through all the stages and forms.

Conclusion

In the course of study of linear algebra it is expedient to carry out the structural analysis of every new action to be developed. It is preferable to present the orientation part with all the necessary operations to be performed and to develop it going through all the stages starting with the material form of an action. The executive part of an operation can be given over to computers or calculators. At further stages the orientation part can become an operation of the executive part of an action and be performed by a computer. It is worth pointing out that in developing the orientation part of an action the use of computers can be highly efficient in creating visual models and a bank of basic concepts, definitions and theorems.

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Visual Venture: Investigations with Images and Video

Lisa M. Brown and Susan Crayne
IBM T. J. Watson Research Center
Hawthorne, NY 10532
Lisabr@us.ibm.com, crayne@us.ibm.com

Abstract: In this paper, we describe an educational software tool, which allows students to take measurements on images and videos. Students become scientists as they measure, collect and analyze data from a wide range of imagery. We will describe two major emphases of this work.

First of all, as a corollary to scientific image processing software, this program was fundamentally designed as a general, open-ended tool for investigation. Students have the opportunity to learn the scientific process first hand. We discuss the relationship of this software to scientific tools, the potential for true inquiry-based learning, and the associated issues and problems that occurred in bringing this to the classroom.

Our second emphasis in this work was to create a tool, which could be used for curriculum development and interdisciplinary learning. The software exploits the recent availability to students and teachers of an extraordinary plethora of scientific images and videos. This allows content to correspond closely to a specific curriculum, to pertinent events and to student and teacher interest. We detail several ways that curriculum specialists and teachers can take advantage of the wealth of imagery that is currently accessible. Lastly, we briefly describe the evolution of the software and the feedback we have received from students, teachers, and curriculum/technology specialists.

Introduction

In this paper, we describe an educational software tool, called Visual Venture, which allows students to take measurements on images and videos. This software was developed by IBM in conjunction with several public school districts as part of IBM's Reinventing Education Initiative. We will briefly describe the history of this project and discuss its capabilities and objectives. Throughout the project, there have been two primary emphases:

1. create a general open-ended tool for scientific investigation in the classroom,
2. create a tool for curriculum development and situated learning.

To achieve our objectives, we have studied other projects and received feedback from students, teachers, and curriculum/technology specialists. In particular, we have brought students into our usability lab and received feedback from teachers at our grant sites and from a panel organized by the Center for Children and Technology in New York City. We also performed a small field test in our local middle school and participated in an internal three day family science event. In the last two sections of this paper, we would like to discuss each of the major emphases of this project including the challenges we faced in bringing this software and its paradigm into the classroom.

History

IBM has been committed to bringing technology to the classroom. Lou Gerstner, IBM's chief executive, has long maintained that while the commercial world is rapidly embracing technology and reaping the benefits, changes in the classroom are lagging far behind (Gerstner, 1994). To help stimulate technological advances in education, IBM funded a range of projects, initiated by selected school districts, called Reinventing Education (Reinventing Education 1999). One of these projects began in Dallas, Texas. The Dallas Public School System was interested in building an integrated math science curriculum for grades 4-8

and proposed to IBM, a joint effort in which IBM would supply technological innovation. IBM's role was to design software to assist teachers in implementing an evolving integrated curriculum based on the latest standards and pedagogic reform. With this objective, Visual Venture was created.

An integrated math science curriculum brings mathematics to real world scientific problems and greater depth and understanding to science. For middle school students, such a curriculum usually begins with an understanding of the scientific method and progresses to hands-on experiences with data collection and analysis. For each subject such as earth science, biological science or physical science, the particular scenarios change. A fundamental theme throughout middle school science, and particularly with the application of mathematics to science, involves data gathering, including understanding measurements and units, and data analyzing and plotting. However, in attempting to implement an integrated math/science curriculum in Dallas, several problems arose.

The first problem was that mathematics was being shortchanged. Many hands-on activities were added to keep kids motivated and learning first hand. But the consequence was that the mathematical principles were introduced only obliquely and not thoroughly taught. The second problem was that in collecting measurements and building tables and plots, students and teachers could easily make mistakes along the way. It was difficult to oversee a laboratory experiment and understand the results in the short time allotted for a typical class. Lastly, each activity and use of a related software package was different. For each new project, students and teachers needed to learn another software program, another piece of equipment, a new modeling method. To design an integrated math science curriculum, schools would need to purchase an extensive set of software and equipment. There was a need for a few common threads to leverage what was learned in previous projects and to elevate the sophistication of the work.

With these problems in mind, Visual Venture was designed to be a "hands-on," general purpose, open-ended software tool. Curriculum designers in Dallas clearly wanted to let kids do things for themselves, to help kids to be involved and to explore first hand. This has been an emphasis in new science and math standards across the nation. But, it also needed to include an in-depth exploration of a wide range of mathematical concepts. By integrating measurement functionality with tabulating and plotting tools, Visual Venture allows students to analyze, predict and model based on measurements they have just taken. A wide range of mathematical concepts can be introduced and thoroughly explored. The two primary mathematical subjects broadly supported are (1) understanding models and relationships through plots and graphs and (2) understanding spatial and geometric measurements. The breadth of mathematics that can be contextually taught using Visual Venture is described in more detail in (Wahl 1999).

The second issue that Visual Venture addressed was the need to assist teachers in providing a thoughtful scientific investigation, from beginning to end, in their classrooms with limited time and resources. How can we help the teacher with all the realistic problems in running an experiment? How do we limit the frustrations along the way, of forgetting to take a measurement, not taking the right measurement, not writing it down correctly, forgetting what it was a measurement of? Visual Venture provides students with the ability to take measurements, explore relationships and predict models. During the same experiment, students can re-take measurements, re-play measurements to see if the correct measurements were taken, easily determine which points in a plot refer to which measurements and quickly test out several hypotheses.

The last issue, which Visual Venture addresses, is to provide a teacher with a software tool that can be used over and over again for different investigations. Since Visual Venture is a general scientific tool, it does require teachers and students to learn how to use it effectively. Teachers and students learn to use a tool which is similar to software used by scientists today. Although it is clear, this can take some time and thought, the advantage is that students are learning to use technology as it is done in practice. On the other hand, it can be used simply at first and in progressively more challenging instances. Most importantly, it can be used in a broad range of scientific applications and it can often come to bear on a question that arises naturally in learning science and geometry.

The first version of Visual Venture was designed with the help of math and science teachers at the Dallas Public School System in Dallas, Texas. This version was then refined and improved for use in the Atlanta, Georgia and Rochester, Minnesota public schools. This was a second phase of the partnership grants from IBM, called Reinventing Education II. In Atlanta, Visual Venture was used to improve the math/science curriculum in grades 3-8 and to support teacher professional development activities. In Rochester, Visual Venture was added to the curriculum in grades 6-8. In the latter project, the district was already familiar with image processing in education, and had worked with the Mayo Clinic and its depository of medical images. Visual Venture allowed the district to extend its introduction of image processing.

Visual Venture

Visual Venture is a prototype of a software tool that lets students take measurements on videos and images. It was designed to be similar to tools used by scientist today, but to be more easily used by middle school students. Its functionality focuses on simple scientific investigation rather than on sophisticated image enhancement and analysis. It also provides more feedback for learning and ease of use by middle school students in a class environment rather than complex manipulations.

Visual Venture can be used with images and videos from several types of sources. Images from textbooks or reference materials can be scanned, images taken by analog cameras can be reproduced digitally, or digital cameras can be used. More and more, images can be found on the World Wide Web. Similarly, analog videos can be digitized using digitization hardware, digital videos can be captured, or videos can be found on the Internet. Projects in Visual Venture can be comprised of a single image, a stack of images or a video.

Visual Venture allows students to measure geometric properties or color-coded information that is portrayed in an image or video frame. Students can measure the length, perimeter or area of an object, or any distance, angle or position. Images and videos can be initialized so that measurements are scaled appropriately. For instance, students can measure the height of a dinosaur in terms of the height of a man, the perimeter of a triangle in inches, the area of a glacier in square miles, the interior angle of a hexagonal honey comb in degrees, or the dynamic position in local coordinates of the eye of a hurricane as it travels across the country.

Images can be flipped, rotated or magnified in order to make measurement easier. In addition, special tools exist to let users take measurements of color-coded maps, of videos involving motion over time, or of complex geometric regions. These tools were selected to broaden the applicability of Visual Venture to a wider range of imagery that could be used in the classroom. For example, students can measure the urban growth of a city shown in a color-coded map, the trajectory of a ball as it falls, or compare the area of each of the continents.

As measurements are taken, students can drag and drop them onto a spreadsheet, perform calculations, and create line or scatter plots, pie or bar charts. Measurements in the spreadsheet can be automatically redrawn. The student selects the measurement on the spreadsheet and depending on the type of measurement, it is shown on the image. For example, if the measurement was the height of a person in the image, taken by drawing from the foot to the tip of the head, redrawing will mark this height on the image in the same way it was originally measured. Similarly, if a plot is created of the height of three objects in the image, the user can click on a point in the plot representing the height of one of the objects. This will highlight the corresponding measurement in the table and the height of the associated object in the image.

Visual Venture has also been designed to link projects to information on the Internet, to allow curriculum specialists, teachers or students to create and share new projects, and to let students create reports with their results.

A Scientific Tool for Students

The majority of software designed for educational purposes can be categorized as one of four types: Drill and Practice, Information and Reference, Simulations and Games, or Investigative Tools. Although each type can be used to enhance education, the latter category of Investigative Tools has a unique role to play in education. A wide range of software and resources already exist and are being used in the first three categories. These types of software are usually straightforward to use and apply. They each play a similar role to activities that have always taken place in the classroom. However, their use is often limited to specific content or to passive perusal. The ability to incorporate investigative tools into the classroom offers a unique opportunity for technology to radically improve pedagogy; in the same way, software tools have played a large part in the technological revolution at the end of this century.

Several researchers in education have shown the merits of investigative software. A class of software referred to in the literature as microcomputer-based laboratory or MBL has been shown to be an effective aid

in teaching science (Nakleh 1994). Researchers have shown that through data logging with computers, a student's ability to perform various types of mathematical abstractions can be improved (Friedler 1997). Others have studied the benefits of active inquiry-based learning (Hoffer 1992). The latest changes to the National Science Education Standards emphasize "Science as Inquiry." The standards that teachers need to address have changed from "knowing scientific facts and information" to "understanding scientific concepts and developing abilities of inquiry" (NSES 1999).

Spurred by this emphasis in inquiry-based learning, a movement has begun to bring image and video processing to education. In 1989, researchers at the University of Arizona in Tuscon began a project called Image Processing for Teaching or IPT (Greenberg 1998). Using software designed originally for scientists, this project introduced image processing to education through teacher education, the design of curriculum materials and strong follow-up support. We believe this undertaking will help bring technology into the classroom. Although evidence for inquiry-based learning is strong and pervasive, our experience has shown that teachers and parents are often uncomfortable in the implementation. True inquiry-based learning using sophisticated technological tools will not widely occur in this country unless it is a required part of pre-service education of science teachers. At this juncture, teacher education through workshops, supporting materials, and follow-up are needed.

The software used by the IPT project was originally designed at the National Institute of Health for biomedical research. It is a complex tool with an extensive range of functionality designed for scientists. It requires some training even for a professional in the field. By using a simpler tool designed specifically for students, it is possible to more easily introduce image and video processing to education. Other projects have begun which introduce motion analysis through video processing (Gross 1998, Escalada 1996, Learning in Motion 1999, Rubin 1996, VideoPoint 1999). These projects/products involve tracking moving objects over time in order to study physical phenomena such as gravity or the Coriolis Effect. (Escalada 1996, Gross 1998, VideoPoint 1999) are each happening at the undergraduate level and involve teaching physics and motion analysis. These product and projects are exciting ways to bring inquiry-based learning into the classroom via technological tools. They differ from Visual Venture in being primarily designed for motion studies and for older students.

Bringing the Technological Revolution to Children

Our second objective in building Visual Venture, was to create a tool for curriculum development and contextual learning. We wanted to take advantage of the enormous range of content available through the world wide web and to allow students, teachers, and curriculum specialists to design materials pertinent to the classroom.

Below is a list of 20 images or videos and a description of the type of investigation that could be used in Visual Venture. This list give the reader an idea of the various types of imagery that can be used and the wide range of subject area that can be covered. By using imagery taken by the classroom or found on the Internet to enhance areas of current discourse, the software can be used to create contextual learning. Contextual learning has been well-documented as an effective means of improving pedagogy (Brown 1989). By engaging students in activities that are real, are relevant to their lives, and are meaningfully related to events that are occurring around them, they become motivated and more likely to retain what they have learned.

1. Video of Satellite Imagery of a real hurricane – students measure the path of the eye of a hurricane and predict where it is going and how far away it is from where they live.
2. Video of the sky over the course of a night – Students learn how to use the stars to navigate. Why did the fleeing slaves on the underground railroad follow the "drinking gourd?"
3. Series of pictures of the nine planets and some of the moons in the solar system– students compare the sizes of the planets. Are some of the moons larger than some of the planets? Also, pictures showing the relative distance of the planets from the sun. Are the planet sizes related to their distance from the sun?
4. Video of night sky at the same time each night over a month, showing the position of a comet relative to the other stars – predict where the comet is going with respect to the stars and whether you'll be able to see it in your backyard on a particular night.
5. Video of the sea surface temperature of the Pacific Ocean – map color-coded with temperature. Students

learn about the effects of El Nino on the temperature of the ocean. When are hurricanes most likely to occur?

6. Video of a glacier over the course of a year. Students measure how the glacier grows and melts during one year.
7. Video depicting urban growth around a major city over the last two hundred years. Students measure the urban growth, visually see the exponential explosion, and predict future growth and its impact on the region.
8. Color-coded map indicating the different regions of the U.S. based on predicted level of earthquake damage. Students are given the role of Secretary of the Interior, and asked how much money should be allotted for each region of the U.S.
9. Map of the world with the continents shown. Students compare the size of the continents by actually measuring the area of each continent. Is Antarctica bigger than Australia? How much more water than land is there in the world?
10. Drawings of various dinosaurs and a man, scaled appropriately. Students decide how far each dinosaur would stretch if it were put in their school hall.
11. Heart electrocardiograms (EKGs) for different patients. Students act like emergency room physicians and decide which patient has the most irregular heart rate.
12. Real photograph of a nautilus shell with all the chambers shown. Students measure and predict how a nautilus shell grows. Will the next chamber be big enough to fit their fist?
13. Series of pictures of a human as they grow from birth to adulthood. Students measure how people grow. How old is a child when his legs become as long as the rest of his body? How does this compare with the age that children normally learn to walk?
14. High-speed videos of a horse running on a treadmill. Students measure how the back leg distance compares with the front leg distance over time. When a horse has its front legs together, what are its back legs doing?
15. Aerial photographs of baseball stadiums. Students determine in which stadium it is easier to hit a home run. Which stadium is the hardest to defend, i.e., has the largest outfield?
16. Videos of an Olympic diver as seen from the side with the camera position fixed. Students measure and compare how high each diver jumped off the board and at what angle their legs hit the water.
17. Real photograph of a target board with each score region colored differently. If you are equally likely to hit any part of the target, what is the probability that you hit the blue part? Given the scores for each region, where is it best to aim?
18. High-speed video of a kid tossing a ball or dropping it. Students study the motion of a falling object and estimate how long it will take to hit the ground if it was dropped from the Empire State Building.
19. Real photograph taken by a security camera at a downtown grocery store. Suspected criminals and their shadows are in the image plane (i.e., to scale). Students become detectives and try to determine if someone that sits next to them at school could have been the at the scene of the crime.
20. Drawings of optical illusions. Students predict and then measure the length of various bars. Then they see examples of similar optical illusions used in architecture.

Conclusions

While a technological revolution is transforming the way we work and live, it is only beginning to impact the way we educate. There is strong evidence to suggest that investigative software can be effective to teach students how to solve problems and model scientific phenomena. It has also been shown to improve the level of mathematical comprehension and sophistication. At the same time, students learn valuable skills in the use of scientific technology. In this paper we have described a new software tool, designed specifically for students, which can be used to help realize these goals. This software provides students with the opportunity for first hand exploration of a broad range of curricula. Students can visually explore scientific phenomena while they measure, tabulate and analyze.

However, unlike software that can be used to drill or teach new information through text, pictures, videos or simulations, investigative software requires additional training for students and teachers. To reap the benefits of technology, we need to improve the technological proficiency of our teachers. The first step of building tools that support scientific investigation, in the same manner as scientific research tools, is

underway. To use these tools to exploit their pedagogical potential, we need to train teachers to use them. Our experience with teachers has led us to believe they are often uncomfortable without step-by-step guidance. Incorporating more guidance into investigative software either through lesson plans or teacher assistance appears to be necessary. The creation of a web-based site for sharing lessons and implementation suggestions would be useful. Lastly, a body of successful lessons, which could be shared among teachers, is needed to bring the use of this type of software to more classrooms. Optimally, lessons should be designed with the assistance of scientists in related disciplines in order to incorporate authentic imagery and scientific phenomena.

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Teachers Implementing GIS in 5th-12th Grade Classrooms: An Investigation of the Necessary Staff Development Experiences and Support

Alan Buss
Elementary/Early Childhood Education
University of Wyoming
United States of America
abuss@uwyo.edu

Patricia McClurg
Natural Science Program
University of Wyoming
United States of America
patmc@uwyo.edu

Abstract: This paper reports the results of a two year study investigating the types of experiences and support necessary for in-service teachers to effectively integrate Geographic Information Systems (GIS) in their teaching/learning environments. Questions guiding the investigation included 1) can GIS be a useful tool in the classroom and 2) will teachers' participation in an extensive in-service affect their level of confidence in their ability to use GIS and/or their attitudes toward GIS as an effective tool in the classroom. Assessment measures included (1) contrasting the level and type of teacher use based on classroom observations, interviews, participation in web-based discussions, and lesson plan analyses; and, (2) teacher self-ratings on a 14-item Likert confidence and attitude instrument. The large majority of participants did plan and implement GIS lessons in meaningful contexts. Statistically significant gains were detected ($p<.001$) for each of the fourteen items on the teacher survey.

Introduction

The development of national and state standards which call for more relevancy and examples of real world applications as well as more emphasis on problem solving skills and inquiry has generated exploration of new instructional materials and strategies. Geographic Information Systems (GIS) is a tool that is being used extensively by researchers, scientists and planners to inform decision making about real world problems. Application of this technology to such concerns as the environment, agriculture, land use management and infrastructure development is occurring on local, regional and national levels. Until recently it was not feasible for educators to use this spatial data resource because the cost of the software was prohibitive and the size of the data files was too large to load on the personal computers used in most school settings. Demand from public and private sectors coupled with spiraling innovations in technology have resulted in the recent introduction of software which can be used to manipulate spatial data on personal computers. While the functional capabilities and methods of spatial data encoding vary among venders, geographic information systems are powerful tools for storing, analyzing, displaying and processing spatially referenced information. Software companies such as Environmental Systems Research Institute, Inc. (ESRI) have produced software bundles for school systems at affordable educational prices.

Educators are beginning to investigate productive uses of GIS in teaching/learning environments. Examples are varied and range from 4th - 6th graders updating a database for a state-run recreation area (Robinson 1997) to a cooperative project between high school students in Michigan and Italy to redesign Aviano Air Force Base transportation and evacuation systems (Michelsen 1997). Other opportunities for substantive, authentic investigations in earth science, geography, life science, physical science and mathematics are clearly available. Additionally, partnerships are emerging between schools and institutions of higher education to tackle the challenge of identifying and creating accessible data sets and developing exemplary instructional materials (McClurg & Lerner 1998; Lyon 1997; Rooney 1997; Slater & Fixen 1998).

Investigations examining the claims that novices can use GIS technologies as problem-solving tools and

that these tools can enhance student understanding are informing instructional practices (Audet & Abegg 1996; Ramirez 1996). Some schools are instituting curricula that require GIS technologies in at least two different modes: GIS education and GIS in education (Palladino & Goodchild 1993; Ramirez 1996).

While initial users of GIS were often self-taught it is not realistic to assume that teachers, while working full time in demanding jobs, will be able to incorporate these new strategies into their professional repertoires. Ample evidence exists to suggest that teachers need information, theory, modeling, support, and feedback to learn a new teaching strategy (Joyce & Showers 1988). Teacher time is another key issue (Fullan & Miles 1992). Bohlin and Hunt (1995) reported an increase in confidence and attitudes and a decrease in computer-anxiety when pre- and inservice teachers were enrolled in courses that met over a longer period of time. Not only do teachers need time to learn the skills, they need time to experiment, to reflect, to revise and to integrate new understandings (Loucks-Horsley, Hewson, Love & Stiles 1998).

Professional development opportunities, such as extended workshops and institutes, are typically the forum for teachers to learn new teaching strategies. Loucks-Horsley, et al. (1998) describe five implementation requirements for such experiences to be effective. These include: 1) expert knowledge through a leader or facilitator; 2) time away from the workplace, with arrangements for substitutes or stipends, to free teachers from their regular duties; 3) a curriculum or syllabus to inform the participants about the content; 4) Access to resources and materials, i.e. classroom materials, texts, tutorials, and software; and 5) incentives such as stipends or graduate credit. Such experiences are necessary for teachers to integrate GIS in their classrooms.

The EdGIS Conference final report (1995) supports the need for effective professional development in using GIS in the classroom. It states, "For GIS to have a broader impact on education, progress needs to be made in several key areas of implementation: development of exemplary curriculum materials... teacher training, and dealing with issues of equity of access" (p. 19). This call for quality teacher training is supported further by a survey of educators using GIS in their classrooms. Audet & Paris (1997) found that 77% of respondents strongly agreed that teacher training is necessary before introducing GIS in the classroom. In addition, 75% of those surveyed agreed or strongly agreed that teaching with GIS requires new teaching methods.

The purpose of this study was to develop effective professional development experiences for teachers to learn how to use GIS resources in their classrooms to increase and enhance student achievement in areas of geography, science, mathematics, technology and art. To accomplish this goal, workshops were conducted, assessed and revised in an iterative process.

Description of the Research

The efforts to provide Wyoming teachers with content background and skills to use GIS in the classroom began in 1995 through the development of the Earth System Science Internet Project (ESSIP). The primary goal of this project was to form a collaborative partnership between scientists and science educators at the University of Wyoming and K-12 teachers throughout Wyoming. The project focused on creating eight authentic learning experiences through the use of remotely sensed data, GIS, spatial data accessible over the Internet, and collaborative lessons requiring participation through the Internet across multiple sites.

In 1996, fifteen 6th-12th grade geography and science teachers from five school districts participated in a week-long workshop at the University of Wyoming to learn the basics of ArcView GIS (ESRI, Inc.) and test the GIS module lessons. As part of the module development process, the teachers were asked to test each of the lessons in their classes and provide feedback to the project directors during the 1996-97 academic year. To assist the teachers in this process, continual support from GIS technology specialists on the ESSIP staff was provided in the form of personal visits, e-mail, and telephone conversations.

Classroom observations and teacher interviews provided the bulk of the data from the first iteration. Each of the teachers was visited during the school year and interviewed about the strengths and weaknesses of the lessons, obstacles to implementation, and suggestions for improving various aspects of the project. The teachers were then brought back together in the summer of 1997 to discuss these same issues.

A second iteration of the workshop was conducted over the 1997-98 academic year. Several changes were made to the content and format of the workshop based on the feedback from the first workshop participants. As with the first iteration, two part-time personnel were available to assist teachers during the transfer of these activities to the classroom. They were available by phone, e-mail and personal visits to the school sites to assist teachers with any hardware or software problems they might encounter and to model teaching in participants' classrooms.

Assessment measures included classroom observations, interviews, teachers' ability to demonstrate their skill to workshop leaders and cohorts, and analysis of: 1) a web-based discussion; 2) lesson plans; and 3) student

projects generated in teachers' classrooms. Teachers were also asked to rate themselves on a 14-item Likert type scale at the beginning and the end of the workshop. Twelve of the items dealt with participants' level of confidence regarding their ability to use and or to implement GIS in the classroom. Two of the items were statements related to participants' attitude toward GIS as a tool in the teaching/learning environments. This instrument was designed by the authors and distributed to a five-member panel for review. Modifications were made and the questionnaire was redistributed to the panel and approved prior to use as an assessment tool for the in-service activities.

Results

Observations from classrooms during the first iteration provided information about the introduction of GIS to 6th-12th students which was then transferred to introducing the software to teachers participating in the second iteration. Students were observed using GIS as an exploratory tool, so the second iteration was planned to provide more opportunities to explore data. In addition, student groups of two appeared to work best where resources were limited, but a 1:1 student-to-computer ratio was ideal, so greater emphasis was placed on each participant having access to a computer in the second iteration.

Along with observing the students, the teachers were tracked and interviewed regarding their use of the modules and general participation in the project. Five teachers expressed hardware obstacles as the primary reason for not fully participating. Seven others described unrelated commitments as the main obstacle in participation. Only three teachers felt satisfied in their implementation of the GIS lessons. Each of the 15 teachers had volunteered and made a commitment to participate, but a stronger incentive was needed to encourage full participation. As a result, the second iteration was offered for graduate credit from the University of Wyoming.

Direct feedback from the participants after the first iteration proved most helpful in redesigning the second workshop format. The participants' suggestions which were directly implemented in the second iteration included: 1) creating a non-computer-based introduction to GIS concepts such as using transparencies to demonstrate overlaying themes and querying; 2) allowing students to create their own data layers to increase motivation and emphasize the local focus of GIS; 3) spending more time discussing databases, queries, and the syntax of querying; 4) addressing the need for complying with state and national standards; 5) learning how to customize the lesson plans; 6) involving more teachers from other districts; and 7) integrating other content areas. The participants also provided feedback about difficulties in accessing computers with sufficient memory or other hardware requirements, garnering support from administrators and colleagues, and simply remembering how to use the software due to the lag-time between the workshop held during the summer of 1996 and implementation of the lessons several months later during the 1996-97 academic year.

This feedback was used to make several modifications for the second workshop. First, the format of the workshops was modified from an intense week-long workshop to a seven day, three-part workshop extended over a six month period. This was to give the participants opportunities to test and refine their skills at home and in the classroom between sessions. The intermediate session would then provide reinforcement, remediation, and continued development in the midst of implementation efforts.

Second, teachers were sought from the areas of geography, mathematics, science and art to provide a greater emphasis on interdisciplinary connections of using GIS. The resulting content composition of the teachers (5^{th}-12^{th} grade) in the second workshop consisted of science (7), geography (4), elementary (4), math (3), art (2), and history (1). Third, the content of the workshop was expanded. The first part of each workshop session was devoted to sharing experiences teachers had had using the software and to discussing solutions to any problems that had arisen. Remote sensing concepts and the use of Global Positioning System (GPS) were also added. Teaching students to use GPS would allow them to generate their own data sets. Teachers also viewed video examples of 6th - 12th grade students using GIS software in school contexts and participated in interdisciplinary activities which incorporated GIS as a tool. Fourth, teachers were asked to bring their own computers to the workshop sessions and learned to install the ArcView software and data sets on their own machines. This allowed teachers to gain a greater understanding of the installation process and file structure of the software. Fifth, all the participants were expected to complete homework assignments during the periods between workshop sessions. These assignments included identifying state and district curriculum outcomes and standards that could be addressed by using GIS/GPS, developing, teaching and evaluating lesson plans for their students, and posting their ideas, assignments and comments on the ESSIP web-based discussion site.

Thirty-six teachers initially registered for the second workshop, but only twenty-one completed the extended seven-day series, nineteen of which took the course for credit. Each of these nineteen teachers identified relevant district and state outcomes and standards as well as posted ideas on the discussion site. Twenty teachers

developed lesson plans, with fourteen being able to implement and evaluate them. Three of the teachers who were unable to implement their plans cited lack of access to capable hardware and three stated that they did not have sufficient time to test their plans.

A follow-up workshop was conducted in February 1999 for the participants in the second iteration. Thirteen teachers stated at that time that they were able to continue implementing GIS and GPS after the completion of the course. Two others were still set back by hardware and time obstacles but stated their intention to forge ahead in their efforts. The remaining six had discontinued using GIS in their classrooms.

Along with teacher participation and workshop development, this study also examined the level and type of use by the teachers who participated. As might be expected by the spread of grade levels and content areas, the complexity of the lesson plans varied. Generally, the elementary and middle school teachers as well as the art teachers used GIS to conduct simple visual investigations without resorting to the Boolean or other intensive querying capabilities of the software. For instance, a sixth grade teacher designed a lesson using GIS to introduce her students to the five themes of geography by looking at such things as the characteristics and features of a place. An art teacher asked her students to use GIS to investigate land forms and land marks then create their own land mark stamps. The students then used these stamps along with principles of design and printmaking skills to create new maps of the areas under investigation.

The junior high and high school science, geography and mathematics teachers tended to use more of the software's functionality. For instance, a junior high earth science teacher designed a plan in which the students would investigate seismic activity in Yellowstone National Park by posing such questions and scenarios as:

> "Does the number and location of seismic events remain relatively constant each year in the park? ... - Do significant seismic events occur near areas of sustained human use, so that some assessment of the likely risk of a seismic event occurring can be conducted? The quake events would have to be examined in relationship to the physical environment of the park (mountains, valleys, rivers, geysers) as well as the human features there (roads, campgrounds, visitor stations, etc.)."

When given the opportunity, the participants of the second workshop were able to develop useful, appropriate lessons involving GIS. Comments from these participants indicated that they were excited about using GIS to teach content they were already responsible for teaching and saw greater potential for integrating this technology into their teaching practice.

Nineteen teacher participants in the second workshop iteration completed both the beginning and ending survey. Table 1 summarizes the beginning and ending means for the pre-workshop/post-workshop rankings on each

	Female Means			**Male Means**			**Overall Means**			**SD**	**t**
	Begin	**End**	**Gain**	**Begin**	**End**	**Gain**	**Begin**	**End**	**Gain**		
Ability to Use GIS	1.1	4.9	3.8	2.2	6.7	4.5	1.7	5.8	4.1	1.84	9.46*
Ability to Use GPS	1.7	6.6	4.9	6.4	8.7	2.3	3.9	7.6	3.7	2.91	5.52*
Create GIS Layer from GPS Points	1.1	5.3	4.2	2.6	7.8	5.2	1.8	6.5	4.7	2.89	7.07*
Display & Overlay Themes	1.1	6.8	5.7	3.1	8	4.9	2.1	7.4	5.3	2.83	8.19*
Query Themes	1.1	5.3	4.2	2.8	7.7	4.9	1.9	6.4	4.5	2.39	8.26*
Query Multiple Themes	1.2	5.4	4.2	2.4	7	4.6	1.8	6.2	4.4	2.01	9.49*
Define & Conduct Original Query	1.1	4.9	3.8	3.2	7.1	3.9	2.1	5.9	3.8	2.34	7.16*
Use GIS as a Tool in Classroom	1.2	6.1	4.9	1.8	6.3	4.5	1.5	6.2	4.7	2.23	9.25*
Geo-reference Images	1	3.5	2.5	1.6	6.1	4.5	1.3	4.7	3.4	2.32	6.53*
Layouts	1.1	5.6	4.5	2	8	6	1.5	6.7	5.2	2.42	9.40*
Charts	1.4	5.9	4.5	1.6	8	6.4	1.5	6.9	5.4	2.27	10.42*
Interdisciplinary Connections	3.3	7.7	4.4	4.7	8.6	3.9	3.9	8.1	4.2	2.75	6.58*
Useful: Classroom Tool	1.1	7.7	6.6	3.8	9.3	5.5	2.4	8.5	6.1	3.30	6.63*
Useful: Discussion Web	1.7	7.8	6.1	2.4	6.8	4.4	2	7.4	5.4	2.66	6.70*
										*p<0.001	

Table 1: Mean scores and summary of t-tests on the level of confidence and attitude survey (n=19).

of the fourteen items in the survey. Examination of these descriptive statistics revealed participants' confidence in

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their ability to use GIS and their attitude toward GIS as a useful tool in the classroom increased substantially. The mean self-ratings of their ability to use features of GIS at the end of the six month in-service were quite high with a range of 4.7 to 7.6 and a median of 6.4 on a ten point rating scale. Interestingly, females consistently ranked their beginning and ending abilities lower than males. Statistically significant gains were detected ($p<.001$) for the items measuring participants' level of confidence in their ability to use GIS. Statistically significant gains were detected ($p<.001$) for both items assessing participants' attitudes toward GIS as a useful tool in the classroom.

Discussion

Designing effective professional development is a complex task. The purpose of the learning opportunity, the content, and the needs of the participants must be matched with an appropriate strategy or combination of strategies for promoting learning and change. Then the professional development must be implemented in such a way as to provide expertise, support learning, and encourage participation through incentives (Loucks-Horsley, et al. 1998).

When introducing new technologies, additional factors must be considered, such as providing technical and moral support as well as a sufficient time period to enable the learners to become comfortable with the technology. The learners must also see the possibilities for applying and integrating the new technology into existing curricular structures. As Audet & Paris (1997) stated, there is a distinction between "knowing how to operate a GIS and knowing how and when to apply GIS to solve problems" (p. 300). Appropriate professional development would allow teachers to learn how to manipulate GIS and how to apply it meaningfully in the classroom setting.

Both iterations of the workshop in this study shared characteristics and elements such as workshop instructional methods and hands-on activities, technical and moral support structures, and follow-up sessions. Some of the teachers in both workshops experienced technical obstacles, lack of administrative support, and lack of sufficient time to fully implement lesson plans involving GIS.

The second iteration of the GIS workshop, however, draws closer to meeting the effective professional development models described by Loucks-Horsley, et al. (1998) than the first iteration. It appears to have been more effective in promoting lasting change in teaching practice in terms of ability to use GIS and implement it into the classroom. The extended time frame of the workshops, stronger incentives, interdisciplinary connections, outside assignments to design and test lessons, and on-going communication using the web-based discussion site were all significant changes from the first iteration. One or a combination of these changes may be the primary factor(s) for increasing the effectiveness of the second workshop. Further interviews of the participants need to be conducted to identify specific aspects of the workshop that led to changes in their practice.

While teachers' confidence in their ability to use GIS grew significantly, there was variability in their confidence to use different GIS features. They were most confident in their ability to display and overlay themes, conduct queries on existing themes, produce layouts and charts communicating results of their investigations, and produce new layers based on data collected during field experiences. They indicated less confidence in their ability to geo-reference images and to define and conduct original queries. Geo-referencing images is very important for users who wish to superimpose existing remotely sensed images. Defining and conducting original queries is an important skill as users work on problems situated in the real world. Continued refinement of the in-service experiences in these important areas is clearly indicated. While not a part of the original intent of the survey, the obvious difference in confidence level of males and females is perplexing. From the perspective of the workshop leaders there was no difference between genders in their ability to use and apply these technological tools.

Teachers' ending attitudes toward using GIS as a tool to support learning were extremely positive (8.5 on a 10 point scale). Will these positive attitudes and high level of confidence result in teachers using these tools in their classrooms? What kinds of learning experiences are being supported through the use of these tools? Have teachers changed their instructional style as a result of using these tools, and if so, how? Are they participating in the discussion/support web site? Do they need other kinds of continuing support? What kinds? Is it important to address the difference in confidence in ability to use GIS/GPS detected between men and women? These questions and others will continue to be addressed by ongoing work.

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Computer Assisted Synthesis of Visual and Symbolic Meaning in Mathematics Education

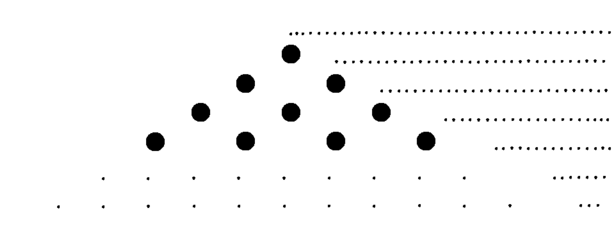
Stephen R. Campbell
Department of Education
University of California, Irvine
United States of America
sencael@uci.edu

Abstract: A number of factors pertaining to a wide variety of distinctions -- such as particular-general, arithmetic-geometry, sense-reference, procedural-declarative, concrete-abstract, object-attribute -- are implicated in developing a meaningful understanding of visual and symbolic aspects of mathematics. A rather simplistic "association-abstraction" model of mathematical cognition, as it stands, appears inadequate to account for these factors, particularly with respect to instructional design and assessment. Such fundamental inadequacies warrant better theory and more research. Methodology directed toward this end, drawing on digital video technology, is sketched out.

Background

Some of the most vexing problems in the history of philosophy and psychology concern understanding the relations and interactions between visual and symbolic aspects of human experience. These problems have proved to be particularly acute and germane in the philosophy and psychology of mathematics. Moreover, theoretical understandings of the relations and interactions between various visual and symbolic representations, processes, and meanings in mathematics and mathematical cognition *per se* constitute, as their more practical counterpoint, a fundamental problematic of mathematics education.

To get an initial sense of this problem, consider (Fig. 1) the familiar and fairly well-known Pythagorean visual images of triangular numbers along with the modern symbolic formula: $f(n) = (n^2 + n)/2$.



$f(0) = (0^2 + 0)/2 = 0$
$f(1) = (1^2 + 1)/2 = 1$
$f(2) = (2^2 + 2)/2 = 3$
$f(3) = (3^2 + 3)/2 = 6$
$f(4) = (4^2 + 4)/2 = 10$
. . .

Figure 1: Pythagorean Triangular Numbers

These representations and the relations between them require some explication. It may at first appear as though there is only one triangular number represented in Figure 1, i.e., 10. It can, however, be readily seen that the triangular numbers 1, 3, and 6, are embedded, i.e., in a layered fashion, within it. The visual representation also, at least implicitly, suggests that the next triangular number, the 5th triangular number, can be generated by simply adding another layer of 5 appropriately spaced units to the previous triangular number in the series. In order to be convinced of this, it is helpful to notice the way in which triangular numbers are "defined" or constrained by this peculiar triangular form. Triangular numbers, as with other kinds of Pythagorean figures, such as square numbers, i.e., $f(n)=n^2$, and oblong numbers, i.e., $f(n)=n(n+1)$, are what Mason and Pimm (1984) refer to as "generic examples" -- in that they provide a sense of being able to see the general case in a particular instance.

Visual representations such as these can be very helpful in understanding fairly sophisticated relationships in the theory of numbers. For instance, by inspection, one can readily convince oneself that the sum of any two consecutive triangular numbers is a square number, or conversely, that a square number decomposes into two consecutive triangular numbers. Symbolically, on the other hand, for most of us at least, it is not immediately

evident that $(n^2 + n)/2 + ((n+1)^2 + n+1)/2 = (n+1)^2$. Even with the use of a few mental short-cuts, I used three intermediate steps of algebraic manipulation to formally derive this equality -- a derivation that would constitute only a part of a full-blown rigorous proof of this relationship by mathematical induction.

Guiding Questions and Assumptions

There are many questions that can be asked regarding these two qualitatively different kinds of representations and the various processes associated with them, but there are two questions of specific interest here: 1) What factors are implicated in developing meaningful understandings of visual and symbolic representations of mathematics? 2) In what ways can computer technology assist learners in developing meaningful understandings visual and symbolic representations of mathematics? Whether the first question is explicitly considered or not, various answers are implicitly assumed in any instructional design, development, implementation, and assessment of educational technology in mathematics education. The main objective of this paper is to consider the first question with regard to the second. The purpose is to begin to sketch out a more viable, richly-textured, and theoretically-grounded basis for research into the instructional design of educational technology in mathematics education, with an eye toward ways in which that technology can be implemented and assessed in the teaching and learning of mathematics.

It is taken as given in this paper that meaningful understandings of mathematics do not exist in visual drawings or symbol systems alone, in and of themselves. Rather, they acquire meaning through the minds of individuals. That is to say, individual learners are assumed to be actively engaged in constructing mathematical understanding, and knowledge cannot be considered, in any absolute sense, to exist independently of them. The most challenging aspect of such a view concerns identifying specific details regarding manners in which learners' understandings are, or can be, constructed, and how to promote and objectively assess such constructions. This general problematic warrants further research into the potential role of educational technology in the visual and symbolic construction of meaning of basic mathematical procedures, concepts and relations in mathematics education. Some consideration is given to how research into understanding these kinds of constructions may be expedited using digital video techniques.

Troublesome Distinctions

There are many troubling distinctions involved in understanding visual and symbolic aspects of mathematics and mathematical cognition. To begin with, do the same guiding questions of this study, as noted above, apply in the same way for different mathematical subject areas? Despite the primary emphasis given herein to arithmetic, it is important to ask whether the relation between visual and symbolic aspects for this subject is the same as it is, let us say, for geometry. From a formalist perspective, there are essential similarities throughout the field of mathematics with respect to axiomatization. Thus, differences in symbolic meaning with respect to formal systematic axiomatizations of geometry and arithmetic do not seem as pronounced as the differences in visual meaning between them. The visual meanings of geometrical, as opposed to arithmetical, notions have traditionally been considered to be much more intuitive for the former than for the latter. Consider the differences, for instance, between visualizing a geometrical object such as a triangle versus visualizing an arithmetical object such as a rational number. Indeed, it may be impossible to visualize a rational number at all without some form of geometrical construct involving spatial extension. All considered, the relation between visual and symbolic meaning is clearly more intuitively evident for geometry than is the case for arithmetic. That is to say, the relation between visual and symbolic meaning seems to be more problematic with regard to arithmetic than it is for geometry.

Other considerations have to do with well-known logical and computational distinctions between sense and reference and between declarative and procedural propositions. The reference of a mathematical proposition is often taken to pertain to the truth or falsity of that proposition. The truth or falsity of "7 + 5 = 12," for instance, depends on whether or not a procedure exists that can establish whether or not the sum of 7 and 5 is indeed equal to 12. Another way of thinking about reference has to do with the conceptual entities involved in the proposition. That is, in this case, whether or not "7+5" and "12" actually refer to the same thing. Such propositions can be considered in a procedural sense, as an operation involving numbers, or in a declarative sense, as an relation between numbers.

However, these differences are further complicated by whether or not numbers are considered in the concrete sense of real physical objects, or in the abstract sense of idealized conceptual objects.

Moreover, semantic confusions can result with respect to shifting meanings of the object-attribute distinction with concomitant shifts in meaning between visual and symbolic representations of numbers. Consider, for instance, a shift in meaning in the notion of quantity from that of an attribute of collections of concrete objects (as often portrayed to learners with manipulatives, in textbooks, and educational software) to that of a formal, abstract, symbolically-mediated object with no concrete attributes whatsoever. Similar difficulties appear to be implicated with shifts in meaning of the arithmetic unit as a unit of discrete quantities to one of a continuous unit of measure. Such subtle and problematic qualitative shifts in meaning are implicit within the visual and symbolic representations of number. These are shifts in meaning that many students never make or begin to appreciate -- even if they do happen to gain procedural proficiency with manipulating symbols in accordance with set rules.

The orientation for instructional design in mathematics education with respect to the relation between the symbols themselves is mostly procedural, and matters of reference suitable for assessment tend to focus solely on the truth of the proposition -- that is, on whether or not learners "get it right." Unfortunately, learners who actually do get it right in accord with these criteria may not have much of a clue, at least with respect to the nature of the mathematical entities involved and the relations between them, as to what it is they are actually "getting."

Association-Abstraction Model of Instructional Design and Assessment

That such troublesome distinctions are germane to instructional design and assessment is evidenced by a plethora of educational software designed for teaching and learning mathematics. The two main criteria for instructional design seem to rely upon simple, if not overly-simplistic, associative relations between visual (qua, concrete) and symbolic (qua, abstract) representations. Visual figures, such as apples, rulers, and pizzas, etc., are associated with, or replaced by, mathematical symbols with little understanding, either on the part of researchers, designers, teachers, or learners, as to how this is done -- let alone what the relation between these kinds of representation may be. Such approaches tend to ignore, dismiss, or trivialize fundamental issues concerning the relation between visual and symbolic aspects of mathematics while placing the onus on learners to make of it what they will, to either "get it" or not. Whether one adheres to a constructivist model of learning or a transmission model of learning, how it is that learners actually "get it" is usually based on some rather vaguely defined or poorly understood notion of abstraction.

The main strength, *prima facie*, of the association-abstractionist model is that it is easy to understand. With respect to number, for instance, collections of concrete objects are simply associated with symbolic expressions and presumably, after a suitable amount of exposure, some learners, some how, eventually develop a more abstract conceptual understanding thereof. The problem with this view is that it sheds little light on any of these other related factors involved in learning, and thus offers little guidance for instructional design and assessment. Moreover, this view is inherently contradictory if the goal is to gain a concept of number composed of abstract units free of all concrete attributes -- for if there is no ground to distinguish one unit from another, then there is no ground for there to be more than one. The closer one looks at this model, the more problematic it seems to become.

If existing instructional design and assessment criteria based on the association-abstraction model are too simplistic for the effective implementation of educational technology in mathematics education, and there are grounds to suspect that they are, then more appropriate criteria are warranted. As it stands, some consideration has been given to ways in which visual and symbolic meaning connects with other important distinctions in philosophy (particular and general), mathematics (geometry and. arithmetic), logic (sense and reference), computational theory (procedural and declarative), psychology (concrete and abstract), and linguistics (object and attribute). It is evident these factors are deeply implicated (and should be accounted for) in any model concerned with understanding the relation between visual and symbolic aspects of mathematics and mathematical cognition. As it stands, the association-abstraction model does not seem to be up to this task. Something else is required.

Computer Assisted Synthesis of Symbolic and Visual Meaning

There has also been much interest over the years regarding visualization in mathematics education (e.g., Bishop, 1989; Clements, 1981; diSessa, 1997). This interest has been spurred on by the tremendous potential of computers for visualizing mathematics. An over-emphasis of the visual, however, also carries a risk of neglecting the more deductive, idealized, and symbolic aspects of mathematics. Such concerns, which by the very nature of the subject are of most acute concern in mathematics education, have recently been recognized within science education as well (Niaz, 1999; Rocchi, 1998). One of the main short-comings of the association-abstraction model noted above is that it provides little insight into what learners actually experience and what they actually do when exposed to visual and symbolic aspects of mathematics. New theories and methods are called for.

That is not to imply that good theory and research is not being done in this area. The analysis provided above only scrapes the surface. There is a significant amount of work being done in this regard that should also be of interest to those involved in the instructional design and assessment of educational software in mathematics education. So much so that it would be impossible to provide any more than a brief sampling of that work here. A wide spectrum of recent theoretical perspectives and empirical research regarding analogical and metaphorical reasoning is available (English, 1997). Many other important initiatives have recently been taken regarding the potential role of computers in promoting meaningful understandings visual and symbolic aspects of mathematics (see, for example, Noss & Hoyles, 1996; Sutherland & Mason, 1995). Nevertheless, there is much more work that remains to be done toward providing a theoretical framework that is comprehensive and detailed enough to do justice to the intrinsic complexities of synthesizing visual and symbolic aspects of mathematical cognition.

Along with the need of new theoretical frameworks for empirical research beyond the bare-bones "association-abstraction" model, there is a also pressing need for more refined and effective methodologies. I conclude with a brief description of my own methodological approach for conducting empirical research in this area, one which draws upon and integrates the work of many others, specifically designed to take advantage of emerging digital video technology for data acquisition and analysis.

Experimental groups in a computer-equipped classroom, consisting of prospective teachers of mathematics, are exposed to educational software specifically designed and developed for exploring relations between visual and symbolic aspects of arithmetic and elementary number theory (Campbell, & Fonthal, forthcoming; Greeno, 1991). All experimental interventions are recorded on digital video tape for subsequent analysis. Data is acquired at two levels of granularity (Rouet, Steffens, & van Oostendorp, 1999). At the macro-level, activities of the class as a whole is recorded. At the micro-level, selected individuals' *and* their screens are separately and simultaneously recorded. Data are collected and analyzed using a procedure that allows for the recording and synchronized digital playback of all data streams.

Participants observed and recorded at the micro-level are instructed in the use of a reflection protocol involving "thinking aloud" (van Oostendorp & de Mull, 1999), and an attention protocol to "keep their mouse where their mind is." Data are analyzed, coded, and indexed using digital video processing software. In particular, a variety of action sequences (Goldman, Zech, Biswas, & Noser, 1999) and meta-cognitive factors (Ertmer & Newby, 1996; Wolters & Pintrich, 1998) are used to help classify the qualitative data. Limitations of the experimental software is analyzed in accord with (Chen, 1995; Hannafin & Land, 1997; Lawless & Brown, 1997; van Oostendorp & de Mull, 1999) to help identify potential systemic constraints imposed on participants' interactions with it. Finally, the data are interpreted, both to determine ways in which visual and symbolic aspects of mathematical cognition are interconnected, and for ways in which the experimental software can be improved.

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Interactivity in Mathematics and Science Education

Ozlem Cezikturk,
University at Albany, SUNY,
Department of Educational Theory and Practice
Mathematics Education
oc7815@csc.albany.edu

Murat Kahveci,
Florida State University,
Science Education,
mkk8653@garnet.acns.fsu.edu

Gulcin Cirik,
San Diego State University,
Educational Technology,
gcirik@hotmail.com

Abstract: Today, interactivity is seen as a key factor for achieving effective learning environments. Research says that "Interactivity" is a messy idea that takes its meaning from a system of metaphysical oppositions. These oppositions range from learner control issue to the debate. A group of academicians and researchers were asked to imagine a "Richly Interactive Learning Environment" to the fullest degree possible. The commonalities and differences in their ideas are investigated in order to come up with a shared understanding of interactivity for the new millennium. The aim of this article, is to both deconstruct and reconstruct a theory for interactivity with some real ground from previous research, ideas from that group, and from the ideas of the authors, as a whole. With this framework in hand, we hope that it will be possible to differentiate the real promises of "interactivity" from the wonderland promises.

Introduction

Recently, there is a term that takes a lot of attention in the educational world. Each day another research study is emerging with some ideas on how to make *something-either a classroom, a software, a textbook, or any instructional design* more "interactive" than it was. These research studies do not share a common ground to attribute the characteristics that interactivity has or should have.

Rose (1999) realized the miscommunication, confusion, and false expectations tied to the word "interactivity" in educational computing. She used a strategy named after Jacques Derrida "deconstruction" to interrogate the system of metaphysical oppositions. She finally claimed that "interactivity" seems to be a messy idea that gains its meaning from many opposite meaning terminology. Although her starting point was educational computing, the ideas that she come up with are not restricted to only educational computing but to whole educational instruction and learning, too.

Rose (1999) points to the importance and necessity of deconstruction through the purpose of breaking down the received assumptions, which are hidden in oppositional terms, is to allow for new perspectives and new avenues of thought. In this regard, we may start with a deconstruction from the area of language of the term "interactivity". The dictionary of Webster defines "interact" as to act mutually to perform reciprocal acts. Although the term deconstructs into two parts as "inter" and "act", the literature seems to give meaning to it as it would be given to the word "intra" + "act", too. We will discuss this more fully later in this paper.

In this article, and derived from our research, we try to discuss the situation as reconstructing the meaning of interactivity but this time in education general. To be specific, most examples and ideas will

reflect science and mathematics education context, since our expertise and interest is in this area, and also since it is the area that the most of the information needed is lacking about interactivity. We are not restricting ourselves to only educational computing or educational technology to get the breadth and depth of the characteristics attached to the term interactivity. With this in hand we aim to come up with a shared theory of "interactivity" for the new millennium.

Interactivity in Examples

The literature seems to have many different interpretations of the term "interactivity". Although, these definitions and contexts seem to bind the usage of the term, we believe that starting from those examples and the contexts that is mostly used or referred, would be really invaluable.

The most recent wonderland of the educational world; Internet seems to be in the center of the discussion to decide whether or not it is interactive. The idea of its having unbounded information source, and the idea of its being static with respect to the information load but not dynamic, seems to be the existing dichotomies. The learner can reach a whole catalog of sources but cannot change the structure of these sources. In this sense, can we say that it is interactive? The idea of the Web being interactive also comes with the possibilities of the new technologies that Internet brings like IRC (Internet Relay Chat), or MUD's (Multiple user dungeons, etc) they provide users the ability to communicate with the other people lively, and on time.

Dockterman (1995) was trying to get the meaning of the term through pragmatics. If its meaning is only what is stated in Webster, then can we say it is like "dressing a child"? Or solar system? What about remote-controlled TV? But then he also mentioned that there should be some kind of intense conversation and debate!

Regarding the context of learning. Rose mentioned that we need to give up our old notion of Socratic Dialogue and search for new situations where we can make the learner play with the path that is given to him/her or change for his/her learning interests. Computers or teachers who practice "Socratic Dialogue" ask questions designed to lead the learner step by step towards the path that is already planned, and hence the learner is no longer on his/her own but tries to accomplish the path prepared for him/her. Then the question becomes should we go on with the early Socrates' ideas about interactivity or should we come up with some more recent and more effective ones for this century (Filipczak, 1996; cited in Rose, 1999). Especially in a century in which technology seems to make any kind of dream possible, we need to find some new and critical answers to these questions.

Although the use of the term is not limited to technology only, technology seems to help it from many sides. Recently, the main debate is about the software programs for learning and their interactive value. Some argue that it is related with the numbers of keys that is included in the software (Poncelet, & Proctor, 1993, cited in Stemler, 1997) and some argue that the much more important thing should be to make students think and be provoked (Dockterman, 1995). He was stating that it is not how many buttons students can push, but whether one can use the technology to spark thoughtfulness and interaction. He was arguing that it should generate a conversation within each student's head. Another main debate about educational computing and interactivity is the idea of high interactivity needs highly advanced technological tools. This idea needs careful consideration, through the critical literacies that our age requires.

To avoid the mistaken value of technology as a "Magic Lantern"

Technology is a tool that is human made. Hence, it should not take the place of humans especially when dealing with humans. For example, teachers should not be replaced with machines. Learning should not be given to the hands of machines, only. The researchers and academicians (Postman, No Date) have always criticized the notion of technology as being seen like a magic lantern. Dockterman (1999) stresses the necessity of pointing to interactive classrooms and interactive technologies.

Allen & Bloom (1997) argues that since technology changes so rapidly, the focus of researchers, educators, and designers should not be on computer hardware but on issues of cognition, & perception.

What are the characteristics of "interactivity"?

Rose (1999) searched for a list of characteristics of the term "interactivity" in learning environments. Her list includes the following (Table 1);

NOTs...	BUTs...
Teacher controlled	Learner controlled
Lecture (where learner is passive recipient)	Active learning through hands-on exploration
Student as spectator	Student as participant
Feeding children information	Letting them to find it for themselves
Linear delivery	Hypermedia Learning
Instruction	Construction
Absorbing material	Learning how to learn
Passive	Active
Rigid	Flexible

Table 1. Rose's dichotomies for characteristics of "Interactivity"

She (1999) uses the expression "the privileged sphere of interactive learning" to point to the most general use of interactivity in the form of a "ideal" which highly motivates learners to explore. She also argues that we should try to achieve rationality. As in her saying, a new form of Socratic Dialogue! so that learner's role is not only to follow the Socrates' logic, and to express agreement rather mindlessly when required to do so, but to pose some questions to break down Socrates' rationale to construct new student knowledge. This new form also brings the theory of constructivism in to the scene so as forgetting the notion and possibility of a true nature of knowledge and excellence, but it lets the student lose his/her way and facilitate the learning environment to open a field of provoked and free mind, to the new insights and ideas of students' own. Another interpretation would be the student engagement with the instructional activity and/or learning activity. Other than learning theories, recently Engagement Theory seems to have a basis for "interactivity", too. Hannafin (1989, cited in Stemler, 1997) argues that cognitive engagement in interactive multimedia can be achieved through use of fault-free questions, queries, real-time responding, note-taking, predicting/hypothesizing, hypertext, and cooperative dialogue. Bangert-Drowns & Pyke (1998) argue that engagement may be thought as in the form of mobilization of cognitive, affective, and motivational strategies for interpretive transactions with text. Sims (1999) argues that the concept of interactivity should not be thought without the idea of user engagement.

Learner control is a highly controversial issue. Rose argues that if it is "learner control" in the same sense of "weight control" and "flood control", then this means that we deal with *control of the learner* instead of the *control by the learner*. Since, weight control means control of the weight, and flood control is the control of the flood, instead of vice versa. Research indicates that instructional design developers should try to avoid control of the learner to achieve higher levels of interactivity. But this brings the question of difficulty of the organization of the design and the restraints in design elements.

Stemler (1997) argues that common view about interaction being stimulus-response reinforcement encounters between the learner and instruction. Schwier & Misanchuk (1993, cited in Stemler, 1997) gave the examples of behavioral orientations to instructional interaction as designer imposed pacing, over responses, immediate feedback, knowledge of results, controlled sequencing, small step size, promoting, and conversation. Here, one needs to notice that designer imposed pacing is not in parallel with control by the learner but with control of the learner.

Regarding feedback, as one of the most important characteristics that is essential for "Interactivity", Stemler (1997) says that, Gagne's nine events of learning that have been recommended, in one way or another, by a multitude of multimedia researchers. These events of learning include gaining attention, informing learner about objectives, activating motivation, stimulating prior learning, presenting stimulus material, providing guidance, eliciting performance, providing feedback, assessing performance, enhancing retention, and learning transfer. Mainly the multimedia developers to achieve some degree of interactivity have used these events of Gagne. Park & Hannafin (1993, cited in Stemler, 1997) argue that feedback should be included in the environment but with some cautions. First of all, it should not narrow the learner's focus to only one content covered in the question-feedback cycle. Secondly, feedback needs to emphasize information that is conceptually relevant rather than explicitly or absolutely "correct".

Wittrock (1974, cited in Stemler, 1997) on the other hand argues for intentional selection of information, as a must to achieve interactivity. A similar argument by Orr, Golas & Yao (1994, cited in

Stemler, 1997), states that opportunity for interaction in every 3 or 4 screens of in 1 minute, chunking the content, building in questions (feedback, also) reviews, summaries, for each segment, asking students to apply knowledge, using thought-provoking questions, and provoking curiosity in learner through active exploration. But, aren't these somehow contradictiry with the control by the learner issue?

Some research studies only consider human-computer communication for understanding interactivity. Rafaeli & Sudweeks (1999) states that it has a continuum from one–way communication on one hand, and to the two-way communication on the other hand.

Interactivity and Design

Sims (1999) argues that interactivity can be perceived as an art. He also states that this is because, it requires a special understanding of the learner, an appreciation of software engineering capabilities, an importance of rigorous instructional design, and the application of appropriate graphical interfaces.

Sirohi(1999) points to the importance of JAVA applets for preparing "interactive" learning environments especially on the web. Sirohi's ideas seem to parallel the idea of computers as at the end of the teaching machine era and at the beginning of the learning machine era (Barker & Tucker, 1990; cited in Rose, 1999). He states that Java as an object-oriented language, is the platform for preparing interactive simulations generally. She argues that John Dewey may be thought as the advocate of interactivity cause it is somehow regarded as "learning by doing." According to Sirohi two types of framework especially are regarded as "interactive". And these are –information delivery with online communication, and immersive collaborative environments as MUDs, and computer conferencing.

Milheim & Lavix (1992, cited in Stemler, 1997) stress the need for one button access to a progress chart or map showing the students' location in the program. Poncelet & Proctor (1993, cited in Stemler, 1997) give guidelines for interacting help keys, answer key, glossary key, objective key, content map, options key, test key, next lesson key, menu key, exit key, summary key, review key, example key, etc.

Stemler (1997) argues that possible match or mismatch of user expectations and the actions on the screen determine the learner's concentration on the material rather than on screen design & how it works. The idea of learner control has many effects on the design issues, too. Overbaugh, 1994; Schwier & Misanchuk, 1993; Hannafin, 1984; Litchfield, 1993; Laurilliard (1987), Orr, Golas, & Yao (1994), Sweeters (1994) (all cited in Stemler, 1997) argue that the number of keys, the place of those keys, the number of animations, the match between text and attached pictures, etc. all shape the learning experience, and hence the degree that the learning environment may be called as interactive or not. Learner control seems to be defined as allowing learners to access information, that is selected and restricted by the designer or teacher, as flexible as possible. The designer should not give them time, opportunity or chance for the learners to be lost. In other words, designer or teacher should leave one line of footprints for learners to follow, and make them think they have the opportunity for control. But, while doing this, he/she should put the story into a restricted environment wherein the child cannot change and has to obey the rules, and hence no room/space for imagination & creativity. This conflicts with the research that mentions very little learning occurs when students are left to explore information on their own with no guidance (Merrill, Li & Jones, 1990, cited in Stemler, 1997).

Rhodes & Azbell (1985) name three levels of interactivity for design issues. They are: Reactive (little learner control of content structure with options and feedback), Coactive (learner control for sequence, pace and style), and finally Proactive (learner control for both structure and content). Sims (1994, cited in Sims, 1999) on the other hand, identifies different levels. These are: object interactivity (objects are activated), linear activity(user's ability to move through a predetermines sequence), support interactivity (opportunity to receive performance support), update interactivity (dialogue between learner and the material), construct interactivity (creation of an instructional environment), reflective interactivity (seeing the answers and comparing them with others), simulation interactivity (individual determines the sequence), hyperlinked interactivity (correctly navigating through a maze of information), non-immersive contextual interactivity (meaningful, job related context), immersive virtual interactivity (computer-generated world).

Similar studies on animation, audio (Sponder & Hilgenfield, 1994; Hannafin & Rieber, 1989; Rieber, 1994; Orr et al, 1994; Kensworthy, 1993; neugent, 1982; Wright, 1993; Ipek (1995) all cited in Stemler, 1997) point to the place and the degree of relevance of those materials to the actual course material to have real interactive value behind. Over all, simplicity seems to be the most important

characteristic of the interactive multimedia design. In this line of research, another main issue seems to be the rigid structures of multimedia development. Even though, if they would try to chance the design structures, the multimedia design software would not give them enough chance, for doing it effectively.

Methodology

A group of academicians and researchers were asked to make one wish to the Genie of Aladdin's Lamp for "Richly Interactive Learning Environments". Interestingly, they are wish they hand in common way to come up with a shared understanding of the term "interactivity". They mention ranges from "interactivity as an intellectual activity" to "interactivity as a communication issue". Seeing the range of their ideas, they all argued that the argumentation of Rose was correct and we need a shared theory and/or understanding of the term "interactivity" for the new millennium.

They mentioned the necessity of time and material, and budget for interactivity to be achieved to the fullest degree. But they also argued that cooperation as in the form of communication in a variety of learners, in which the learners have the capability of observing, experimenting, debating, playing, navigating with and within a huge information system. A laboratory or a field site, a dream world that everything is possible, a holographic n-dimensional shared environment, with a lot of opportunities for hands-on experiences or manipulatives, or a classroom with real world happenings, within the framework of integrated mathematics and science curriculum. Communication in the form not only oral, but also, written, and visual. Technology for the interactivity is considered as a tool but not as an aim to achieve.

They seemed to have some disagreements about the degree of structure. Some mentioned that it should have lots of structure, some said that it should have no limits. Feedback was conceived as a form of structure that should be built in to the environment. Especially, feedback was assumed to be taken by the experts in the domain through the help of the technology, not only from a teacher or only from a software.

Learners were conceived as both creators and players of those environments. To achieve this, making learners to have some personal learning goals were the main idea behind the discussion.

Conclusion

Interactivity is not a word, that its identification should be left only to instructional design developers. In mathematics and science education, the ideas that it is associated with are directly related with learning issues, and hence should be carefully considered.

Kirsh (1997) points to the theory of interactivity as being in the early stage of development. He also gives some additional ways of interacting with the environment as preparing the environment, maintaining the environment, and reshaping the inherent cognitive structure of the environment. With these in mind, and the possibilities that the new technologies bring to the learning issues, the development of highly interactive learning environments, may mean enabling learners to possess the environment to shape it with respect to their own learning styles, interests, and aims. In this way, we may cover the problem of the need for a settled view of interactivity as Rose (1999) and Kirsh (1997) suggests.

However, it should not be overlooked that a new definition without an understanding of the old and recent ones would result in a new definition, that is useless. To avoid this, we have thought that we may gather the data from researchers and academicians in the universities, to have a much more shared and excepted theory of interactivity. This would help us to solve the problems like different interpretations within the same domain. If "interactivity" would be a key term in the effective learning environments, then we need to come up with a theory behind it.

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The Teacher's Attention Empowering Children's Math Learning With Computers

Ni Chang
Curriculum and Instruction
University of Wisconsin-Whitewater
Changn@uwwvax.uww.edu

Abstract: This paper reports the findings of a study, a pilot study, conducted in a childcare center in Whitewater, WI. Eight children were involved and divided into two groups: control and experimental groups. Quantitative and qualitative methodologies were used to analyze the data collected from pre- and post tests and interactions of a child with a computer. Findings show that children who are observed and helped by a teacher gain mathematical concepts faster and more efficient than those who are completely left alone at the computer. This pilot study implies that the teacher needs to pay attention to children at computers while working with or supervising children doing other activities. An extended study is suggested to replicate the findings of this pilot study.

Introduction

In our contemporary society, it is not surprising to see a child manipulating a computer at preschool or a primary classroom setting. Research has shown that computers help children learn (Clements, Nastasi, & Swaminathan, 1993; Davidson & Wright, 1994; Haugland, 1992; Haugland & Wright, 1997; Hohmann, 1994; Hoot, 1986; Grabe & Grabe, 1998; Wright & Shade, 1994). Pertinent research findings will continue to inspire more schools to invite computers into classrooms. Concurrently, however, questions and concerns surface as developmentally appropriate use of computers in children's learning is taken into consideration. Some of the questions and concerns, for example, are: "How can a child learn with a computer on his or her own in an effective and efficient manner?" "Is it developmentally appropriate to leave a child alone or unnoticed at a computer?" "What is developmentally appropriate practice associated with the integration of computer technology into children's acquisition of knowledge?" To attain answers to the questions, a former colleague and I conducted a pilot research study.

The Pilot Research Study

Setting: We conducted our research in a preschool classroom of a child care center where the enrollment differentiated daily: A number of children were full time every day throughout every week. The rest of the children came to the center either on Mondays, Wednesdays, and Fridays or Tuesdays and Thursdays. We went to the classroom mostly on Tuesdays and Thursdays.

Getting Consensus: Before this research project started, one of us casually talked with the classroom teacher and the director of this child care center. With their oral permission for us to conduct the research project in this 4- and 5-year-old classroom, we scheduled an official meeting with the classroom teacher and the director, expressing the detailed information about the research project. This meeting was followed by two written permissions: one was from the director with the other from the classroom teacher. Having received the written permission, we sent out the consent letters to the parents of the children. Included in the permission slips also were a series of survey questions with respect to children's mathematics concepts from their parents' perspectives. Before the research study, we also asked the classroom teacher to reveal the knowledge of each child's mathematic level. The parents' perceptions of their child's level of mathematics combined with that of the teacher determined the eight selected subjects in the research.

Subjects: There were eight children involved in the study. The subjects were ages 4- and 5-year old (see Table 1. Note: We employed the pseudonymity to safeguard the subjects in any form of publication). The average age was 5. 175 (n=8). The mathematic concepts that each chosen child possessed were roughly

alike. The selected children basically had little understanding of six categories of mathematical concepts, including numbers, sizes, shapes, matching, patterns and numerical counting 1-10. The selection enabled us to test the influential power that computers had on children's mathematic inquiry.

Table 1

Name	Age (Yr.Mo)	Name	Age (Yr. Mo)
Reed	4.11	Neth	4.9
Adam	5.6	Ade	4.7
Emy	5.3	Tyler	5.7
Sara	4.10	Dane	5.1

We randomly divided the eight children into two groups, one control and one experimental. There were two computers placed in the classroom. The children from both of the groups had opportunities to work/play at computers. While a child from the control group interacted with the computer, a child from the experimental group worked with the computer observed by a researcher.

Instrument: Our research study was a quantitative and qualitative study, intending to examine the effect of a teacher's presence on children's mathematics learning with computers. A quantitative methodology was used in pre- and post-tests before and after our research project. We developed a rubric, with which we used to measure the results of the tests. However, when being with the children at the computer, we were unable to measure the occurrence with a pre-determined instrument because the occurrences were not fixed numerals. Therefore, the instrument of this part of our research was us, the researchers.

Data Collection: We administered pre- and post-tests before and after the subjects learned mathematics concepts with computers. The tests' scores were recorded. When the pre- and post-tests were administered, while one researcher reset up the materials for a test, the other was responsible for bringing a child to a the table where the test was given from either playground or from a learning center. We used unifix cubes with different colors, including red, green, yellow, and orange, to examine the children's understanding of patterns, and numerical counting. The subjects were asked to build with the unifix cubes following a pattern assembled in advance by one of the researchers (In addition to the six pre-assembled cubes (red, green and yellow, each child was expected to add six more) and then to count the number of the assembled unifix cubes (Each child was asked to count to 10). Then, this same child was given two plastic bag, each of which was filled with a number of plastic forks, plastic knives, plastic colorful shapes with two obvious different sizes adopted from a commercially produced attribute block box, sugar packages, and straws. The task of this child was then to pair items from the two bags. This activity intended to examine the children's abilities in terms of matching, shapes, and sizes. The provided shapes included square, rectangle, triangle, and circle. The final test item was to have the children identify numbers 1-10 that were neatly and clearly printed on a piece of paper.

Each child from both of the groups worked at a computer for four times, with each session lasting four 20 minutes. The children from both groups interacted with the provided software Mille's Math House produced by Edmark. This software was designed for preschoolers to enhance their awareness and understanding of basic mathematical concepts, including counting, numbers, shapes, and sizes. We took notes when each subject from the experimental group was learning with a computer but we did not give direct attention to the subjects from the control group. The notes were taken at the time when each subject began to learn with the computer to the time when each subject finished at the computer. While notes were being taken, we also used a video camera to record the process. Therefore, in addition to pre-and post-tests, our investigation also employed naturalistic observation to capture ways that children learn mathematics with computers.

Data Analysis: Naturalistic observation data of children's acquisition of mathematical concepts with computers provided us with valuable information. We reviewed our recorded data—notes and video taped data each time after a daily segment of the research project was completed. We compared with our notes to categorize and code the data in order to look for patterns. To analyze children's inquiry of mathematics, we developed a coding system involving five categories: numerals, counting, shapes, sizes and matching. We

coded the videotape and note of each child's working with the computer; we closely examined each of the target children as individual case studies to provide a kind of "think description" (Greertz, 1973), that is, we focused on the child's reaction to the section that he/she picked to play. In the analysis process, we were conscious of reliability. Our view is that reliability involves the community of scientists in reliable interpretations that were rationally and sensibly derived from the weight of the evidence that we collected (Ginsburg, Klein, & Starkey, 1998). We implemented this by viewing as a group the video segments of a child's working at the computer; next, each of us presented interpretations with specific and sufficient evidence to support the interpretations. We also compared the results of the pre- and post-tests to examine the impact that the computer had on children's learning of mathematics.

__Results:__ This research centered on the examination of the efficacy of the role that the teacher plays in children's acquisition of mathematics with computers. We conducted this research by staying with the children from the experimental group throughout. The principle was to closely observe the children working at the computer but to intervene at the right moment with questions that we considered as simulators. The questions that we posed and the intervention that we created were helpful in assisting the children to acquire concepts efficiently. Table 2, 3, 4, and 5 manifest the results of pretest and posttest taken by the children from the control and experimental groups. Table 2 and 3 demonstrate raw scores that the children from the experimental group produced whereas Table 4 and 5 revealed the raw scores of pre and post tests that the children from the control group gained.

In patterns, we provided three colors of unfix cubes, i.e., red, green and yellow. These three colors were constructed together in the order as red, green, yellow, red, green, and yellow. The children were expected to put together the same patterns. If a child had five colorful unifix cubes assemble in the ordered fashion, that is, red, green, yellow, red and green, he or she got 100 points. In matching, four shapes were offered. They were triangle, circle, square, and rectangle. If a child was able to match two different sets of the same four shapes, he or she had 100 points. The same token was applied to shapes, with 25 points each. In counting, if a child was able to count one to 10 without making a mistake, 100 points were given. The same rule was applied to testing of numbers. If a child recognized the printed numbers from one to ten, he or she attained 100 points.

Table 2

Name	Patterns	Matching	Shapes	Counting	Numerals	Total
Reed	20	75	100	100	70	365
Adam	0	50	75	80	80	285
Emy	80	100	100	100	90	470
Sara	60	75	100	100	60	395
Total	160	300	375	380	300	1515

Table 3

Name	Patterns	Matching	Shapes	Counting	Numerals	Total
Reed	80	100	100	100	90	470
Adam	60	75	100	100	100	435
Emy	100	100	100	100	100	500
Sara	100	100	100	100	80	480
Total	340	375	400	400	370	1885

Table 4

Name	Patterns	Matching	Shapes	Counting	Numerals	Total
Neth	40	75	75	90	80	340
Ade	60	75	75	80	70	360
Tyler	60	100	75	100	90	455
Dane	80	100	80	90	90	440
Total	220	350	305	360	360	1595

Table 5

Name	Patterns	Matching	Shapes	Counting	Numerals	Total
Neth	40	100	100	90	80	410
Ade	80	75	75	80	70	380
Tyler	80	100	100	100	90	470
Dane	80	100	80	90	90	440
Total	280	375	355	360	330	1700

The comparison of the grand total from Table 2 and Table 4 unveils that the children from the control group had a higher level of mathematical knowledge than those in the experimental group. With the supervision and intervention of the researchers at the computer, the children's mathematic scores in the experimental group increased from 1515 to 1885, having 14% growth mathematically (see Table 6 or Figure 1 and 2). The mathematical concepts that the children from the control group gained were not dramatic. The raw scores grew from 1595 to 1700, increasing 5%(see Table 6). Individual mathematic achievement also bears differential outcomes.

Table 6

Name	Before Test %	After Test %	Increase %
Control Group	63	68	5
Experimental Group	61	75	14

Figure 1

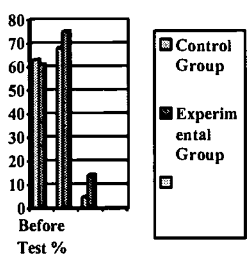


Figure 2

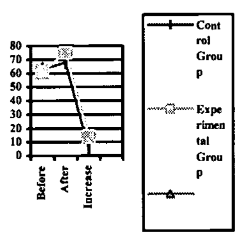


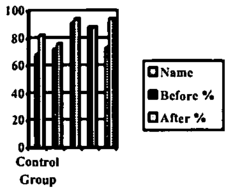
Table 7(or Figure 3 and 4) shows the general progress level of the individual subjects from the two groups in the inquiry of basic mathematical concepts before and after the treatment.

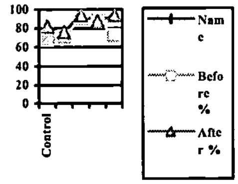
Table 7

	Control Group				Experimental Group			
Name	Neth	Ade	Tyler	Dane	Reed	Adam	Emy	Sara
Before %	68	72	91	88	73	57	94	79
After %	82	76	94	88	94	70	100	96
Increase %	14	4	3	0	21	13	6	17

Discussion: The focus of this research was on the effects of the presence of a teacher on children's construction of mathematical concepts with computers. The software Mille's Math House especially designed for preschoolers was chosen for this purpose. Eight subjects participated in this study with four randomly included in the control group and the rest in the experimental group. Two computers were moved into the preschool classroom for the subjects to manipulate. While each child involved in the study has a chance to play with the computer. The difference was the child at the computer from the control group might have his or her friends to join him or her, whereas the child from the experimental group had the researchers to accompany him or her. The researchers observed the child and provided necessary assistance

Figure 3 **Figure 4**





when it was appropriate time. The researchers also, at the right moment, intervened with provocative or stimulated questions in order to prompt the child's understanding and thinking. For example, Adam had trouble recognizing the numbers 6, 9, and 10. As Adam chose the section of the software "Drawing a Caterpillar, the researchers closely watched him and lent him a hand whenever it was a right teachable moment. Our presence and questions reinforced his understanding. His each achieved success built in him the confidence and encouraged him to explore more in depth. In the process of Take another example; Sara had difficulties in construct patterns. The pretest enabled us to follow her and provided her needed support and help whenever it was necessary. Her scores on Patterns increased from 60 to 100. Like the children from the experimental group, the children from the control group had the same amount of opportunities working with the same software. However, success, compared with the experimental group children, was little. For example, Reed had 40 points on Patterns, and 80 points on Counting and Numerals, respectively. After working with the computer, his posttest scores in these aspects remained the same, although he gained in Matching and Shapes. This situation occurred because Reed and his joined friends commonly found patterns and numerals difficult areas to comprehend. They might explore the sections of patterns and numerals. However, without proper expertise helps, Reed or his friends might quickly wanted to quick as they encountered "complex" situations that they did not conceive that they had capabilities to resolve. Although they might have attempted to give a few tries to the emergent problems, they were discouraged by not being able to attain right answers or apply right ways to work on the section.

Conclusion

Although it has been commonly recognized that computers develop children cognitively and intellectually (Clements, Nastasi, & Swaminathan, 1993; Davidson & Wright, 1994; Haugland, 1992; Haugland & Wright, 1997; Hohmann, 1994; Hoot, 1986; Wright & Shade, 1994), attentiveness should be given to developmentally appropriate practices (DAP) (Bredekemp,1987; 1997) in teaching and learning with computers. DAP suggests that to bring about effective results of inquiry, it is fundamental that a teacher understands the level and status of children's learning and how children retain concepts. Knowing about a child individually is conducive to promoting children's positive desire of deepening knowledge about the world around them. Vygotsky (1978) advises that a child is able to comprehend a certain thing on his own but needs an adult's help to reach maximal effect. Vygotsky's theoretical framework, Zone of Proximal Development (ZDP), sustains the conception that the role of a teacher builds a driving force in children's positive disposition to learn and that an adult should be a part of a child's learning process. Completely relying on himself, a child may feel discouraged when facing emerging problems that are difficult to solve alone by his limited amount of knowledge. Because of a limited and restrained body of know-how and understandings, a child is unable to govern successfully a learning process and resolve dilemmas unless the availability of the adult's attention and awareness exist. Provided that inability to do away obstacles that a child encounters undermines the confidence of the child to continue exploration of his interest, the perception that learning is unconquerable incubates as a result of constant failures. The availability and accessibility of the teacher's timely "rescue" may avoid this troubling phenomenon. A timely assistance is from the observance and from flexible thinking of the teacher.

To enhance children's learning, the teacher needs to be alert not only to children at traditional learning centers, but also to children at a computer center. Absolutely depending on children's autonomy at a computer is an inappropriate instructional approach. Inadequate amount of knowledge in academic domains and lack of computer techniques may possibly overthrow a child's initial excitement in learning. A teacher's ignorance of what is ongoing at a computer and of the demands each child holds about a computer can counterblow the child's determination of working with computers. A teacher's interruption at right moment rescues a child from an otherwise disaster dilemma at a computer (Chang, 1996). Intervening

at the right moment results from constant and attentive observation of the teacher and a sufficient body of knowledge that the teacher possesses about her children (Chang, 1996; Edwards, Gandini, & Forman, 1993). The quality of the teacher's work is followed by the increased confidence that children embrace. Highly self-assured feelings ensure the continuation of exploration that is the basis of extension and in-depth of understanding of concepts (Chang, 1996).

Although this research, a pilot study, results in a positive gain in terms of children's learning with computers with the attention from the teacher, the finding needs to be examined and tested. A future study may be considered to involve a large sample.

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Progressive Comparison of the Effectiveness of Computer-Assisted Instruction on Science Achievement: A Meta-Analysis

Edwin P. Christmann
Mathematics and Science Teaching Program
Slippery Rock University
United States
edwin.christmann@sru.edu

John L. Badgett
Mathematics and Science Teaching Program
Slippery Rock University
United States
john.badgett@sru.edu

Abstract: This study compared science students who were exposed to traditional methodology with those who received traditional methodology supplemented with computer-assisted instruction (CAI). From the 24 conclusions, an overall mean effect size of 0.266 was calculated, indicating that, on the average, students receiving traditional instruction supplemented with CAI attained higher academic achievement than did 60.4% of those receiving only traditional instruction. The effect sizes were categorized into four subject areas. In descending order, the mean effect sizes in general science, physics, chemistry, and biology are: 0.707, 0.280, 0.085, and 0.042, respectively. Differences in educational settings revealed that CAI is most effective among science students in urban areas; followed by those in suburban areas; and weakest among rural students. However, a -0.335 correlation between effect size and years indicates that the effect of CAI on academic achievement has declined during this period. Some of the findings were reported in Christmann and Badgett (1999).

Introduction

Since the 1970s, the American educational system has been besieged with criticism from the American public. In response to this criticism, the Bush administration created America 2000, a plan designed to ameliorate problems within the fading scholastic establishment of America. The Presidents Committee, inherent within America 2000, set forth goals including that by the beginning of the 21st Century, America's students would be ranked first in the world in science.

More recently, however, the Third International Mathematics and Science Study (TIMSS) reported another continuing truth about the waning science achievement of America's students. In summary, the report furnished little hope that America's students would be ranked first in the world in science achievement by the year 2000 (TIMSS, 1997).

American education is at a crossroads; current direction must be examined to reclaim the future competitiveness of American students. Educational research resounds with reports that have examined the effectiveness of computers in education, providing evidence that computers are valuable aids in the enhancment of student learning. Hence, much of the past research concentrates on a diverse latitude of subjects and settings. However, researchers are now able to examine prior findings within the context of the present through the statistical technique of meta-analysis.

The United States is in the process of entering a period of major change, in which a metamorphosis in demographics, shifting world commerce, updated technologies, and an emerging world order all suggest that a reorganization for our schools should be considered. Indeed, Mauriel's (1989) research suggests that students differ not only because of their social, economic and demographic backgrounds, but because of their educational environments as well.

Christmann and Badgett (1997a) suggest that further research is necessary to determine whether computer-assisted instruction (CAI) is comparatively more effective in different subject areas. In compliance with this suggestion, the purpose of the present study was to compare the contributions of CAI to student achievement in a

variety of science disciplines across differing educational settings. Thus, the study has disclosed those areas where CAI is more, as well as less effective than traditional methods of instruction.

Statement of the Problem

The necessity for improving science achievement in the American secondary schools was the catalyst for conducting this meta-analysis of all available science CAI research pertaining to computer-assisted instruction in varying educational settings. The study has focused on the following research question:

> What differences exist between the academic achievement levels of science students who were exposed to computer-assisted instruction, and those who were not exposed to this instruction within the academic areas of general science, biology, chemistry, and physics within three demographic settings.

The research evaluated the effectiveness of CAI on the science achievement of students across four science areas within urban, rural, and suburban demographic settings. Additionally, a comparison was made between the effectiveness of microcomputers and traditional instructional methods.

Methodology

The compiled data from the studies were analyzed through a meta-analysis technique, a secondary statistical analysis or re-analysis of previous research, which is used as a vehicle for answering new questions through existing data (Glass, McGaw, & Smith, 1981). In essence, it is a quantitative application of deduction that would have been impossible through any other previously known methodology (Borg & Gall, 1989).

Locating of documents. The studies examined in this research were selected from a computer search of the databases ERIC (1966 – March 1999), Dissertation Abstracts (1861 – August 1997), and PsychLit (1974 – September 1997). These databases were searched with the keywords "science;" "traditional;" "computer-assisted instruction;" "CAI;" and "achievement," which identified over 1000 studies to be reviewed for inclusion in this meta-analysis.

The studies included in this research met the following predetermined criteria:

1) they were conducted in an educational setting;
2) they included quantitative results in which academic achievement was the dependent variable and microcomputer-provided computer-assisted instruction was the treatment;
3) they had experimental, quasi-experimental, or correlational research designs;
4) the sample sizes had a combined minimum of 20 students in the experimental and control groups.

Eleven relevant publications met the predetermined criteria for incorporation within this meta-analysis; whereas rejected studies did not meet all four selection criteria for inclusion. The majority of those CAI publications that did not meet the criteria for integration into the study did not statistically analyze the reported data.

Analysis

As previously mentioned, the data were analyzed through the meta-analysis procedure, a technique that relies heavily on the calculation of effect sizes for establishing statistical meaning (Wolf, 1986). According to Glass et al. (1981), effect size is the degree to which a phenomenon is present in the population of the study. In meta-analysis, effect size is calculated to determine the presence of a statistical difference between mean standard deviation units (SDx) (Wolf, 1986).

Table 1

Content Area, Sample Size, and Effect Size of Each Study

Author(s)	Content Area	n	ES
Carnes, et al.	Physics	100	0.280
Durnin, R.	Gen. Science	154	0.928
Durnin, R.	Gen. Science	154	1.360
Durnin, R.	Gen. Science	154	1.000
Durnin, R.	Gen. Science	154	0.857
Emerson, I.	Biology	122	0.371
Glenn, C.	Gen. Science	300	0.600
Hauben, et al.	Chemistry	56	-0.338
Hauben, et al.	Chemistry	54	0.194
Hauben, et al.	Chemistry	54	0.507
Hauben, et al.	Chemistry	53	0.616
Hauben, et al.	Chemistry	56	0.429
Hauben, et al.	Chemistry	56	-0.048
Hauben, et al.	Chemistry	55	-0.256
Hauben, et al.	Chemistry	53	-0.842
Hauben, et al.	Chemistry	54	-0.107
Hauben, et al.	Chemistry	54	0.094
Horton, et al	Gen. Science	43	0.049
Hounshell, et al.	Biology	202	0.438
Lu, C.	Biology	56	0.030
Lewis, et al.	Gen. Science	148	0.156
Morrell, P.	Biology	56	-0.142
Morrell, P.	Biology	54	-0.485
Yalcinalp, et al.	Chemistry	101	0.685

Meta-analysis

Eleven of over 500 studies met the predetermined criteria for inclusion in this meta-analysis. Table 1 presents the content area, sample size, and the mean effect sizes for each study. A total of 2343 students participated in eleven studies, which resulted in 24 conclusions. The sample size ranged from 43 to 300; the mean sample size was 98 students.

Mean Effect Sizes

From the 24 effect sizes calculated, an overall mean effect size of the meta-analysis was also calculated. The sum of the 24 effect sizes is 6.376. The mean effect size of 0.266 is positive because higher scores were attained by those science students receiving CAI. However, Cohen (1977) classifies this effect as small.

Wolf's (1986) graphical interpretation of average effect in SDx units for the comparison between the traditional instruction group and the CAI group indicates that the average student exposed to CAI showed academic achievement that was greater than that of 60.4% of those students who were exposed to traditional instruction. Moreover, the typical student moved from the 50th percentile to the 60.4th percentile when exposed to CAI.

The 24 mean effect sizes across the differing content areas (see Table 2) were catagorized into four content areas, and the mean effect size was calculated in each of the subject areas where the effects of CAI on academic achievement were studied. The mean effect size of CAI on general science students' academic achievement was the

largest effect size in the meta-analysis, when comparing the effects between CAI and traditional methods of instruction. In descending order, the mean effect sizes by subject area are: general science, 0.707; physics, 0.280; chemistry, 0.085; and biology, 0.042, respectively.

Table 2

Content Area, Sample Size, and Effect Size of Each Study

Content Area	ESn	Effect Size (ES)
Physics	1	0.280
General Science	7	0.707
Biology	5	0.042
Chemistry	11	0.085

Relationship Between Effect Sizes and Time

A correlation for the data revealed that the mean effect size and progressive time span (in years) were significantly related, $r = -0.335$, $n = 7$, $p > .05$, two tails. Furthermore, Figure 1 displays a scatterplot showing a negative correlation between consecutive years and the effectiveness of CAI.

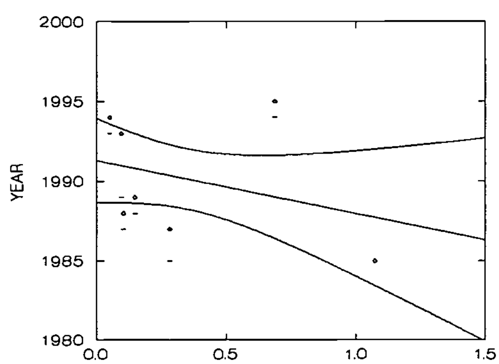

Figure 1. Relationship between mean effect sizes and years.

Discussion

This meta-analysis shows that CAI positively affects the achievement of science students in various content areas. Again, the specific objectives of the study were to: (a) select studies that utilized CAI as a supplement to traditional methods of instruction, (b) statistically analyze the studies through meta-analysis techniques, and (c) compare the effectiveness of CAI among different subjects and demographic settings.

Comparing mean effect sizes and differing years. Studies included in this meta-analysis were conducted between 1985 and 1995. The 24 effect sizes examined ranged from a low -.842 to a high of 1.360. During the ten-year span, the overall mean effect size by year progressively decreased from 0.049 to 1.072 (see Figure 1), thus contradicting Mason's (1984) belief in the relationship between technological advancement and academic improvement. However, this finding is in agreement with Christmann et al.'s (1997b) study, suggesting that decreases in effect size may be attributed to a widening between hardware and software development. Plausibly, the

software implemented between 1985 and 1995 was not in conjunction with the high performance hardware. Moreover, from 1985 to 1995, microcomputers were rapidly improved through the development of more advanced microprocessors. Markedly, the calculated effect sizes reflect a downward trend in academic achievement during the 1985 to 1995 period.

Mean effect size. The mean effect size calculation across the 24 conclusions of the 11 studies generated by this meta-analysis is 0.266. Cohen (1977) interprets this effect size as small. The difference in academic achievement resulting from CAI was an improvement of 10.4 percentile ranks from the central region of the distribution. Using this measure, it can be concluded that CAI is more effective than traditional methods of instruction in raising overall academic achievement in science content areas. This finding supports the research of Bangert-Drowns et al. (1985), which shows a positive effect of CAI on academic achievement in secondary schools.

Comparing mean effect sizes by different science content areas. The mean effect sizes were tallied according to subject matter, showing that: one was calculated in physics; seven in general science; five in biology; and eleven in chemistry. When comparing CAI with traditional instruction, the largest mean effect size occured in general science (0.707), indicating that the average science student exposed to CAI attained academic achievement greater than that of 78% of those general science students exposed to traditional instruction.

Computers and science achievement. Microcomputer simulations enable students to learn science through their actual experiences rather than through the transposed method of reading or the discussion of actual experiments. Here, students can complete experiments that are ordinarily considered hazardous, unworkable, or unrealistic. For example, simulations can engage students in research where an analysis of the genetic attributes of many generations is concluded within a single laboratory session. Other problems, such as experiments with motion, force, velocity, temperature, diffusion, osmosis, mitotic division, and population problems can be simulated by microcomputer-based software in a minimal time period at a nominal expense. Such simulations release students from time-consuming procedures so that they can intensify the comprehension and mastery of additional subject matter.

Table 3

Educational Setting, Sample Size, and Effect Size

Content Area	ESn	Effect Size (ES)
Urban	1	0.685
Suburban	18	0.273
Rural	5	0.156

Different educational settings. The mean effect sizes were tallied according to demographic setting (see Table 3). CAI appears to have its strongest effects among science students in urban settings; its effects are weaker among suburban students; and weakest among rural students. The mean effect size of the study in urban settings was 0.685. In suburban areas, eighteen studies yielded a mean effect size of 0.273, and a mean effect size of 0.156 was calculated across eight studies in rural educational settings.

In conclusion. Educational planners should understand that meta-analysis is a method of reexamining existing research; it is not a forecaster of prospective developments in science education. Therefore, it should not be concluded, for example, that CAI will never be effective in raising student achievement in chemistry, or in any other subject area. Clearly, more research is needed to determine whether CAI is more or less effective among certain kinds of students or within certain academic areas, thus eventually leading to a more effective use of CAI among science students. Regretfully, however, only a paucity of comparative research has been directed toward this phenomenon in recent years. Specifically, as Miller (1999) laments "When policy is made, do people reflexively ask, 'what does the research say?'" Thus, it is imperative that immediate research be conducted to determine the effectiveness or ineffectiveness, of CAI in the science classroom of America's schools.

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Enhancing Science Field Trips with a Digital Camera

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

Alice Hosticka
Early Childhood Education / Reading Education
Georgia Southern University
USA
ahost @gasou.edu

ABSTRACT: Digital cameras in the science classroom can be used as a tool to enhance field trips. Field trips are meant to provide students with important hands-on experiences to further the goals and objectives of the curriculum. Many times they turn into no more than a day away from school. These trips can add value to the curriculum by providing pre-trip preparation, structured experiences on the trip, and experiences taken back to the classroom from the trip. The digital camera can be used to develop materials to use in preparation for the trip and record aspects of the trip to bring back to the classroom for further study. Although film based technologies can provide the same opportunities, the use of the digital camera provides a hassle-free way to capture, manipulate, and present images relative to the instruction.

Field trips are designed to provide students with important hands-on experiences to further the goals and objectives of the curriculum. Many times these trips turn into no more than a day away from school. In order to add value to the curriculum, field trips should provide valuable content information to connect what is being studied in the classroom with the out of school world. Teachers must carefully plan the experience prior to the trip to include relevant content and methodologies related to the instructional experience. There are three distinct stages of a well-planned field trip. First is the pre-trip preparation of the students, second the experience of the trip and thirdly the use of the trip experiences in subsequent instruction.

The pre-trip preparation includes an overview of the visit and tasks to be accomplished for further study after the trip. On the trip experiences should be structured so that they directly correlate with the experiences back in the classroom. The camera can be used to develop materials to use in each of these stages. Using a digital camera provides a relatively easy way to capture, manipulate, and present images to be used in the instructional process. Film based technologies can be used to provide these materials but is a much more cumbersome process. On the field trip, incorporating visual images enriches the experience by allowing the students to process information visually. This limits the need for students to write and make sketches of what was seen on the trip. Photographing with a digital camera provides images that can be viewed and/or downloaded immediately. Images can be analyzed in the field and if undesirable can either be retaken immediately or deleted. The ability to delete unwanted images and to manage storage space allows the user to get the picture they want and maximizes the number of usable pictures taken. Digital cameras save pictures in standard JPEG format, which is compatible with a wide variety of computer programs and can be directly inserted and integrated into word processing, database, desk-top publishing and presentation programs. Cost of image use, following the initial outlay of funds for a digital camera and storage device (flash card or floppy disk) is minimal. Therefore, one time funding provides equipment and materials for use over several trips and years. Eliminating continuous costs encourages teachers and student to use the camera frequently.

Using the Camera as a Pre-trip Tool

Using the camera to develop pre-trip activities requires teachers to produce material to provide the students with an overview of the coming experience. Pictures of the site to be visited serve as an advanced organizer or anticipatory set to the field trip. These materials can be used to prepare students to pursue problem tasks in small group investigation on the trip by providing images of actual examples of what they will see. This will help the teacher explain the tasks to be studied in the context of the trip. Presetting of the task eliminates the need to use valuable time on the trip. As these tasks are being set, they should be integrated into the content of the curriculum that the field trip is to complement. During instruction, a lesson on the specific concepts that provide the prerequisite skills necessary for a task, or observation, could include the images from the

location of the trip. When working on concept development (giving examples and non-examples), images from the field trip location could be included. Use of a digital camera can provide images for first observation opportunities. Often times when we first observe something, we do not know what to look for. Using these images the student can note specifics and then on the trip they can focus on these specifics and go beyond them.

On the Field Trip

Using the camera on the field trip provides the opportunity to preserve aspects of the experience that can then be brought back into the classroom for further study. While on the trip students can document their investigations by taking pictures of relevant experiences. They can gather images of specific items that have been predetermined to fit into a database of information, and to look for trends, patterns and functions. Finally they can use the images to record events, not limited to those which have been predetermined, that will be used for future study when back in the classroom.

After the Field Trip

After the field trip the student could use the digital images taken on the trip in follow up classroom lessons to complete the tasks started in the field. The use of field manuals to identify the specific species observed and to look for similarities and differences in members of a population are examples of this type of task. Students can develop presentations of their investigations in either a show and tell experience at the primary level or a report of the study that would incorporate both text and images at the middle grades and secondary school levels. On a field trip designed to collect information for further study the images would provide an important part of the base for subsequent instruction. In tasks focusing on research of specific topics, the images provide data to either support or refute pre-field trip hypotheses and suggest other hypotheses for investigation.

Illustrations of Three Field Trips

Three field trips that can be taken in the K-12 situation will be used to illustrate the use of the digital camera as an enhancement for the experience. At the early primary level, field trips are taken to explore the student's community and its workers; an example of a field trip to a local beekeeper will be used. The middle grades, where field trips provide students with an opportunity to simulate activities done in the world of work, the example will be a study a biological habitat of a coastal barrier island. The secondary field trip, designed to bring content into the classroom to analyze, will investigate the integration of geometry into the structural design of the community and its buildings following a visit to a city or construction site.

Primary Grades

At this level, social studies objectives focus on the community and the interdependence of its members, science is working on process skills such as classification and observation and the content objectives of the animal life around us, and math is working on serration and classification. The study of honey and its production is an appropriate topic and one that will capture the student's interest. The study should include the process and sequence of honey production, the care of the insects, and the distribution of the products. A pre-trip presentation of the overview will familiarize students with what they will see. There are many things the students can do and see on a trip to the bee yards, including the bees. They need to know safety behaviors to eliminate startling the bees and to reduce the chance of getting stung. Young children viewing bees for the first time may become excited, crowd around the bees to get a closer look or run away in fear. The beekeeper will smoke the bees to make them less active. Children made familiar with the purpose of smoking and what the bees and the supers look like through digital images before coming on the field trip can remain calm and take turns viewing the live bees without pushing and shoving, or showing signs of fear that may alarm the bees. On the trip, students will be given a chance to view the bees, the extraction of the honey from the supers, the bottles of honey and the wax, in addition to doing a little research on the site. One of the research tasks for students could be to investigate where the bees gather their nectar. For this task the teacher would define survey areas by loops and have the students survey the bee activity within each area. These survey areas would include a variety of flower populations and the students would tally the number of bees moving in and out of the area as part of the survey. This task requires students to be able to tally information. The prerequisite instruction on this could include a picture of an area they will see on the field trip, with bees. The students count the bees in the picture and make a tally mark for each bee seen. While the concept to be generalized is taught using many different examples including an example from an upcoming field trip makes the task on the trip familiar when the students are asked to do it.

At a primary level most of what we want the students to do is work on gathering broad-based awareness of the experience. On the trip students could take pictures of what they see to help recall the experience and set it in their knowledge base. While developing a formal database may not be conducive to every field trip topic and age range. Children could take pictures of all the types of flowers they see the bees on and use the survey data begin to sort by the number of times a bee went to each type flower. This would provide a knowledge base from which to discuss how different types of honey are formed, i.e., orange blossom,

clover, and blackberry. Pictures of anything unusual that a child or teacher saw could be taken, the children can discuss the trip and determined more questions to ask on a follow-up visit by the bee keeper to the classroom. The teacher and the beekeeper could take additional pictures that may help answer theses questions after the students made the trip.

Middle Grades

In middle grades science, students study the knowledge base of the interdependence of the separate populations in a specific habitat. In mathematics, they use numbers to quantify trends and predict the future. An overview of the biological habitat of a coastal island provides the students with a chance to study the effects of the different types of land forms and their plant life (the beach, primary dunes, inter dune meadows, secondary dunes, the maritime forest and the marshes). The use of pre-trip visuals encourages the students when on the trip to focus in on more detail and specific variations then a first time viewing would allow. A student who knows what to look for will begin finding instances of the concept immediately. The teacher on this trip would want the students to not only note the different zones and their habitat but to also pick a specific aspect to study, such as the plant or animal populations. On the beach, one of the task groups may be assigned to study ghost shrimp populations. Photographs of the area of the beach where ghost shrimp are located, an active ghost shrimp hole, and illustrations of appropriate survey techniques prepare the students to be able to begin the study upon reaching the beach without the need for the teacher to explain the task. A group assigned the task of studying live mollusks on the beach, that has the prerequisite knowledge of identifying the footprint of a mollusk, the track the animal leaves and what the animal looks like, can begin to locate live mollusks immediately. Unfortunately, at any one visit there is no guarantee that specific shelled animals will be present but from study before the trip using pictures, the students have trained their eye so they know what to look for and can transfer this knowledge to the animals present. On a trip, pictures of biological specimens of plants, shells, animals, birds, and insects could be taken and then looked up in the field guides back in the classroom. Using a field guide with the images after the trip will encourage the students to focus on the details of the specimen and spend time gathering more information on the trip. Using the guides they can note likeness and differences in specific specimens within and across species.

Databases could be developed of such things as bird sighting, shell types, crab sighting, etc. A database for a population such as birds gives students the chance to identify patterns in size of populations, time of day the birds are seen, behavior, and migratory patterns. The information in the database could be increased by the class or individual class members who might return to the site of the field trip over the year or by using data from previous class trips. Looking at other pictures in the database would lead to a discussion of the range of the bird. For instances, if a middle grades class kept the database beyond the field trip, students could record sightings of herons in many different settings and add it to the database. Sightings included in the database could be from the Atlantic Coast, Pacific Coast, Great Lakes, inland waterways, and marshes. A group looking at live seashells, when doing a population study, can bring back information showing the a footprint of a buried mollusk, the track leading to the animal, the uncovered animal to verify the type. The group could then take pictures to document the aspects being studied of the animal (if the survey addresses size, a picture with a measuring tool would provide evidence, without having to remove) before reburying. The images provide data in instances where it is undesirable to remove specimens due to environmental restrictions, possible hazards of handling an unknown specimen, or violating state or federal law.

Secondary

At this level, much of what we do is only successful to the degree the student sees how it is going to help them "in life". Chances to make connections between the classroom and the world the student will be entering are always needed. In the geometry classroom, the use of the shapes and formulas in construction could be made apparent to the students. A field trip to a city will provide examples of the role geometry plays in the design and construction of a city. Images of different building and their functions would provide the "eye" necessary to view the actual buildings. A general presentation of buildings with accompanying architectural drawings, showing the relationship of the design to the finished product provides an overview of the trip. For example, showing an image of a finished hotel / motel constructed of individual modules which were built off site and imported into the construction site as prefabricated units could be used to illustrate how geometry is necessary to determine the relationships and measurements of each unit. Students on the trip could then look for current examples of this type of construction. Students given the task of looking for buildings showing examples of the architect's use of golden rectangles, would be shown an example from an image of a building with this feature and would then search the city for further examples. Other mathematical principles that can be illustrated include the parallel postulate, instances of geometric solids, and use of similar triangles to determine height. When on the trip, documenting geometric application is done by taking pictures of a variety of buildings to provide a wide range of shapes used. Images would replace sketches and written notes. These images would then be imported into a draw program for future instruction. Pictures imported into a draw program can be analyzed to complete the given task. This could be done by manipulating and studying the characteristics of the shapes, using a grid superimposed on an image to develop formulas for geometric aspects of the building, or to show elements of projective geometry by drawing vanishing points. A database on buildings could be developed and might include the function of the building, the dimensions (including square footage of floor space & cubic volume of usable space) image of buildings and image of the building's environment to show esthetic qualities.

Teachers: Using Digital Images After the Field Trip

The images also have uses that are not included in the planning of the trip. The images could be used to enhance future instruction, evaluate the objectives related to the field trip, and provide documentation of the quality of instruction provided by the trip.

Teachers can build a collection of the digital images taken on the field trip for use in follow-up activities either identified in the planning stage, when questions that were not planned occur or at a later date if questions that relate back to the experience arise. Images from several field trips could be combined to compile a resource file for use with future classes. On field trips often times unique things occur that the teacher may want to preserve for use in future classroom presentations. A bee keeper may be requeening or medicating a hive; a bird or shell might be on the beach that is unusual or not in season during the field trip; or a building under construction would offer an opportunity for taking pictures to compare later with the finished product.

Images from the trip can be used when developing evaluation instruments of the content delineated by the curricular goals and objectives for which the field trip provided instruction. At the primary level a child could demonstrate their oral skills by giving show and tell reports of pictures taken on the field trip. At the middle grades and secondary level test questions could present a visual image and ask the students to identify or discuss the situation (e.g., include the identification and the use of plants for medical use, both historically and presently). Demonstration of the student's ability to use research tools could be documented by presenting the student with a picture of a plant or animal and have them use the appropriate field guide to identify the specimen and its characteristics. For instance, birds in flight are often shown in silhouette in the field guide. This is very hard for the neophyte to see and remember in the field. Looking at a picture they can begin to compare what they saw with what is shown. Teachers can have students include images in papers and reports of investigations that will be used in portfolios and other authentic assessment situations of the student. Images collected from all trips could also provide excellent documentation of the quality of instruction the teacher is providing and could be included in a portfolio of their own work when needed.

The teacher could construct a virtual reality (VR) field trip to be used as part of the advanced organizer to prepare students, to be used after the trip to debrief the student, and discussion what was and was not seen. A VR field trip could provided students who missed the trip an opportunity to participate in the planned experience. In addition it could be used to allow the parent to see what the students will experience.

We have presented ideas from only three examples of field trips. As teachers use and become familiar with the camera they will find that using the digital camera frees them from the worries and expense of film based pictures, the time consumption of processing images, and expands their ability to manipulate the pictures and insert them into classroom presentations.

RiverWatch Project: The Confluence of Science and Technology

Gregory A. Coverdale, Ph.D.
Department of Behavioral Sciences and Education
Penn State Harrisburg
United States
gcoverdale@earthlink.net

Abstract: National standards in science education argue that science learning should be interdisciplinary, inquiry-based, and involve students in real-world projects. Most rhetoric in science education also argues for technology integration in science instruction. This paper describes the RiverWatch project, which integrates science and technology, and models scientific collaboration between 5th grade students in Indiana and preservice teachers at the Pennsylvania State University in Harrisburg.

Introduction

> I am pessimistic about the human race because it is too ingenious for its own good. Our approach to nature is to beat it into submission. We would stand a better chance of survival if we accommodated ourselves to this planet and viewed it appreciatively instead of skeptically and dictatorially. E.B. White in (Carson 1962).

One aspect of science education that is often minimized in schools is a history of science itself. In thinking about this article and my students' work in science education, I was drawn back to one of the classic works in science research and writing: Rachel Carson's *Silent Spring* (Carson 1962). Carson's purpose for writing *Silent Spring* was to inform America of the dangers of DDT and other toxic herbicides and pesticides to the environment, wildlife and its habitat, and to humans. As I revisited this classic case, I was struck both with the courage of the author (writing in the face of massive opposition from the chemical industry) and the clarity with which it foreshadowed environmental issues that still frame the national discourse. Indeed, *Silent Spring* became a manifesto for the environmental movement that began in earnest in the 1970's.

Silent Spring was pessimistic about then current practices of society and the effects of these practices on the global ecosphere. The book began with a fable about a fictional town that became poisoned by pesticides due to the indifference of its citizens. In the fable, songbirds and fish disappeared from the landscape. Livestock sickened and died, and life itself became endangered. Carson ended the fable by stating:

> This town does not actually exist, but it might easily have a thousand counterparts in America or elsewhere in the world. I know of no community that has experienced all the misfortunes I describe. Yet every one of these disasters has actually happened somewhere, and many real communities have already suffered a substantial number of them. A grim specter has crept upon us almost unnoticed, and this imagined tragedy may easily become a stark reality we all shall know (Carson 1962, p. 3).

Given today's debate about genetically engineered food, irradiated fruit, and organic farming practices, Carson's story is still poignant today. As I re-read Carson, I began thinking deeply about how educators today could teach children about the environment and ecology, thereby helping them become scientifically literate citizens. This paper focuses on one pedagogical approach to effecting environmental and technological knowledge in today's youth.

The purpose of this paper is threefold. First, the paper will describe a long-term project that utilizes information technology and promotes hands-on, minds-on learning in Environment and Ecology (E & E). Next, the paper will describe the integration of environmental science and information technology in the RiverWatch project. Finally, the paper will discuss implications for Pennsylvania's preservice teachers as they prepare themselves to meet the new requirements in Environment and Ecology.

Rationale

Two-thirds of Americans report that they either know "a lot" or "a fair amount" about the environment (NEETF 1998). However, when specifically tested on their environmental knowledge, many Americans reveal they possess misinformation and misconceptions (NEETF 1998). For example, when asked to explain the "goal of paper recycling programs," 63% of respondents gave incorrect responses. The average score on the NEETF/Roper Survey is 2.2 out of 10. Thus, America's report card on environmental knowledge is not good (NEETF 1998).

To compare the national cross-section of survey respondents to my elementary preservice teachers, I administered the 10-question NEETF/Roper Survey as a methods course pretest. Although this represents a small sample (N = 49), the average score of 6.5 out of ten indicates that even university students with college-level science courses on their transcripts still need substantial content knowledge preparation in E & E so that they will effectively integrate E & E as a core elementary subject.

The new millennium will see continued emphasis in science education and technology integration in Pennsylvania's schools. Joining the current standards-driven K-12 curricula is a new player in the core curriculum: Environment & Ecology (E & E). All elementary children are required to have E & E in their official curriculum every year. To help K-12 teachers frame their instruction in E & E, the state legislature has approved comprehensive academic standards for E & E.

A 1997 statewide assessment in E & E found that professional development and preservice teacher education in E & E "to be among the greatest E & E needs in the Commonwealth" (Johnson and Hoy 1998, p. 4). Currently, no colleges of education in Pennsylvania require preservice teacher preparation in E & E. This finding highlights an interesting paradox: K-12 students are responsible for rigorous core knowledge in E & E, but their future teachers have little content or pedagogical content knowledge in this field. In addressing this paradox, the Pennsylvania Department of Education is drafting three proposals, which will directly impact preservice teacher preparation in Pennsylvania:

1) E & E will soon be included in teacher preparation requirements;
2) E & E academic standards for K-12 students have been approved; and
3) A statewide assessment test is being developed that will assess students' knowledge in E & E, science, and technology.

These new standards and requirements in E & E seem to be in line with current research that suggests using the environment as "a framework for interdisciplinary, collaborative, student-centered, hands-on, and engaged learning" (Lieberman and Houdy 1998, p. 1). In *Closing the Achievement Gap*, Lieberman and Houdy (1998) assert the following educational benefits of using the environment as an "integrating context" (p. 1) for learning:

•better performance on standardized measures of academic achievement in reading, writing, math, science, and social studies;
•increased engagement and enthusiasm for learning; and
•greater pride and ownership in accomplishments (Lieberman and Houdy 1998).

In *Technology and the New Professional Teacher: Preparing for the 21st Century* (NCATE 1997), the National Council for the Accreditation of Teacher Education describes the impact of technology on teaching, provides case studies of exemplary technology integration in school curricula, and frames new requirements for teacher preparation institutions. NCATE (1997) asserts that "the new technology will transform the role of the teachers as thoroughly as did the introduction of printed textbooks" (p. 5). Thus, there exists a confluence of science and technology that will provide a major challenge to inservice and preservice teachers as the new millennium dawns.

The RiverWatch Project

Hoosier RiverWatch is a state-sponsored water quality monitoring initiative that involves schools, clubs, and citizens in collecting water quality data. RiverWatch has three major goals:

•to encourage local action to improve watershed management;
•to encourage volunteers to prevent pollution and cleanup streams; and

•to provide data to state agencies so they can improve planning for streams and watersheds (DNR 1997).

The RiverWatch project began in 1997 with a partnership between the author and his elementary science education students at DePauw University, Greencastle, Indiana, and a local fifth grade teacher, Ms. Eve Startk. The project focused on a water-monitoring project on the Little Walnut Creek, which is just outside of Greencastle. Through a series of field trips, 5th grade students worked with DePauw students to establish baseline data on the water quality and riparian forest buffer of the Little Walnut. This long-term, inquiry-based, collaborative project was a good representation of the goals for engaged science teaching and learning asserted in the *National Science Education Standards* (NRC 1996). Research questions that framed this project include the following:

•how ecologically healthy is the Little Walnut Creek?
•how might the creek's health change over time?
•what factors affect the creek's health?
•do physical, chemical, and biological indicators change over time?
•what can we learn about the Little Walnut Creek watershed?

Through the 1997 and 1998 school years, Ms. Stark's students implemented RiverWatch using the "trend monitoring" technique. Using this technique, students performed tests on a regular basis, over a long period of time. This technique provides a broad view of a stream's health and teaches students to distinguish seasonal variations from long-term changes (DNR 1997). Trend analysis data included the following parameters used to monitor water quality:

Habitat	*Chemical*	*Biological*
watershed land use	dissolved oxygen	benthic macroinvertebrates
stream bank, channel, flow	nitrate nitrogen	
riparian zone	total phosphate	
	biochemical oxygen demand	
	pH	
	turbidity	
	temperature	

In the second year of the project, 5th grade students submitted their data electronically via a worldwide stream quality database called RiverBank. This allowed students to share their research with other students across the country, and analyze stream data from various U.S. watersheds.

In the 1999 school year, Ms. Stark continued the RiverWatch Project but the author had assumed a new position at the Pennsylvania State University in Harrisburg. In Fall 1999, elementary science methods students at Penn State Harrisburg began trend monitoring on the Swatara Creek, which is part of the Susquehanna River watershed. Penn State students and Ms. Stark's students shared their research results throughout the semester.

Interdisciplinary Science

Ms. Stark's elementary students focused primarily on trend monitoring on the Little Walnut, and enriched their science study through children's literature selections, and by participating in an Internet-based project called Rivers of Life, a virtual trip down the Mississippi River during flood season. In this project, students learned about land use, ecology, and watersheds. Interdisciplinary activities included data collection, analysis, and graphing, utilizing information technology, poetry writing, and looking at how archeology uncovers the history of a river. Students' poetry and trend monitoring data were also published in a state journal, *The Riparian* (Indiana Rivers and Streams Project & Water Watchers of Indiana 1999).

Penn State students implemented trend monitoring on the Swatara Creek, but also focused on other environmental issues discussed in the *Report of the Pennsylvania 21st Century Environment Commission*. Issues outlined in this report provided an interdisciplinary view of E & E and included:

• land use;
•conservation of natural resources;
•water quality in a healthy environment; and
•air quality, waste, and efficient energy use (21st Century Environment Commission 1998).

Penn State students' trend monitoring focused on habitat, chemical, and biological parameters. In cooperation with experts from the Chesapeake Bay Foundation, students also focused on collecting data on the Swatara Creek riparian forest buffer zone. Parameters of this study included:

•water quality;
•streambank stabilization;
•habitat provided in the buffer zone; and
•aquatic habitat.

Technology Integration

> The moment man first picked up a stone or a branch to use as a tool, he altered irrevocably the balance between him and his environment....While the number of these tools remained small, their effect took a long time to spread and to cause change. But as they increased, so did their effects: the more the tools, the faster the rate of change. James Burke in (Gates 1999. p. 63).

Information technology was used as the primary tool for collaboration between Ms. Stark's class and the Penn State students. Ms. Stark has developed a classroom web page and an extensive PowerPoint presentation that have both been used in conference presentations.

During the Fall 1999 semester, Penn State students shared their trend monitoring results with Ms. Stark's class via two mediums: email and digital photographs. Penn State students conducted field tests once per week, compiled and analyzed results using Microsoft Excel, and emailed their results and digital photographs to Ms. Stark's students. Ms. Stark's students maintained a continuous dialogue via email and asked pertinent questions about the analysis process. A sample email exchange follows:

> 5th Grade Students: We are giving you our update on RiverWatch. It was quite a day at the river. We were surprised at some of our results at the site. The benthic macroinvertebrates was really low with a only a total taxa rating of 9. We found what we think are some rat-tailed maggots which are tolerant to pollution, and one aquatic worm which is also tolerant to pollution. One thing that we were all concerned about was the water quality based on the benthic macros which was poor. Otherwise we had some better results in the chemical tests from the lab. We did have a higher total phosphate than normal. We are seeing different results because it has been so dry here and the level of the river is very low. It was only 70cm deep compared to 120cm that we usually have. We are interested in what you found at your river. Send pictures too.

> Penn State Students: Your taxa count was really low compared to last season's numbers. You mention an interesting point about the very low water level, which we also noticed from the digital images. Frankly, we were shocked at the low water level of the Little Walnut. How would lowering water levels potentially contribute to increased levels of pollution and therefore the presence of pollution tolerant species like the rat-tailed maggot and worms? Today in class we are going to do our taxa count and graph the bottom profile of the Swatara. To give you some idea of the water depth, etc. the stream was 53 meters wide yesterday, and about 51.5 meters wide today. Please stay in touch as your research progresses.

The email exchanges between the preservice teachers and the 5th graders proved profitable on several occasions. For example, when Penn State students were puzzled by their chemical results, they emailed the results to the 5th graders. The email reply suggested that the test tubes used to collect the water samples might have been dirty and the recommendation was to clean the test tubes and repeat the tests. This proved to be good advice and illustrated the power of telecommunications in science collaboration.

The next stage of technology integration scheduled for the Spring 2000 semester is to implement scientific collaboration via Quick Cam technology. This will allow real-time video communications between classes via the Internet.

Conclusion and Implications

As the literature review indicated, inquiry-based science instruction combined with technology integration are mandated by current standards in science, technology, and E & E. Preservice teachers should be involved in projects that integrate these disciplines and model scientific inquiry. The collaborative RiverWatch project has enabled fifth grade students in Indiana and preservice elementary teachers at Pennsylvania State University in Harrisburg to gain experience in this interdisciplinary, technology-based learning.

Because trend monitoring is a long-term process, Penn State Harrisburg students will continue to participate in RiverWatch and expand its partnership to include several schools in central Pennsylvania. As technologies continue to emerge, they will be integrated as necessary into RiverWatch so that more data on technology integration in inquiry-based science can be collected, analyzed, and shared with the education and research communities.

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Animations in Physics Learning

Patric Dahlqvist
Department of Computer and Systems Sciences
Stockholm University and Royal Institute of Technology, KTH. Sweden
patricd@dsv.su.se

Abstract: The study reported on in this paper investigates the effects of different presentation formats on learning an important principle in classical mechanics (the principle of equivalence). The presentation formats were abstract (classical vector representation), analogue (a more experience based illustration) and animated analogue. The study was conducted (N = 55) at the department of physics, Stockholm University.

Analyses indicate that animations do not facilitate learning in this case. An interesting observation is that the analogue and animated groups performed better than the abstract group on the analogue problems. But the abstract group did not outperform the other groups on the abstract problems. A tentative interpretation is that it is easier to move from an analogue representation to an abstract than vice versa. Another interpretation is that it may be the case that the students in the concrete conditions expended more effort into applying an abstract thinking on their concrete memory image.

Introduction

When arguing for the use of multimedia in educational settings the usual argumentation follows the "more is more" path (Scaife & Rogers, 1996), that is: a picture is better than (a thousand) words, an animation is better than a still, sound is better than silence, etc. However there is not much empirically founded work to support that line of arguing. In this study we try to address some of the questions regarding the effectiveness, in regard to learning outcome, of different multimedia presentational formats in the domain of Physics.

Theories of cognition and learning

The cognitive theories that are of interest in this study are of two different categories; theories about learning in general and theories about the interplay of different presentational formats.

There is an ongoing debate within cognitive science between what could be called the situated camp (e.g. (Lave & Wenger, 1991)) and the traditionalist camp (e.g. (Andersson, 1995)). The issues discussed are very interesting and have direct impact on the design of learning material. However important and interesting this debate is, we believe that the results of this study could be applicable in both camps (Wærn, Dahlqvist, & Ramberg, 2000).

When creating instructional material you have to be aware of what your goal is. Understanding, remembering, or applying are three different outcomes. A strategy that facilitates learning in one of these outcome classes need not facilitate learning in the others (Levin, 1989). Ohlsson (1996) makes a distinction between skill acquisition and higher-order learning. In skill acquisition the outcome is competence. The outcome of higher-order learning, on the other hand, is understanding. Skill acquisition has throughout the short history of cognitive science been quite successful. There are models like ACT-R and SOAR which are both theoretically powerful and empirically founded (Reimann & Spada, 1996). Research about higher-order learning, on the other hand, is still in its infancy (Ohlsson, 1996). What we aim at in this study is what Levin would call understanding and what Ohlsson might prefer to call higher-order learning.

It is fairly well established that visual instruction aids are very powerful means for enhancing learning (Wærn, 1995). However, since human attention and perception is limited, different presentational formats can interfere with each other (Andersson, 1995). Paivio has put forth a theory about the processing of information in the mind, the Dual-Coding theory. In this theory he claims that the human mind has two distinct (but inter-connected) systems, one to process language and another for the rest of the information (Paivio, 1986). These theoretical arguments

promote the use of multiple presentational formats in instructional material. This claim is also founded on some empirical findings. Mousavi, Low, and Sweller (1995) for instance, claim to have increased learning of geometry problems by mixing auditory and visual presentation modes.

Presentational Formats

When constructing instructional material, whether it concerns books, videocourses, or educational software, there are many different ways to present the learning material. The choice of media puts different restrictions on which presentational formats are possible. For example, it is not possible to use sound in an ordinary book. But there are still many choices to be made: text or picture, diagram or images, etc.

Illustrations

The use of pictures in prose has been thoroughly studied by many research programs (for a longer summary see (Willows & Houghton, 1987) or (Mandl & Levin, 1989)) and it is quite clear that, used with some common sense, pictures facilitate learning from text. Pictures in themselves can have different functions. Levin (1989) has classified pictures in prose learning according to five different functions: Decoration, Representation, Organization, Interpretation and Transformation. There is no uniform theory or even design principle that states how to use pictures in all learning situations. It is very much dependent on the task. The saying that "a picture is worth more than a thousand words" is not always true (Winn, 1987). Levin (1989) joins the cautious choir and states: "Two things that we have learned from research on pictures in text are that pictures are not uniformly effective in all prose-learning situations, and that not all types of pictures are equally effective." (p. 97)

Animations

In many computer-based instructional products animations have become popular. Unfortunately, the animations are often used to impress rather than to teach (Rieber, 1990a). There is a lack of theoretical foundation for the use of animations in computer-based instruction. Animated graphics represent a subset of instructional graphics but to which extent animations depart from and coincide with static visuals is questioned (Rieber, 1990a).

In contrast to static graphics, animated graphics can show information about two important visual attributes: motion and trajectory. Animations can provide information about an object's motion, if it is moving, if the motion is changing, and how it is moving (path, patterns, etc.). They can also show information about which way the object is moving (Rieber, 1996).

There has not been very much research done on how, if at all, animations can facilitate learning. However there are some studies (ChanLin & Chan, 1996; Mayer & Anderson, 1992; Mayton, 1991; Poohkay & Szabo, 1995; Rieber, 1990b; Rieber, Boyce, & Assah, 1989). The problem is that the results are inconsistent. Rieber (Rieber, 1990b) shows that animations facilitate learning for children (under certain conditions) but not for adults (Rieber et al., 1989). On the other hand there is for example the study by Mayton (1991) which suggests that the use of animations in computer-based tutorials can be beneficial for adults.

Even though the results from the research on animations in instructional material are mixed to some degree, the use of animations in computer-based instruction still appears to have significant potential (Milheim, 1993). Palmiter and Elkerton (1993) found in a study that in a condition of text only, users spent less time learning a different, but similar, task than did the users furnished with animations. Milheim has put together a set of guidelines (Milheim, 1993) on how to design and use animations in instructional material. Some of these guidelines are:

- Develop simpler animations rather than complicated ones. In general, the animated graphic should be sufficiently complex to convey the important information within it, yet simple enough to be easily understood.
- Use animations when the instruction includes the use of motion or trajectory. In terms of motion animation can clearly show specific characteristics of an object while it is moving, e.g. its trajectory.
- Avoid overuse of animation since it can be distracting to learners.

The animations used in the instructional material in this study has been designed with these guidelines as a point of departure.

Method

A study was conducted at the department of physics at Stockholm University. It tested if there where differences in the learning outcome regarding the principle of equivalence when provided with different kinds of illustrations. This principal within Newtonian physics concerns acceleration and was regarded as suitable for animating according to Rieber's (1996) notion of what information animations can provide further than still illustrations. 55 first year students counted as subjects. The study was conducted in two phases, with 35 subjects taking part in the first phase and the remaining 20 subject participating the next year (same course and same education). The principle of equivalence was part of the curriculum for the course they attended during the period of the study. The study was conducted before the principle of equivalence was treated in the course. All the subjects participated in the study voluntarily.

Design and Procedure

To perform the study a small CBI[1]-program was constructed. This program tried to teach the students one important principle in classical mechanics: the principle of equivalence. A test was also administered in the program in order to test if the subjects had learned something from the initial instruction phase. The study was conducted in groups of 3 to 10 subjects at a time. On entering the room where the study took place the subjects randomly picked a computer with one version of the CBI-program already started. There were 10 computers in the room, and each session therefore consisted of a maximum of 10 participants. During the time the subjects ran the CBI-program the supervisor was always present in the room. The supervisor answered questions regarding the use of the program, when there were misconceptions due to language difficulties (some of the subjects did not have Swedish as their native language), or other non physical science related questions. When seated, the subjects followed the on screen instructions. After the subjects were finished they just left the room, and the supervisor collected the data that had been saved in a text file.

Material

Illustrations

The illustrations were of three different kinds: abstract, analogue and animated analogue. Abstract here means a classical illustration with arrows representing vectors which represent forces (gravitation and inertia) (see Figure 1). This illustration was constructed for another study (Ramberg, 1996) relating to the same area in physics.

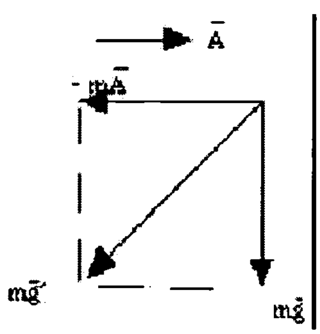

Figure 1: The abstract illustration

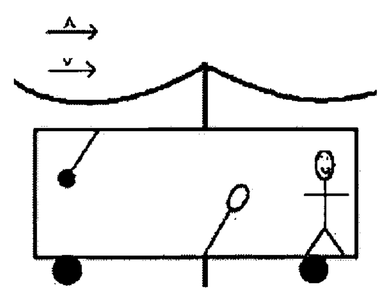

Figure 2: The analogue illustration.

The analogue illustration is a more everyday experience based type of illustration which the student can relate to, in this case a railroad cart seen from the inside, with a helium balloon attached to the floor and a steel ball hanging from the ceiling (see Figure 2).

The animated analogue illustration consists of the same setting as the analogue with the exception that movement is added. In the animation, the sequence proceeds from: the railroad cart standing still, accelerating, travelling at constant speed, applying its breaks until it comes to a halt. The sequence is then repeated.

[1] Computer Based Instruction.

The CBI-Program

The program consisted of four phases: an introduction, a learning phase, a test phase, and a debriefing phase.

The introduction consisted of a text that explains some practical details about the program. The introduction also contained three background questions regarding the subjects gender, age, and previous knowledge of the principle of equivalence.

The learning phase consisted of a text and one of the illustrations described above. The text was divided in four parts containing increasingly more detailed explanations of the principle of equivalence. When the subjects were finished (with the learning phase, before the test phase) they were asked to estimate (on a scale ranging from 1 - 10) how much they felt they had understood and how much they felt they had learned.

The test phase consisted of three different types of problems:

1. In one problem the subject's task was to predict what would happen to grass growing on a record player (the old-fashioned kind with a turntable). This problem was varied so that in one problem the scenario consisted in a rotating turntable whereas in another, the turntable was not rotating. Hereafter referred to as question number 1 and 2, or the grass questions.
2. Another problem consisted in the subjects filling in the missing parameters in one abstract-type illustration given that a particle is accelerating to the left or to the right. Hereafter referred to as question number 3 and 4, or the abstract questions.
3. In the third problem the subjects were to predict what would happen to the balloon in the railroad cart given that the railroad cart is accelerating, keeping an even pace, or applying its breaks. Hereafter referred to as question number 5, 6 and 7, or the analogue questions.

All the questions were multiple choice questions. After having answered the questions the subjects were asked to motivate their choice, i.e. give an explanation in plain Swedish (or English). After each question the subjects were asked to estimate (on a scale from 1 - 10) how difficult they experienced the problem to be, and also, how confident they were that they had answered it correctly.

In the debriefing phase the subjects were asked how much they felt they had understood and learned. There were also some questions regarding the use of the program itself.

There were three different versions of the program corresponding to the three different types of illustration. Within the three different versions there were two different orderings of the test questions (called 1 & 2), summing up to six different versions. The variation in presentation order was performed to eliminate any effects of presentation order. In both versions the two questions about the grass on the record player (see above) came first. In the version called 1 the two questions about the missing parameters followed, and after that the three questions about the balloon in the railroad cart. In version 2 it was the other way around.

Results

The participants' answers were grouped according to which kind of illustration they received during the learning phase. These groups are hereafter called: abstract, analogue, and animated. In all there were 55 participants resulting in 19 in the abstract group and 18 in both of the analogue and animated group.

Quantitative Results

The answers were counted as correct when totally correct. In questions 3 and 4 there had to be four correct statements to count as a correct answer (the correct picture and three correct parameters). On questions 1 and 2 there were almost identical results in all the groups. There was almost the same number of correct answers (Table 1) and the mean values of the estimations, on how certain they were of the answer and how hard the question was experienced to be, were very close to each other.

Group↓ \ Question→	Rotating turntable (#1)	Turntable not rotating (#2)
Abstract (19)	6	16
Analogue (18)	8	17
Animated (18)	6	17

Table 1: The number of right answers on the grass questions (1 & 2) (The total number of subjects in each group within parenthesis.)

Concerning the abstract questions (number 3 & 4) there was a drop in performance in the animated group compared to the other two groups (see Table 2). On the other hand the abstract group were significantly ($p<0.05$) more certain about their answers being correct compared to the other two groups.

Group↓ \ Question→	Accelerating right (#3)	Accelerating left (#4)
Abstract (19)	4	4
Analogue (18)	5	3
Animated (18)	1	1

Table 2: The number of right answers for the abstract questions (3 & 4) (The total number of subjects in each group within parenthesis.)

On questions 5 & 6, the analogue and animated groups were better than the abstract group. The ceiling effect on question 7 is obvious (see Table 3).

Group↓ \ Question→	Accelerating (5)	Breaking (6)	Constant Speed (7)
Abstract (19)	7	7	17
Analogue (18)	14	13	18
Animated (18)	15	14	18

Table 3: The number of right answers for the balloon questions (5, 6 & 7). (The total number of subjects in each group within parenthesis.)

Qualitative Results

When comparing the answers and the motivations it seems that most of the subjects that answered correctly also understood the principle well. There were a few obvious "guessers" but they often made a wrong guess.

Beside the multiple-choice answers, the subjects were asked to motivate each answer in what we called "Plain Swedish". These motivations show some very interesting tendencies. There seems to be a connection between the kind of language used and the illustration pro-vided. For a more thorough analysis see (Wærn et al., 2000).

Concluding remarks

The reason to have the grass questions (1 & 2) was that it would be an unknown presentation format for all the groups. If one of the groups would have had a better score on the first question this could be taken as an indication that the presentation format of this group made for a better and deeper understanding of the principle of equivalence. This did not happen, but this does not say that there are no differences between the presentation formats. More research is needed to sort these questions out.

It is reasonable to assume that the analogue and the animated groups should outperform the abstract group on the balloon questions. This because they are more familiar with the presentation of the problem. But following this line of reasoning the abstract group should outperform the analogue and animated groups on the abstract questions. This did not happen. This could be because the abstract question was too difficult (small amount of correct answers). A tentative interpretation is that it is easier to move from an analogue representation to an abstract than vice versa. It can be hypothesized that physics students are more used to abstract representations and descriptions and this in turn made it easier for the analogue and animated groups to perform well on abstract problems. Another interpretation is that it may be the case that the students in the analogue and animated conditions expended more effort into applying an abstract thinking on their concrete memory image, whereas the students in the abstract condition had difficulties in seeing the concrete application of the principle.

Subjects were asked to rate the difficulty of the problems and how confident they were in their answers being correct. The analogue and animated groups rated their confidence significantly lower on the abstract problems and slightly lower on the other problems. One hypotheses is that the analogue group has a deeper understanding of the principle but when presented with a presentation of the problem they had never seen before they felt uncertain. This

however does not account for the fact that the abstract group did have about the same confidence level on the analogue questions (5, 6 & 7).

A possible reason for the learning difficulties in the abstract groups lies in the fact that the behavior of the balloon is counterintuitive. In the explanations to their answers, many students based their reasoning on prior experience. Ramberg & Karlgren (1999) found similar effects in another study.

Throughout the test the animated group did not differ significantly from the analogue group. This is in accordance with what Rieber and associates (Rieber et al., 1989) found in their study.

Based on these results, it seems that animations do not add anything to the learning outcome in physics teaching. However the use of illustrations based on everyday scenarios can be beneficial. Instructional designers should also work with contradicting the everyday experiences. Concrete examples and illustrations are better in this respect than abstract reasoning.

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Mathematics Standards 2000 and the Virtual Environment

James T. Dorward
Department of Elementary Education

E. Robert Heal
Department of Mathematics and Statistics

Nancy Puhlmann
Department of Psychology

Utah State University
Logan, UT 84322-2805
jimd@coe.usu.edu
heal@math.usu.edu
nancyp@coe.usu.edu
www.matti.usu.edu

Abstract: This paper describes the rationale for the forthcoming Principles and Standards for School Mathematics and accompanying electronic pedagogical examples. Many of these electronic examples are part of a web-based national library of virtual tools and manipulatives being developed at Utah State University with support from the National Science Foundation. Also included is a review of research on the use of computer-based manipulatives, description of applet design considerations and characteristics, and a discussion of research implications.

The National Council of Teachers of Mathematics (NCTM) recently distributed a discussion draft of a set of national standards for school mathematics (NCTM, 1998). This draft built upon the highly regarded Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989). The final version of the new document, commonly referred to as Standards 2000, is being prepared for publication and will available for distribution in April, 2000.

The NCTM adopted national curriculum standards or guidelines to "ensure quality, indicate goals, and promote positive change in mathematics education in grades pre-K - 12" (NCTM, 1998, p. 11). The fact that over 40 states have developed mathematics curriculum standards patterned after the NCTM Standards, suggests widespread appeal for focused efforts to increase quality of instruction, establish specific goals, and promote evaluation and assessment of content and pedagogy. The appeal of the mathematics standards is also evidenced by fundamental changes in commercial textbooks and funding initiatives at federal and state levels.

There is also some evidence to suggest that establishment of national curriculum standards, associated changes in commercial textbooks, and implementation of federal and state funded reform initiatives, have resulted in a noticeable improvement in standardized test scores of mathematics achievement. While these suggested correlations need further investigation, it appears that positive change is underway.

However, the pace of change in mathematics education is slow compared to change in access to technology and information. In the introduction to the draft version of Standards 2000, NCTM recognizes that, "student access to computers and the World Wide Web is now relatively common, whereas in 1989 availability of handheld scientific or graphing calculators was uncommon" (NCTM, 1998, p.15).

In conjunction with publication of a printed document, NCTM is developing an electronic version of the Standards 2000. This 'e-version' will include on-line examples of mathematical content and pedagogical strategies that correspond to the philosophy and goals of the new standards. The e-version

will "allow a richer array of examples to illuminate and extend the ideas provided in the text and ...make possible the inclusion of links to resource and background material" (NCTM, 1998). The current electronic version and associated supplemental materials is available at: http://www.nctm.org.

Certainly, there is enormous potential for professional organizations to utilize web-based technologies to make curricular and pedagogical information retrieval and use more efficient. Teachers, constrained by increased demands for academic accountability, increasing numbers of students, and pressures to meet social, emotional, and academic needs of increasingly diverse groups of students, have limited time to seek information and strategies to address the multitude of challenges they encounter. A challenge for funding agencies, professional organizations, teacher educators, and educational technologists is to promote, design, and test mathematical models and activities that address core mathematics concepts.

Purpose

The purpose of this paper is to describe a rationale for development and use of web-based interactive applets in school mathematics. In addition, we will illustrate several of the examples being developed for the electronic version of Standards 2000.

The authors are co-principal investigators for a National Science Foundation project to create a web-based National Library of Virtual Manipulatives for learning mathematics in the elementary grades (K-8 emphasis). Many of our virtual manipulatives are based on physical manipulatives commonly in use in the schools (i.e. geoboards, tangrams, pattern blocks, fraction bars); others are concept manipulatives especially designed to teach or reinforce basic mathematical concepts. Our emphasis is on interactivity for the user, so the learner controls the variable aspects of the manipulative and is not only free, but encouraged, to explore and discover important mathematical principles and relationships. Teachers or parents can provide direction, but control of the activity remains with the user.

We are now working very closely with the Electronic Format Group and the writers of the new Principles and Standards to provide appropriate E-examples for all four grade- bands. The majority of electronic examples that will appear with the web version of the Standards, to be released at the annual national meeting of NCTM in April of 2000, will be our interactive applets.

Rationale

The rationale for development of web-based instructional technologies is two-fold. First, the web has the potential to provide users with easy access to information about curriculum, research, needs assessment instruments, instructional strategies, supplemental resources, assessment tools, diagnosis and remediation strategies, and instructional models (or manipulatives) and tools. Traditionally, access to educationally sound curriculum and associated physical manipulatives and tools has been limited to school experiences. Even then, expensive supplemental materials are often not available in schools. Web-based, interactive manipulatives and tools are freely available at any time. The challenge is to provide easy access to materials that are intuitive

Second, the virtual environment offers potential for substantial enhancements over similar physical materials, manipulatives, and tools. Digital enhancements to physical models and tools include: rapid upgrades or revisions to existing information, increased interactivity between developers and users, unlimited availability of relevant data and related information, capability to enlarge print or enable voice activation for handicapped users, and ability of user to change or modify existing information or materials to suit their particular needs or creative instincts.

In subsequent sections, we review the literature on development and utility of electronic manipulatives and tools and discuss design and development characteristics of emerging technologies.

Review of Research

The development of web-based virtual manipulatives and tools for school mathematics has the potential to realize educational advantages from use of both technology and physical manipulatives. It has been suggested that the use of technology for mathematics instruction enhances "mathematical thinking, student and teacher discourse, and higher-order thinking by providing the tools for exploration and discovery" (Bitter, G. & Hatfield, 1998, p. 39). Specific benefits for using technology include:

1. Promotes active versus passive learning.
2. Offers models or examples of exemplary and non-exemplary instruction.
3. Is illustrative and interactive.
4. Facilitates the development of decision-making and problem solving.
5. Provides user control and multiple pathways for accessing information.
6. Provides motivation and allows for variability of learning styles.
7. Facilitates the development of perceptual and interpretational abilities.
8. Offers efficient management of time for learning and less instructional training time.
9. Allows for numerous data types.
10. Offers multilingual presentation (p. 106).

Justification for the use of physical manipulatives in mathematics instruction includes: making the abstract world of mathematics more meaningful, assisting in the transfer of knowledge from learned to unlearned situations, improved student motivation, and enabling greater insight into children's thinking (Fennema (1973). Suydam and Higgins (1977), in an extensive review of on the role and use of manipulative materials in mathematics also suggest that "lessons involving manipulative materials will produce greater mathematical achievement than will lessons in which manipulative materials are not used" (p. 91).

A recent review of research located five dissertation studies and four research articles from 1989-1999 where computer software was used to simulate or model physical manipulatives. Four studies provided evidence to suggest that students who use computer-simulated manipulatives and tools experience higher achievement and conceptual understanding in mathematics than those using associated physical manipulatives or no manipulatives (Kieran, C. & Hillel, J., 1990; Smith, J., 1995; Thompson, P., 1992). In another two studies, use of computer-simulated tools and manipulatives was shown to increase conceptual understanding in mathematics when used in combination with physical manipulatives and tools (Ball, S., 1988; Terry, M., 1996).

Comparisons between studies where use of computer-based manipulatives resulted in higher achievement, and those that did not, reveals that achievement may be affected by a myriad of design and sampling characteristics. For example, computer-simulated Base-10 blocks, two color counters, fraction strips, and ruler and protractor were used in the six studies producing positive results. Studies using simulated attribute blocks (Kim, 1993), pegboards and color cubes (Berlin, & White, 1986), and geometric shapes (Nute, 1997) realized no noticeable increase in student achievement.

Similarly, treatments from studies that yielded positive change in understanding were administered when classroom teachers believed they fit in with the natural flow of the curriculum. Of the studies where no increases in achievement were noted, treatments were administered at times that interrupted the normal curriculum. Additional variables that may influence computer-based manipulative effectiveness include: previous experience with computers, grade level, mathematical topic, treatment length, and computer-to-child ratio.

While research on the use of computer-based mathematical models and tools is mixed, there are some findings that provide promise and direction for future design and experimentation.

Design Philosophy

Initially, as we contemplated constructing electronic manipulatives that could be used by children, we were guided by existing physical manipulatives (See Figure 1). We were confident that we could make electronic versions that, because of their residence on the Internet, could be made available to students, teachers, and parents, at any time and in any location having a web-connection.

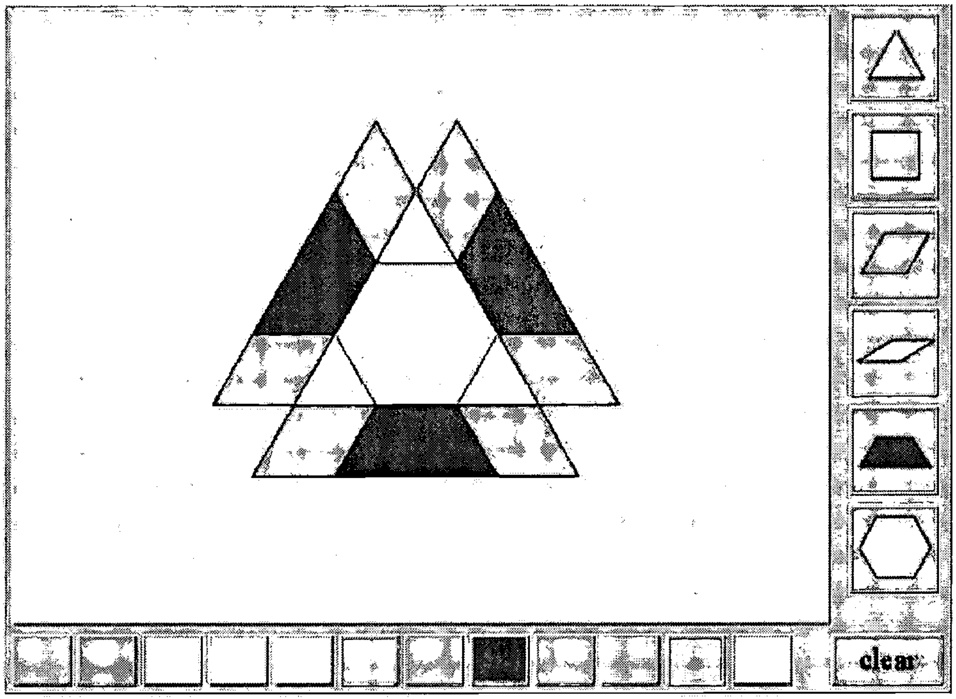

Figure 1 – Pattern Blocks Manipulative

One of our first creations was a virtual geoboard, mimicking the common nails in a board version using rubber bands. As we shared an early version with teachers, recommended we enable users to color the regions inside the rubber bands. Later reviewers wondered if it would be possible to translate an elaborate construction around the board without having to shift the band from every vertex. We are now working on incorporating both translations and rotations, illustrating the mathematical concepts of slides and turns.

Building such features into a virtual manipulative allows users to do things that are not possible with corresponding physical manipulatives. We constructed a circular geoboard, and a third board using nails spaced to form an equilateral triangular grid. The circular board has immediate applications as diverse as creating pie-chart fractions and illustrating trigonometric functions.

In the design of all of our virtual manipulatives, we make a conscious effort to avoid doing too much. We would rather have five manipulatives, each doing a well-defined task, than a single applet that requires more complicated operations to accomplish the same five tasks. Each applet has a tightly designed focus and the simplest interface we can create. The mathematics underlying the functionality is often very sophisticated; what the user sees and does is very simple (See Figure 2).

Another principle that guides all of our design is that the student must interact with the applet to accomplish something. There is never simply a watch this clever animation or see what happens when we do this attitude. Mathematics, perhaps more than any other discipline, cannot be learned by watching someone else do it, no matter how elegantly. Any student, to be successful, must be involved and engaged in the activity. We believe that thoughtful engagement requires participation. Interactivity is thus essential to the design of every one of our applets, the one feature that we absolutely require.

The kind of interactivity we design requires the user to think about a specific task, to formulate strategy to achieve a specific goal (almost always informally, and seldom articulated), to engage in some physical action (clicking to select something, dragging an object, or moving a slider), and to observe (and perhaps, describe) consequences of the action. The goal is to allow students to control events and to discover relationships. Differences between coincidence and causal relationships become clearer when we allow the user to repeat an activity as many times as desired. We can ask questions to direct explorations and, we hope, guide meaningful discovery, but control remains in the hands of the user.

Nothing happens until the user takes action, and an activity can be repeated until there is satisfaction; the computer never tires of repetition.

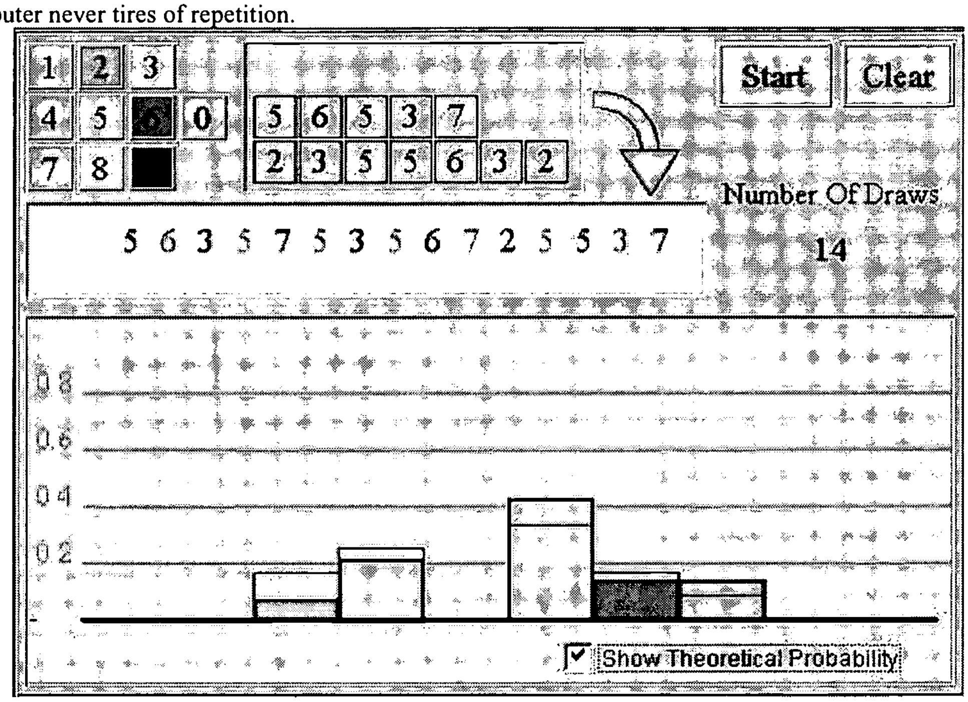

Figure 2 - Box Model applet for comparing empirical with expected frequencies.

Future Research and Evaluation

Initial evaluation and research efforts have focused on analysis of instructional design features that enable applet users to increase their understanding of mathematics concepts and incorporate applet use in their math curriculum. Primary information gathering methods are interviews and observations of student and teacher interaction with the applets. In addition, solicitation of formal feedback from writers of the Standards 2000 document on activity suitability will be forthcoming. These efforts continue to yield valuable anecdotal information that is being used to inform applet design and associated activity development.

In addition, researchers are conducting quantitative investigations on the effects of using Geoboard, Tangram, and Pentomino applets on geometric concept acquisition among students in grades six through eight. Of particular interest are studies that investigate whether there are differences in knowledge and reasoning abilities between students using virtual manipulatives, physical manipulatives and no manipulatives. While studies of this nature have potential to inform multiple audiences, there are obvious challenges associated with research design and implementation that make generalizations about benefits to the use of virtual manipulatives a matter for the future.

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Teaching Computer Programming Languages Through WWW

Mahmoud M. El-Khouly
Behrouz H. Far
Zenya Koono
Computer Sciences & Information Dept. Saitama University, Japan.
{elkhouly,far,koono}@cit.ics.saitama-u.ac.jp

Abstract: This paper presents web-based tutoring system (W-TCL) for teaching computer programming languages through WWW. In this version, two new features have been added: blackboard module and adaptive interface. With blackboard module a teacher can exchange his expertise with other teachers, and with adaptive interface the novice student will be satisfied because the system avoids complex interfaces. The system contains three sub-agents: the personal assistant agent for teacher (PAA-T), the personal assistant agent for student (PAA-S) and tutoring agent (TA). Using PAA-T, many teachers can cooperate together to: (a) put the curriculum of one/more computer programming language(s), (b) add or modify the commands' structure that will be taught, (c) generate different tutoring dialogs for the same command, and (d) generate different tutoring styles (e.g. text or Q&A).

Introduction

Learning one of the computer languages today, is essential for students in both undergraduate and graduate levels. However, the lack of good instructors is a problem. Using computer-aided instruction (CAI) and Internet technology can solve this problem.

The movement toward client-server applications began in the late 1980s and so in many organizations there are already many server applications with well-structured APIs for RPC or IPC access by a client. However, in many cases the backend server is a relatively standard database monitor, which provides no logic or protocol specific to the current application. The emergence of network computing, where the client side of the application logic is provided by JAVA applets that are downloaded at runtime to a Web browser, offers a new opportunity for constructing the agent-equivalent of a Web browser (Alper, 1997). With the WWW as an educational platform, it will be feasible for the students to access the multimedia courseware with general-purpose browsers. No special tools are required to start learning. For the courseware provider, it is not necessary to worry about the distribution and maintenance of the copies of the courseware but they just take care of the original on their server (Nakabayashi et al., 1997).

Lewis Johnson (Lewis Johnson, et al., 1997) support interaction with teachers and students through their project ADE, using off-the-shelf whiteboard and teleconferencing tools. But this required both teachers and students to be on-line.

The proposed system consists of three agents representing a server-clients relationship, tutoring agent (TA) as a "server", personal assistant agent for teachers (PAA-T), and personal assistant agent for students (PAA-S) as a "clients". The PAA-S can communicate with TA through WWW to retrieve the tutoring dialog of the command(s) that a student wants to practice, and to access the experiences of other students in blackboard module. While the PAA-T communicates with TA to add/modify semantic rules of computer programming languages and to check the correctness of the contents of the blackboard database (as shown in Figure 1).

Personal Assistant Agent for Teachers

The object of the personal assistant agent for teachers (PAA-T) is to standardize the decomposition of the language under investigation (as shown in figure 2), such that TA can deal with all languages with the same way. Each computer programming language has been stored at a different directory, and each file in its directory

represents a command name associated with (level of difficulty, text or Q/A or quasi). For example, the file named for01t.html at BASIC directory, means that this file contains the text describes the FOR command for first level. PAA-T consists of three parts, expertise module, semantic rules base, and tutoring text base. PAA-T helps the teacher to cope with the knowledge base of a computer programming language under investigation, to add or modify the command's structure that will be taught, and to produce a meta level language representing this computer language, which we call it "semantic rules". To construct the semantic rules base, PAA-T uses BNF (for Backus-Naur Form) (Aho, etc., 1986).

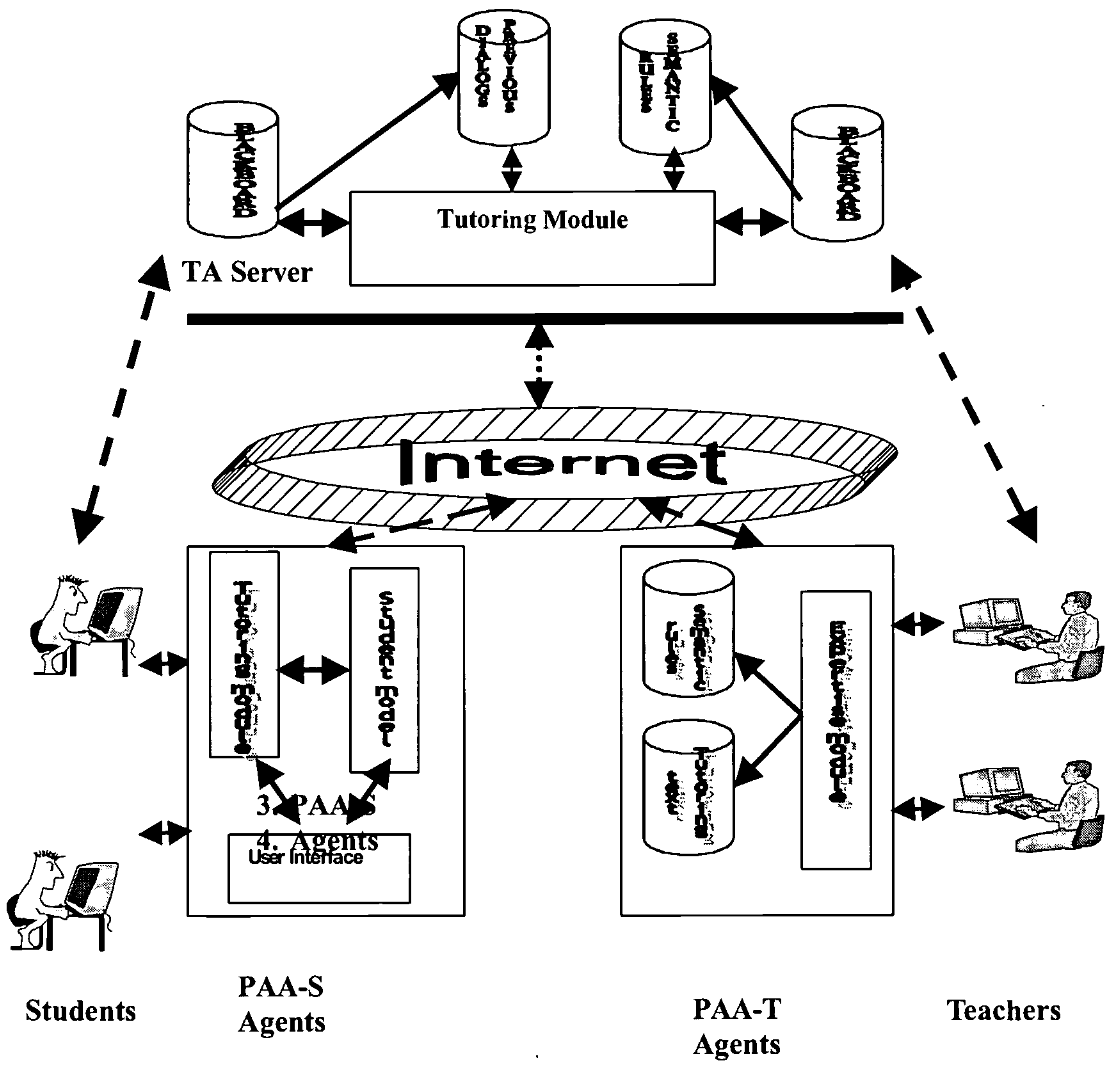

Figure (1): W-TCL System

Tutoring Text

Tutoring text-base contains the text that represents the commands of computer programming language. Text is organized in terms of a conceptual network (Brusilovsky, et al., 1996) hierarchically into lessons, sections, subsections, and terminal pages. Terminal pages contain the problems to be solved for the current command under investigation before it introduces new command. Each teacher can contribute in this tutoring text-base: he/she provides an optimal learning path for an assumed average student. The tutoring text

will be retrieved by the name of the command. At the database, the extension of the command's name represents the teacher's ID number as well as the order of this text. The ID number of the teachers and the order of the text will be used to determine which text should present first at PAA-S. Taking into consideration the teacher's specialist (since a text of one computer programming language can be used in teaching another computer programming language, as we shall later).

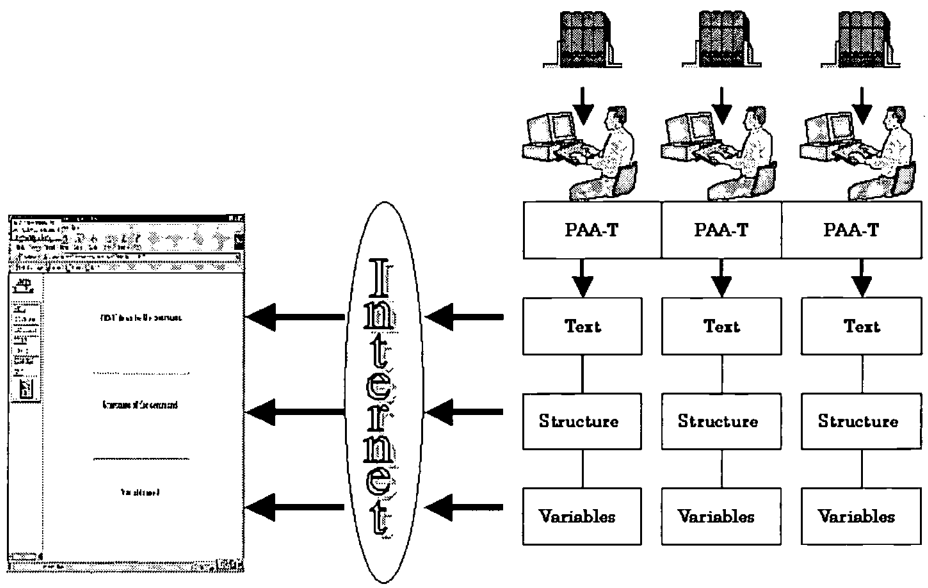

Figure (2) : Teachers decompose computer languages

Blackboard module

Teachers can share their experiences through blackboard module. The blackboard module has three components:

- global database called the blackboard (hosted at the TA-Server),
- independent knowledge sources (from any PAA-T),
- Scheduler to control knowledge sources and the blackboard database.

All experience elements are recorded in a structure, global database called the blackboard (Avelino et al., 1993). The blackboard structure organizes experience elements along two dimensions, computer language name and command name. Each record contains the following fields (teacher ID, computer language, command name, new quasi, and suggestion of solution).

When a teacher wants to generate some examples and he needs some previous examples even from different computer programming language, then he sends a message to the message center at the blackboard module. A statement of the example required is displayed by the message center to all teachers on line. When a participant feels that he can contribute to the solutions, he sends his contribution to the message center.

Personal Assistant Agent for Students

The personal assistant agent for students (PAA-S) consists of three components, student model, tutoring module and user interface module.

Student Model

PAA-S invokes the student model to check the student answer. In order to accept a free format answers from a student, one of the Compiler-phases had been used, it called "Lexical Phase" (Philip et al., 1978). The lexical phase is concerned with breaking up the string of characters into the words they represent. For example, if the system asks the student to construct a conditional statement that calculates the tax as 10% of the salary if the salary exceeds 200000 yen, then the answer of one student might be:

if salary>200000 then tax = salary * 0.1

The lexical phase would discern the fact that this character string represents the word "IF" followed by variable "salary" followed by the operator ">" followed by the number "200000" followed by the word "THEN" followed by a statement "tax = salary * 0.1". Again the last statement will be broken to be variable "tax" followed by an equality operator followed by variable "salary" followed by multiply operator followed by number "0.1".

Each token consists of two parts, a *class* part and a *value* part. The class part denotes that the token is in one of a finite set of classes and indicates the nature of the information included in the value part.

Moreover, during lexical phase in the above example, PAA-S makes spell checking for the reserved word character by character. For instance, if the student enters "if salary > 200000 tha", then the agent will not accept any other characters and underlines character "a" and an error message appears, guiding the student to correct it to be character "e". Then the student can complete his answer. Note that, if the student enters "tex" instate of "tax", the system will not correct it, since the system checks only reserved words for the computer programming language under consideration. The system always consult *semantic rules base* to do that.

Using the tutorial module

When the student accesses the module, the system asks about the computer's language, which the student wants to learn. The system downloads the tutoring dialog of this language and waits for the student to select the command he/she wants to practice, to retrieve the associated tutoring dialog's file(s). The system presents the text that describes the command, and asks the student if he/she understands it or not. If the reply is "no", the system presents another text for another teacher. If still the answer is "no" the system converts to another style for presenting the command (e.g., Q&A) or consult the blackboard database. If the reply is "yes", the system asks the student to write an example statement to check it. The system can accept a free format text from the student, and then infer the student model to check this statement. If the statement is correct, the system increments two counters, one for the number of questions which had been asked to the student, and the other is the correct answer counter. Otherwise, only the first counter will be increased. If the correct answers of a student exceed 75% then the level of difficulty will increase by one, but if it is less than 50% the level of difficulty will decrease by one. After the student completes this step, the system re-presents the first menu to allow the student to select one of the followings: (a) select another command, (b) present the score, and (c) exit.

PAA-S & TA interface

Students can share their experiences through blackboard module. All experience elements are recorded in a structure, global database called the blackboard. The blackboard structure organizes experience elements along two dimensions, computer language name and command name. Each record contains the following fields (student ID, computer language, command name, problem description, and suggestion of solution).

When a student faces a problem, and he/she could not catch the required meaning from the teacher's text, he sends a message to the message center at the blackboard module. A statement of the existing problem is displayed by the message center to all students on line. When a participant feels that he can contribute to the solutions, he sends his observations and/or conclusions to the message center.

The scheduler organizes the knowledge source activity as well as the blackboard database and sends the content from time to time to teachers to check its correctness, if it is correct it is moved to previous dialog database (hosted at TA) (as shown in figure 1). Each teacher observes the messages written by others and considers those messages related to his specialty. Some of those teachers (who built the knowledge base for the same computer programming language under investigation) are able to offer immediate suggestion on what to do since their knowledge applies directly to the information currently in the message center. Others (who built the knowledge base for another computer programming languages), however, are forced to wait, possibly for an extended time, before their expertise is needed and can be applied.

PAA-S User Interface

In most of intelligent learning environments (ILE) systems, only tutoring component is adaptive. The user interface usually looks the same for the novice and for the advanced student, while the student's knowledge changes from the beginning to the end of a course (Brusilovsky, et al., 1995). In PAA-S we use the student model for creating an adaptive interface. This done in several ways: (1) last state adaptation, (2) visual adaptive annotation of links, and (3) function panel adaptation. By this way, the student can feel better, because when the interface is oriented towards an experienced student, the interface appears to be too complex for a novice student, and vice verse.

The browser downloads the HTML page and the applet code from TA server to PAA-S. The applet then runs on the client's computer. First, the applet downloads the data file containing the initial variables about how the user interface should looks like. Then according to the student performance, which will be recorded in the file, the browser downloads the suitable page for him.

Last state adaptation

Last state adaptation means adaptation to the last state of the user-system interaction, i.e. the system keeps the "settings" of the individual user (working directories, window position, etc.) and comes up when starting like the last time the user worked with it.

Visual adaptive annotation of links

PAA-S uses an extension of the traffic lights metaphor to annotate links visually. When presenting the current command tutoring under investigation, links to the other commands were annotated corresponding to a simple traffic lights metaphor referring to knowledge state of each student. A red font of the link indicated that the corresponding command or section was not ready to be learned because necessary prerequisites were not met. The prerequisite relationships between commands are not represented directly, but the system is able to compute them from part-or and is-a relationships using several heuristics. A green font of the link indicated that this command or section was ready and recommended to be learned and a yellow font indicated that this command have been learned. If the student visit a tutoring part of a command and did not success to solve its exercise, the link of this command will be marked as a green font not as a yellow one in the next invoke.

Tutoring Agent

TA contains tutoring module, previous dialogs database, semantic rules base, and blackboard database.

Any computer language has command(s) for I/O, condition, loop, and etc. The way to teach those commands is almost the same for all computer languages, for instance, to teach the condition command in BASIC will be done in quite the same way as the condition command in FORTRAN. The tutoring agent can construct the tutoring module for the new language by retrieving the tutoring dialog of similar command in another language and adapts it. This is very useful to produce several tutoring texts from different teaching point of views to fit students needs. For example, if TA has the tutoring dialog of IF command in BASIC, then it consults the semantic rules of FORTRAN to substitute the BASIC command in tutoring dialog with the FORTRAN command.

W-TCL & WWW Interface

A main design consideration in W-TCL version was to reuse as much of component as possible. In the stand-alone version (El-Khouly et al., 1999), students receive immediate feedback on every action they take. If they enter an incorrect statement, the system will present a message error and guide them to correct answer. HTML forms do not allow this kind of tightly coupled interaction. TA server receives information about student actions only when the student submits that information. In W-TCL system, the TA, PAA-T and PAA-S agents can find and communicate with each other dynamically, using Common Object Request Broker Architecture (CORBA). CORBA allows agents find each other and coordinate their behavior on a common object bus. This makes CORBA ideal for component-based applications. The advantages of using such technology in W-TCL

system is using those objects as a metaphor for using existing stand-alone A-TCL application as well as personalizing and task sharing between the client and server. In Internet based W-TCL, the Java ORB is used. With a Java ORB, an applet can invoke methods on CORBA objects using the IIOP protocol over the Internet. Consequently, there is no need to use HTTP and CGI programs that are the cause of extra overhead on the server and also the client-side ORB enabled applets can be used in any Java enabled browser.

Conclusion

In this paper, W-TCL system had been presented for teaching computer languages. W-TCL consists of three agents, tutoring agent, personal assistant agent for teachers and personal assistant agent for students. They communicate with each other as client-server through WWW. This allows the system to communicate with other agents to exchange semantic rules and tutoring text for different languages. The adaptive learning environment had been used in PAA-S. Moreover, both the teachers the students can share their experiences through the blackboard modules hosted at TA, i.e. the system can be dynamically enhance by all members (teachers & students).

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College Science via Internet: How effective is it?

Dr. Kathleen Ireland Flickinger, Maui Community College, Division of Math / Science, Kahului, Hawaii, USA, kathleen.flickinger@mauicc.hawaii.edu

Dr. Constance P. Hargrave, Iowa State University, College of Education, Ames, Iowa, USA, cph@iastate.edu

Abstract: In this paper college science instruction via the Internet is examined from three perspectives: students' on-line learning experiences; a comparative examination of learning on-line versus traditional instruction; and instructors' experiences teaching on-line. The setting was a freshman-level human anatomy / physiology course. Three students participated in a collective case study to describe the learning environment created by the Internet course. Motivation, computer savvy, and self-confidence were important to their success. A quantitative study of the on-line course and the traditional course evaluated the comparative effectiveness of the learning environments. Achievement scores and survey results indicated content understanding and retention were not effected, while desirable student study habits were used more frequently in the Internet section. To better understand the instructional implications of on-line courses, a case study was conducted. Internet instructor's time commitment and level of teaching satisfaction were high. The instructor's role changed, causing some lessening of job satisfaction.

Introduction

Higher education is increasingly using advanced technologies, such as the Internet, as a means of instruction. The asynchronous nature of advanced technologies is causing a cultural change in instruction. No longer is a college education confined to the traditional campus, where students and instructors meet at designated times; the dynamic nature of information technology is changing higher education (Connick 1997). Despite these changes, the responsibility of the instructor to maintain (and increase) the quality of instruction and create an appropriate learning experience remains. (Wagner 1997). The purpose of the research presented in this paper is to better understand the implications the Internet is having on higher education.

Distance education at the collegiate level is no longer novel, but the use of the Internet as a means of instruction is a relatively new phenomenon. Several studies have explored the supplemental instructional use of the Internet without delving into the effects of that use (Brooks 1997; Chute, Thompson & Hancock 1999). As a partial answer to this dearth of knowledge, this research was undertaken to examine Internet teaching effectiveness in a college science course. Three studies were conducted and comprise the research reported here. In the first study, on-line learning experiences were investigated using a case study approach. The second study was a comparison study in which student study habits and achievement in Internet-based instruction were compared with those in traditional instruction. In the third study, an investigation of teaching via the Internet was conducted. The intent of this case study was to better understand instructional factors of Internet-based instruction by gathering data from professors who teach via the Internet.

The Course

At Iowa State University, the freshman-level Human Anatomy and Physiology course (Zoology 155) was offered via Internet as well as via traditional format. A three-credit course, the traditional format for the Human Anatomy and Physiology class is taught in a single-section via lecture to more than 500 students who enroll each semester. There are no laboratory exercises associated with this class, although a companion laboratory class may be taken during the same semester. Course assessment is based on student performance on three or four exams, one comprehensive final exam, and 3 to 7 homework assignments and/or quizzes throughout the term. Typically, the class is taken by students from all colleges and majors in the university. It is required for a degree in Psychology and Food and Nutrition, and is used to fulfill requirements for coaching certifications and entry into the Veterinary Medicine program. Additionally, the course is taken by many students to complete their general science requirements prior to graduation.

An Internet offering of the same class was prepared in the Summer of 1997. The Internet version follows the protocol created through ProjectBIO (an externally funded project to create a protocol for internet-based college instruction). This protocol allows instructors to teach college courses entirely on-line. Each course in ProjectBIO, including Human Anatomy and Physiology, includes a series of lectures with pages of text and visuals as they appear in the traditional lecture. An audio stream accompanies the lectures, following as closely as possible to that given during traditional instruction. For the Human Anatomy and Physiology course, all lectures, exams, quizzes and homework assignments were created and made available to the student on the first week of the fall 1997 semester.

Case Study of Students' On-line Learning Experiences

To assess the learning environment perceived by the students enrolled in Internet-based science course, a case study was conducted. The research was guided by the question: What, specifically, does the student experience as he or she works through a semester-long science course taught entirely on-line?

Three students were chosen as subjects to be followed as they worked their way through the Internet offering of Zoology 155. As a basis for choosing these students, demographics on previous Zoology 155 enrollment was analyzed. The typical student in the traditional class, averaged over three semesters, was a female of sophomore standing with a GPA of 2.7. She was an Iowa native graduating from high school in the 68th percentile and currently enrolled in the College of Liberal Arts and Sciences. In choosing the three subjects for this study, one was chosen to match the traditional demographics as closely as possible. Her case was referred to as "Judy". A second student, "Mitch", was chosen as a representative of the "non-traditional student population" as defined by the University handbook. "Sara", the third student, was chosen from the University - defined at-risk population.

Data collection was carried out using the qualitative methods of interviews, informal chats, open-ended telephone conversations, participant journals and e-mail correspondence. These many avenues of data collection were employed to reduce the likelihood of misinterpretation, to include redundancy in the findings (Denzin 1989, Goetz & LeCompte 1984) and to provide triangulation of findings to ensure validity of the conclusions (Stake 1994). Additional information was gathered using the standard course assessment tools, including homework and exam scores as well as participation points for joining in discussions and chat sessions.

"Judy" was a native Iowan enrolled as a sophomore in the College of Liberal Arts and Sciences. At the start of the semester, she had a GPA of 2.8. She was a Psychology major; thus, Zoology 155 was required for completion of her degree. Her goals included becoming a Mental Health Therapist or a Counselor. In her first journal entry, she wrote "Today was a disaster! It took me an hour to figure out how to register on ClassNet. Talk about vague directions.". Judy had persistent difficulty with the technology, evident in her e-mail correspondences. "Did I really miss all the points or did I do something wrong? Please try to respond. Also, if I messed up when I entered them, is there any way I can go in and fix them?". "I tried to see lecture 6 - damn computer wouldn't let me - it's lucky I didn't break it! So I moved on to lectures 7, 8, and 9, which it allowed - You figure it out - I even tried 6 again later - but it still hated me - damn modern technology!!!". In her final course evaluation, Judy noted the class was interesting, the content was explained well, and the format was not a deterrent.

The second student, "Mitch", was selected as a representative of the adult student population. At the time of this study he was a 52 year old senior in the Bachelor of Liberal Science program, College of Liberal Arts and Sciences hoping to graduate in December. His grade point was high - 3.7 - but he graduated from high school in the lower half of his class. Mitch held a full-time job as a policeman, taking classes on nights and weekends to finish his degree. Mitch had a positive outlook on life. Each time we met, he was friendly and full of smiles. He is a realist, admitting his limitations and also his strengths without hesitation. This was evident in his e-mails: "I am looking forward to this course because not only will I find it challenging, but working my way around the web promises to prove challenging". Mitch felt that his grade was affected not by the computer technology, but rather by the "science technology - I just didn't know enough". During an interview, he emphatically noted that the medium did "not at all affect my grade. I could go back and repeat lectures and study before tests. This was a good thing". "This is a totally personal experience. I was hesitant at first - motivation? This was the first course where you got down and studied.". Although I did not sense his leaning on me as much as other students in the Internet section, Mitch admitted to being "quite reliant on the instructor. I re-listened to lectures, sent you lots of mail. I never felt out of touch". Mitch did note that motivation was a big factor in passing the class. He expressed concern for the average college student. "They can get lost easily. I got lost at first, then caught up. This is a benefit as well. You can get a week ahead if you want".

Sara, the third participant in the study, was a senior at the time of the class, with a 3.0 GPA. Her grade point had dipped slightly in the past semester from a 3.5 due to "senioritis". Sara was a native of Bombay India, and spoke both Hindi and English fluently. Sara fell under Iowa State University's "at-risk" student definition due to her low high school rank and her nationality. In her first interview she described herself as a "non-exceptional student who was on every school team she could". She did enjoy science in high school but did not take it in college. "I was afraid it would be too hard". She called me at the start of the semester to beg for help getting her computer to work. I felt badly for her, as she was almost in tears over the technology. "Initially I was really excited about this class - a little nervous but when I logged on that was really smooth. Did the first homework, that was easy! Next day - went to lecture - no sound. Why? I tried everything - frustrated". This frustration plagued Sara throughout the course. "I was excited to begin. The freedom excites me. I can do it at 3:00 am if I want. This is the height of customer service. The best thing college can do for you. I'm not trying to keep up with you. At the same time it is scary. Am I doing this right or wrong? There is a loss of the personal touch.. "I do one lecture over and over again. I am not confident. There is no immediate feedback. I feel like I am groping. Anxiety - am I really learning? This is not a factor in normal classes". Her reaction to the course was entirely technology-driven rather than a reaction to the content covered. "I have lost confidence doing [the class] this way".

Although case studies do not lend themselves to generalities, a list of the findings from these cases may help illuminate the students' experiences with on-line learning. These include:

1. The technology was problematic for some, particularly females. Confidence in the technology and in the user were important to a positive experience with the Web class.
2. Instructor availability was important to all students regardless of their level of comfort with the technology.
3. Attitude toward the subject did not seem to be affected by the Internet. In fact, students who scored low on exams still rated the class as "excellent" or "better than most".
4. Enthusiasm was high at the outset of the semester, and with nurturing can remain high throughout the term.
5. Motivation appeared to be the single most important factor affecting success in the Internet course.

Either internally or externally motivated students fared better.

Comparison of an Internet and Traditional College Science Course on Student Learning

With a rudimentary understanding of the learning environment created by Internet-based Human Anatomy and Physiology course, a quantitative comparison of the effectiveness of an Internet and traditional course was conducted. The following questions were used to guide this study: 1) How does Internet-based science instruction effect student achievement? 2) How does Internet-based science instruction effect student study habits? 3) Do the students perceive Internet-based science classes differently than traditionally taught classes? 4) Do students enrolled in an Internet-based science class perceive their education differently than do students enrolled in a traditional science class?

Five hundred seventeen students participated in the study; 457 and 60 in the traditional and Internet sections of Zoology 155, respectively. With the exception of the percentage of students enrolled as part-time students, the two sections were demographically similar. Student achievement in the traditional and Internet section of the class was assessed using grades earned on the four exams and assignments. Study habits were examined using a study habits survey adapted from Mohamed (1980). Also working with Zoology 155 students, Mohamed (1980) designed the original survey to assess the effect the availability of video presentations of class lectures had on student study habits. The modified survey was administered week 12 of the semester. In addition, the Attitude and Epistemology Survey was administered to examine students' attitudes and beliefs about science. This survey was administered in the second week of semester to determine students' attitudes when entering the course (not a change due to the course). T-tests were conducted on all survey and grade results to determine whether statistically significant differences existed between the two groups.

The results of the Attitude and Epistemology Survey revealed no significant differences between the two sections (alpha = 0.05). The survey results were grouped into four categories based on underlying concepts: attitudes toward science usefulness, interest in the field of science, problem solving abilities (use of the scientific process in problem solving), and understanding of the scientific process. These survey results were analyzed using gender, year in school, reason for enrollment Zoology 155, and choice of Zoology 155 section enrollment as parameters for comparison. Regardless of which parameter was isolated, no differences between the two self-selected populations could be ascertained from the survey.

When study habits were examined, differences appeared between the two sections. Tests were run comparing Internet section responses with traditional section responses. In addition, gender comparisons were made both within each section and between sections. Those enrolled in the Internet section reported missing fewer lectures, reading the text more often, reading a higher percentage of the required readings, and having more faith that the readings were an integral and helpful portion of the class than did those in the traditional section. The Internet students reported recognizing that their course allowed for different learning styles and self-paced learning; this was so for the traditionally taught section. The freedom to arrange study schedules around other classes was appreciated in the Internet section, while seen as indifferent in the traditional section. Responses to questions concerning the use of tutors, notes taken during the class, or outside resources such as experts or libraries did not significantly differ between the two sections. Males in the Internet section missed fewer lectures and relied more on the text than did the males in the traditional section. The males in the Internet section reported an increase in interest in the subject due to the class and an appreciation of the freedom allowed by the class. This same pattern also was evident when comparing mean responses in the two female populations. The females enrolled in the Internet section differed significantly from their traditionally-taught female peers in that they missed fewer lectures, relied more on the instructor-prepared notes and the textbook, found the lectures and readings more useful, and appreciated the freedom to schedule their studies.

Overall course grades were slightly higher in the Internet section of the class. Scores on the cumulative final exam were significantly higher in the Internet section. Retention rates, analyzed by percentage enrollment dropping the course at midterm, were also different between the two sections. The Internet section lost a higher percentage of students than the traditional section . Achievement was not adversely effected by the use of the Internet as a means of course content delivery.

The Internet has not created a better way to teach, but appears to have facilitated the use of instructional design methods that move the student toward more interaction with the material. The benefits seen are not inherent in the medium, but rather they are due to the effective use of the properties of the medium. The learning environment created in the Internet-section of Zoology 155 did not appear to adversely affect learning. Students enrolled in the Internet section of this college science course demonstrated more efficient study habits (such as spending more time interacting with the material, using the text and ancillary materials, and attending the lectures) than those in the traditional course. Their content retention was better than those students taught in the traditional lecture, and their study habits more closely resembled those proven to lead to success (Piaget 1975, Pintrich 1994, Posner, Strike, Hewson, & Gertzog 1982).

Teaching On-line Courses: A Case Study of Instructors

The instructor experience while teaching on-line was investigated to complete this look at Internet-based science instruction. The guiding question for this study was "How does internet-based instruction impact the tasks of the instructor and the instruction itself? To examine this, two faculty members teaching on-line college science courses participated in this study. The time they spent on the class, as well as their comfort level with their workload, course product, and teaching effectiveness were investigated. Data were obtained through interviews and observations during the spring 1998 semester. The two participants had been teaching in the Zoology Department at Iowa State University for at least four semesters prior to their involvement with on-line courses through ProjectBIO. Both were full-time employees of the University, although neither held tenure-track professorial positions. Both participants held earned Doctoral degrees in science. At the time of the study, they were each approximately 40 years old, married and had children.

One instructor, Dr. Jenson, had been with ProjectBIO for more than two years, and was teaching an Internet science class for the fourth consecutive semester. The other instructor (Dr. Douglas) was new to on-line instruction and would teach his first Internet-based course during this study. Dr. Jenson had taught his biology course on the Internet using the ProjectBIO protocol three semesters including a summer session. Spring 1998 represented his fourth run of this course through ProjectBIO. He had an enrollment of 70 students in his Internet section during Spring 1998. While not particularly outspoken, he attended all ProjectBIO meetings and presented issues for group discussion many times. Dr. Jenson's input on teaching strategies and administrative routines was sought after and respected by the ProjectBIO staff.

Dr. Douglas was hired into the Zoology Department in 1995 as a spousal appointment. At the time of this study his position, like Dr. Jenson's, was defined as staff. His original duties included coordinating and instructing upper level laboratories, so few changes were necessary when Internet instruction was added to his responsibilities. The Internet course was viewed by the administration as equivalent to teaching one laboratory section. Dr. Douglas

was given a sophomore-level biology class to instruct via the Internet. Dr. Douglas was first and foremost a scientist, and he viewed teaching was a small part of his job. At the start of the semester, he had nothing prepared for Internet delivery, although he had previously taught the course (via traditional methods) and was confident in his knowledge of the content.

Dr. Douglas' lectures were not prepared until they were needed by the students, This did not allow students to work completely in an asynchronous manner. When asked about the time he spent on creating WWW lectures, Dr. Douglas responded "I spend much more time working on my WWW section. The preparation is very time-consuming. I spent 3 to 4 weeks working incredibly hard on getting my lectures done. It takes longer to do a lecture - it costs more to prepare". When talking with his spouse, Dr. Douglas' level of involvement with his Internet course was indicated. "He is demonstrating excessive signs of stress. He's not sleeping and staying up late several days a week. He writes out all his lectures, then reads them verbatim. He also does all his own graphics. He spends one hour per figure and has 5 to 6 per lecture. He wouldn't do that for live lectures". This high level of time commitment was indicated again when Dr. Douglas' spouse reported "I have hardly seen him for weeks. This definitely cuts into family time. He should have started in a more timely manner. Spring Break he began in earnest". In Dr. Douglas' opinion, he spent "longer on the WWW, and my time was not well spent. I had the entire lecture written out and tried to sound animated. I went back and edited mistakes - I fixed lectures because it's there and people hear it 3 or 4 times". He created his own lectures, but did have help with HTML cue points and other technical aspects of web delivery. Learning these skills again required more of his time then he anticipated "I spent more time piddling around with the Web resources".

Because he had taught the course previously, Dr. Jenson was involved not in creating lectures, but with "maintenance and fixing to make it better". Dr. Jenson mentioned that "editing took an incredible amount of time. I had to do lectures all over again. You have to be more efficient and careful about what you are saying. I want the product to be good quality - this takes a fair amount of time. Just the audio took a lot of time". After the initial creation, Dr. Jenson planned to go back and fix up the lectures. "I haven't yet. I would like to add new stories and change the information that's in there. The development phase is long. Once its developed there's maintenance - well, more than that. It requires attention. New exam made up. I type all the exams in myself. I now know HTML - this is a nuisance that takes a while. Far longer than regular lectures. I should be tweaking the course, but I have no time".

Both instructors talked about their feelings of job satisfaction while teaching on-line. They reported similar experiences. In an interview, Dr. Jenson noted "I do get frustrated doing all this. I feel I'm not using my time most effectively. With my experience and knowledge I don't need to be doing this [administrative work]. I'm not teaching [repeated twice]. In traditional classrooms, you feel like you are teaching. You have tried to communicate and some may have gotten it. With the Web, there's no immediate feedback. The e-mail has nothing to do with content at all. I'm not really teaching. The sense of personal satisfaction is a problem". Dr. Douglas' interview comments mirrored this. "I generally dealt with only two things - all procedural questions. No course information, almost no content questions. I had only one or two questions on each assignment - was the paper available or is the content relevant? Student feedback is not enriching". There was a bright spot for the experienced Web instructor. Dr. Jenson was surprised by the level of interaction between student and instructor that this format provided. "The students e-mail me constantly, telling me things that I don't usually hear in traditional lectures". "I feel like I know these students personally, much more so than I do with traditional students." Even his spouse was able to see the relationship that developed between Dr. Jenson and his Web students. "He talks more about his Web students. He has more contact with those students. It's weird - especially the off-campus students". Dr. Douglas was not far enough along in his Web teaching experience to notice many differences in the student attitude, but he did notice there were fewer "no hope-ers" in his WWW class than he'd been seeing in his traditional classes.

Despite the acknowledged increase in administrative work the instructors experiences in teaching via the Internet, their overall impression of teaching on-line was positive. Dr. Jenson's spouse noted "He has been excited about the possibilities of teaching in this way all along. He sees a lot of potential in on-line teaching". Dr. Douglas noted that "the on-line experience could be positive - it has the potential to be positive. I would like to do it again and do a better job".

Conclusions

The dynamic nature of the Internet makes it viable tool for instruction. As more and more colleges and universities offer on-line courses, it is important to understand the potential and limitations of the Internet as a means of instruction. The research reported in this paper suggests that the Internet can be an effective means of

college science instruction. The case study about students' on-line learning experiences indicated that students enjoy learning on-line, and although students do not meet with instructors regularly, instructor availability was important to the students. Also, motivation is a key factor impacting student success in on-line instruction.

When compared with traditional instruction, Internet instruction appears to be an effective method for teaching college science, as student achievement was not adversely effected. Students in an Internet course were less likely to miss lectures and used lecture notes and textbooks more frequently than those in the traditional course.

Internet instruction changes the role of the university professor. The results of the instructor case study suggest that teaching on-line courses consumes more time than traditional courses. In addition to understanding the course content, instructors who teach via the Internet must possess technical skills to design and maintain course materials. Although the instructors spent a great deal of time designing and maintaining their web-based courses, they possessed positive attitudes about teaching on-line.

To better understand the implications of Internet teaching and learning, additional research needs to be done. Future studies should examine instructional design and on-line instruction; policy issues with on-line instruction in higher education; and student self-efficacy in on-line courses.

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Issues in the Preparation of Prospective Elementary School Teachers to use the Internet in the Teaching of Mathematics

Jane Friedman
Mathematics and Computer Science Department
University of San Diego
USA
janef@acusd.edu

Abstract: The Internet, particularly, the World Wide Web, has had a substantial impact on society. Whether or not these technologies will be able to effect beneficial change in K-12 education is another question. In the past educational reforms have often foundered due to a lack of teacher preparedness and on-going teacher support. This paper will discuss the experience and attitudes of a group of pre-service elementary school teachers enrolled in a required content mathematics course.

There is a great deal of excitement about the Internet and the Web these days, and for good reason, the Web is an exciting technological development. The Internet is also touted as having the potential to revolutionize K-12 education. The Internet may indeed have that potential, but there is much that will need to be done in order for that potential to be realized. One problem is simply availability of technology. There are still many schools and teachers who have very inadequate access to technology. There are two other categories of issues, one is the suitability of technologies and Internet and Web-based materials for actual use by K-12 teachers and students. These technologies and materials are often developed without the input of K-12 educators and may not suit their needs. One could think about this type of issues as the problem of developing the technologies in a direction which is more friendly to education and educators. The other category of issues is the mirror image of these issues. It is the issue of teacher preparedness to use the Internet and other technologies in an effective way. What do teachers need to understand in order to use the new technology effectively? How can we support teachers in their efforts to gain this knowledge? This is the problem of developing teachers who are well-prepared to use these technologies in creative and effective ways. Together these two problems combine to be the bigger problem of developing teachers and technologies which can together effectively educate our children.

Putting together the Web, elementary school teachers, and mathematics, in fact has the potential to be a disaster. Elementary school teachers, are often, math-phobic and math-avoiding. Their knowledge of mathematics is often procedural rather than conceptual. In Liping Ma's book, *Knowing and Teaching Elementary Mathematics: Teachers Understanding of Fundamental Mathematics in China and the United States*, a comparision is made between American and Chinese elementary school teachers. The American teachers have a much more superficial understanding of mathematics and less sophisticated teaching techniques. For example, the American elementary school teachers were much less able to explain the principles behind the algorithm for subtraction with borrowing than Chinese teachers. There is a danger, that teachers with weak understanding of mathematical concepts could use the Internet as just another source for materials which focus on procedure rather than on concepts. To quote Ainley and Pratt (1995, pg.85)

> *The use of information technology to draw out mathematical potential is a relatively new area and thus demands a degree confidence and mathematical awareness. Primary school teachers may not have sufficient confidence or experience in mathematics to enable them to plan computer-related activities which will be rich in mathematical potential.*

Just as computers in the classroom, often become merely tools for drill and practice, the Internet can offer elementary school teachers another way to avoid struggling with the concepts of mathematics and teaching children to do the same.

At the beginning of the fall semester of 1999, I surveyed students enrolled in my mathematics content courses for future elementary school teachers. The students are almost all female and are almost all traditional

students in the sense of attending college immediately after graduating high-school. They are attending a moderate-sized private college in Southern California. A total of 47 students in two sections of the course participated in the survey.

These students are not computer illiterate, but they are unsophisticated in terms of their thinking on how to use this technology in the classroom. This is not surprising since most have not had much in the way of technology education. In fact, the youth of my students masked the degree that lack of technological knowledge is a problem in educating future teachers. At other institutions a large percentage of the students in a course such as this one would be re-entry students. These students are often computer illiterate and phobic, whereas my students are mostly just technologically unsophisticated. For example, only five students had any knowledge of programming in any language, and one student responded to the question about programming by asking what it meant to program. On the other hand almost all the students are regular users of email.

I received 46 meaningful responses to the question:

How often do you use email? Circle the response that best describes your situation.

Response	number	percent
At least once a day	28	61
Several times a week	12	26
Once a week	2	4
Rarely	3	6
Never	1	2

Offered a choice of a variety of other activities that they might use the computer for, all of the students selected one or more.

Activity	number	percent
Word processing	46	98
Game-playing	27	57
Shopping	13	28
At a job	12	25
To get information in daily life	21	45
To research for school	44	94

At the end of the survey the students were asked to write, as specifically as possible, about how they see themselves using computers in their future work as teachers. Most of the answers were vague, not specific at all. On the other hand, it's hard to be specific about the future. Forty students answered this question in some way. And the majority of the responses focussed on use of the computer as a tool to help the teacher with writing, grading and organizational tasks. Thirteen students mentioned using the computer to write lessons, worksheets, letters to parents or other materials, and eleven students mentioned using the computer to do grading

Here are a couple of typical responses:

I am sure I will use computers to record grades and to create daily lessons.

For keeping track of grades, maybe; making worksheets and tests; writing letters to parents.

Also commonly mentioned was using computers or educational software for instructional purposes, this was mentioned in some form by eleven students. However, this is only 27.5% of the respondents. Nine students mentioned the importance of children developing familiarity with computers while young, as in this response:

Because computers are becoming such a big part of our world. I think it is important that we teach our students at a young age so that they can become comfortable with them. I don't know exactly how but I want to integrate the use of computers into my classroom.

Interestingly, given that 27 of the students mentioned that they play games on the computers, only two responses mentioned the value of educational computer games. Also, although these students almost all use the email, only two students mentioned that their students might benefit from using email, only one mentioned that students might use the Internet specifically, and only three mentioned that as a teacher they might use the Internet.. The numbers were also surprisingly low for the use of computers to do research, five students saw themselves as teachers using computers as a research tool, and three mentioned that their students might use computers as a research tool.

Very few students were aware of any possible negatives involving the use of computers. Controversial issues, such as the correct balance between teaching paper and pencil computation and allowing the use of technology did not appear. The following response was interesting, both for the note of caution it sounds, and for the fact that this response was from one of the most technologically adept students. This student was one of the few who had taken a programming course, and mentioned a knowledge of both Basic and Unix.

Computers are a major part of my daily life. I always have a computer around, even when travelling. It will help organize me for teaching and keep my life in track. I plan to expose children to computers, however not a great amount because I want them to think, not for the computer to do it all. Rather have kids playing with hands not a clicker.

There was one other cautionary response

....I believe that computers could slow down the creative processes of children, especially if all of the thinking is done by the computer.

The lack of cautionary responses is troubling, since it suggests a superficial view of mathematics and of the role that technology can play in computer education.

Preservice elementary school teachers are often weak in the area of mathematics. Their understanding, tends to be procedural rather than conceptual. Without a deeper understanding of mathematics and training in using computers in creative and rich ways, the Internet will become just another tool teachers can use to teach in the same old way.

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USD's Web Group:
A service learning experience in Computer Science

Luby Liao and Jane Friedman
Department of Math/CS
University of San Diego
San Diego, CA 92110
liao@acusd.edu janef@acusd.edu

Abstract: This paper will describe the University of San Diego's web group, an unique and innovative service-learning experience for computer science students.

1. How Did the USD Web Group Get Started?

As the chair of the Math/CS department, Luby Liao receives frequent calls for help with computer related problems. In September of 1998, Catherine Crutchfield of the Dean's office asked whether we can find a Computer Science (CS) student to help her set up a database application. A CS graduating senior Alphonse Esper took the challenge and worked on the project to her delight and satisfaction. We consider this the motivating event for the web group and fondly call Catherine the mother of the web group.

We formed the web group in the Spring semester of 1999 after being encouraged by the satisfaction of both the student helper Alphonse and his client Catherine. The goals of the web group were simply:

1. to provide a forum for the students to study web-related problems and their solutions, and
2. to help the USD community with their web-related problems.

Given the frenzied interest in everything related to the web, we quickly attracted eight students to the web group. Two joined for independent study credit. The others simply did it out of interest. A group member Tom Hua embarked on a semester-long project of helping Michele Magnin, a faculty member in the Foreign Language Department, with her web-related problems. The web group was less active in the summer of 1999. Yet, at that time, a student member Jaime Garcia started helping Gretchen Ponts of the Graduate Admissions office with their web site. This has been ongoing and will continue until Jaime graduates in May of 2000.

Just as web continues to grow, so does the web group. In the Fall of 1999, the web group became more visible. It now routinely received requests for help. Its 30 odd student members were busy helping many members of the campus.

The clients are happy because they now know that there is an organization they can turn to, to ask for free help. The student servers are happy because they enjoy the satisfaction of helping others and learning in the process. They are proud to be respected as experts.

2. Web Group Activities

Internally, the web group meets weekly to present problems and solutions, to give presentations, and to listen to lectures. Students learn to use databases in their web applications to enable dynamic contents. They learn how to use different technologies such as PHP, JDBC, Java applets, CGI and JavaScript. They learn how to choose the proper languages (Java, Perl, Python or others) for a given task. They learn how to set up Linux server machines.

The web group gave three workshops in the Spring of 1999 and one workshop in the Fall of 1999. These workshops are hands-on tutorials to teach web site construction. The attendees first run a script to create a rudimentary web site, this takes just one second. The rest of the time is spent on learning how to polish (edit-publish-edit-publish) web pages using Netscape Composer, a free web page editor.

The three Spring workshops attracted an average of about 5 attendees each. This was because the web group was young and unknown, and the workshops were not well publicized. In contrast, the Fall workshop drew an enthusiastic crowd of more than 50 people. We promised more workshops for those who were unable to attend. We attribute the success of this workshop to the fact that the web group has become more visible and to more aggressive advertising. The Fall workshop was followed by a reception, supported by the USD Enhanced Student/Faculty Interaction Funds, during which student web group members discussed new projects with faculty and staff.

The web group has become a web help center for many. The following letter is typical:

> *Dear Dr. Liao,*
> *The (newly formed) Committee for the Enhancement of Teaching and Learning is in the beginning stages of developing a "faculty development" web page. We are working with Media Services to develop the site. I was hoping to find a student intern to help with the maintenance. The committee recommended that I contact you to determine if any help is available through your department. I am the individual responsible for the web site as well as the coordination of events and workshops. Student help on the web page would be an invaluable service. Truthfully, I need all the help and direction I can get on maintaining this web site. I'm just a novice. Thank you in advance for your help on this subject matter.*

The following appreciative comment from Gretchen Ponts, Graduate Admissions Officer is equally typical:

> *For various and a sundry reasons we found ourselves in a pickle. Our web site stated old application deadlines and outdated applicant information, and no one in the office knew how to update the site. I contacted Dr. Liao because I heard he organized a student web group and was hoping to find a student willing to help us. Jaime Garcia came to our rescue by helping to update site information, creating one of our site links, and fixing java script errors. Jaime also offered to teach me how to work on the site so we wouldn't find ourselves stuck again! Many thanks to Jaime, Dr. Liao and other members of this web group!*
> *Sincerely, Gretchen Ponts Graduate Admissions Officer*

As of December 1999, there were roughly ten web group students actively helping USD faculty/staff and offices.

3. How Do We Recruit Web Group Students?

In the Spring of 1999 when the web group got started, we recruited eight students by word of mouth. In the Fall of 1999, Luby Liao taught a Topics course in Web Programming which had an enrollment of 34 students. We decided to build a service learning component into the class, all the students are web group members by default. In order to have a group of comparable abilities, we also decided not to recruit new members. One highly motivated student, Johnny Bui, did join the group and made great contributions helping others, although he was not enrolled in the University for the semester.

In the Spring of 2000, we will be back to word of mouth recruitment. We already have a core of about ten students. We expect an active group of more than 20 students.

4. Future Directions

For now, the web group primarily serves the USD community. But we hope it can serve a larger community in the future, including K-12 school teachers. Two current web group members, Jeff Wagner and Susan Spencer, have begun a K-12 outreach effort. These students are working with Hidden Valley Elementary School in an effort to get all the teachers on-line. They plan to use Perl to create an object-oriented program which teachers at the school can use to create their own web sites. They also hope to develop a database which will contain student information and could be accessed by parents to keep track of their childrens' progress.

Jane Friedman, one of the authors, has been brainstorming about helping local K-12 school teachers. One of the ideas is to collect phased out Pentiums, put the Linux operating system on them, and give them to K-12 school teachers on condition that they be trained to use them. To motivate the teachers to apply for these machines and mandatory training, the teachers should be compensated for their time and effort. We will apply for grant to make this possible.

Distance Education Technology on the Example of Course "Artificial Intelligence"

Tatiana Gavrilova
Intelligent Computer Technologies Dpt.
Saint-Petersburg State Technical University
Russia
gavr@limtu.spb.su

Udaltsov Sergey
Institute for High Performance Computing and DataBases
Russia
svu@pop.convey.ru

Natalie Stash
Automation and Control Dpt.
Saint-Petersburg State Electro-Technical University
Russia
nvs@fn.csa.ru

Abstract: The paper presents the way of organizing distance learning course on the sample of discipline "Artificial intelligence". Peculiarity of the project is in adaptive character of education, i.e. in possibility of distance learning system implemented for development courseware to be arranged under individual features of the concrete user. The aim of the system is to define the best program of education for him by adapting scenario of the learning material and to help in the process of navigation. Adaptability is especially important for educational applications on World Wide Web which are expected to be used by very different groups of users without assistance of a human teacher.

Introduction

Distance education is of great popularity nowadays. The majority of existing in the Internet distance learning (DL) courses present by themselves static electronic copies of regular textbooks: chapter by chapter, page by page. So different users (further we will call them "students") get the same educational material in the same form. Some of the existing courses may possess test subsystem for checking how the student gains knowledge. But test results do not have influence upon the program of education.

One and the same material may be differently understood by different students. It can be rather easy for the student with some preliminary knowledge of the subject domain and difficult for the student without any basic knowledge. The student may need help to orient himself in hyperspace, especially if it is large and complex one, to know where he is or how he can reach a given piece of information. Without help he may get lost in hypertext area.

It is necessary to take into account student's preferences, goals while he chooses particular DL course. In dependence with this information the student should be presented necessary volume of the learning material. He may be given only basic questions. Or if the student knows material rather good but wants to define some of the questions more precisely he may be directed to the glossary (list of subject domain terms with the links to the texts) without looking through all the course material. Approach described in this paper is aimed at investigation of possible strategies for automatic adaptation of a DL system to the concrete student. It is supposed that the system may use the following characteristics of the student: goals, subject knowledge, hyperspace experience, personal characteristics (demographic, professional, physiological and psychological), preferences. Development is based on the concept of the "student model" that presents a formal description of student's characteristics. It is obtained through his interviewing and is getting more precise dynamically in the educational process according to the results of the intermediate examination tests.

Subject domain of the course – Artificial Intelligence – is not enough presented in the existing distance learning courses. The course is intended for teachers giving lectures on Databases and Knowledge Bases, scientific researchers, students, post-graduate students are interested in the problems of Artificial Intelligence and Distance Learning.

Architecture of the adaptive DLS

Architecture of the adaptive DL system implemented for development coursware is presented on figure 1.

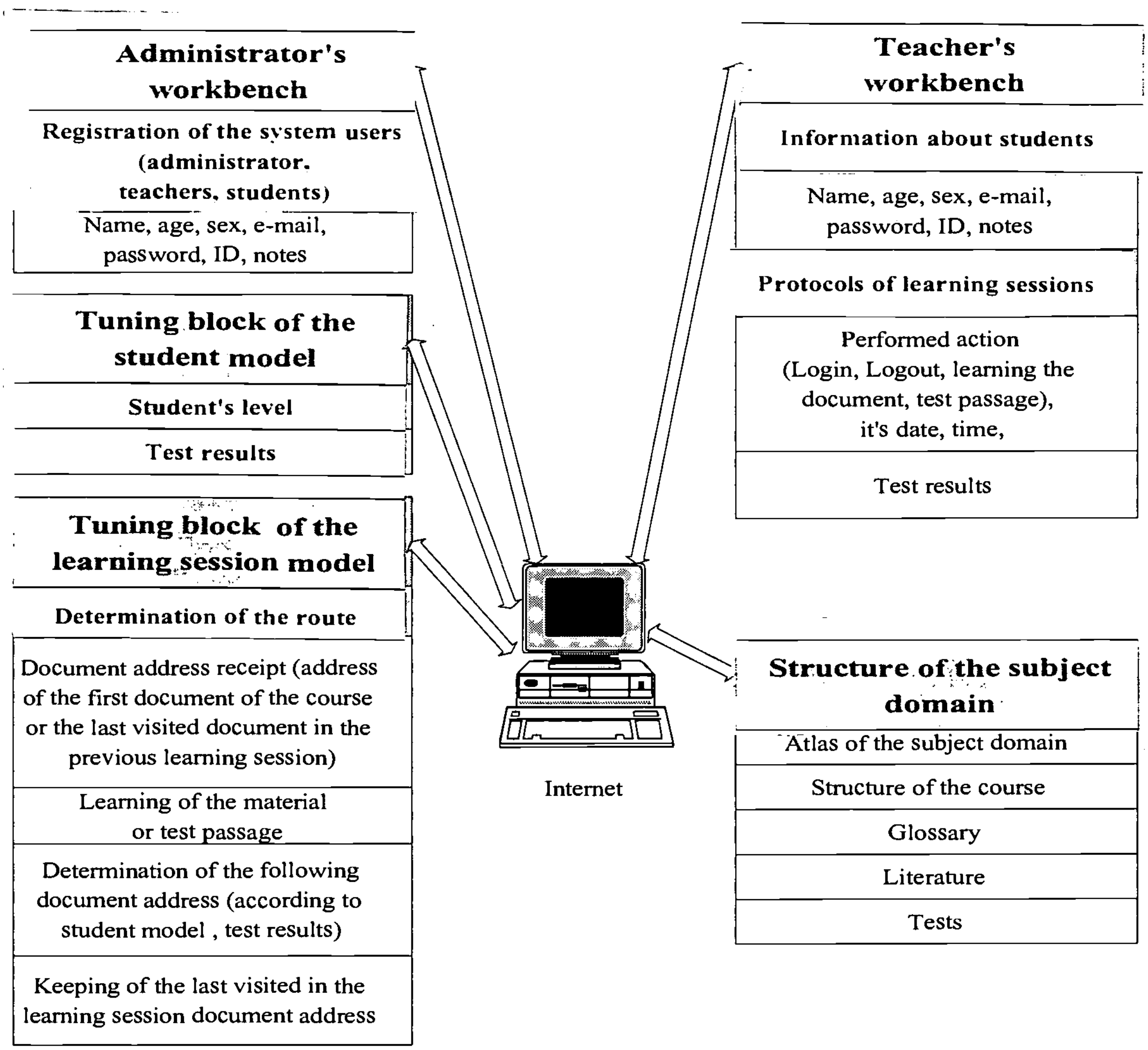

Figure 1. Architecture of the adaptive DL system

It consists of the following components:

- Administrator's workbench – fulfilling functions of system administering. System administrator may add and delete users (teachers and students), enter all necessary information about them, assign teachers to the students.
- Teacher's workbench – accumulation and provision of knowledge on subject domain, maintaining examination tests, analysis of the student "feedback". Teacher can get all information about his students: students's characteristics, information about the state of educational process (learned part of the course material, test results).
- Structure of the subject domain – documents presenting program of education.
- Tuning block of the student model – determination of student's level.
- Tuning block of the learning session model – determination of the route of education.

Navigation in education

Learning material is presented in the form of hypertext. But not the whole hypertext area may be accessible for the concrete student. He is presented only those links that lead to parts of the course with the material corresponding to his level. In the context of education the student do not passively examines learning material but also learns a certain amount of relevant information. Therefore the system includes some level of control by means of testing. The student may be left free to examine some area of the course but before passage to the following area the system checks how he gained the material.
In the process of navigation he must pass some intermediate examination tests which results define the further route of education. He is not presented the following part of the material until he doesn't successfully overcomes corresponding test. In case of wrong answers to the questions he is returned back to the previous parts of the material that he didn't understand enough. The navigation within the mastered area of the material is unrestricted.
It is possible to distinguish several student levels in dependence with the volume and complexity of the learning material and according to the students' characteristics. The system allows to chose scenario of the learning material to each student level. In our case the volume of learning material is not large so the course is developed with the use of two user models: "novice" for whom profound learning of the material would be difficult and only part of the course including basic questions is presented for him and "professional" for whom the whole learning material is presented.
The users who found themselves on the main page of the course can get information of common character about the proposed learning program and developers. They are able to look through the contents of the course (titles of chapters, paragraphs). Besides, for better understanding the structure of the course is presented in the form of graphical schemes - Atlas. It allows to discern classes and subclasses, concepts and objects of the subject domain, reflect semantic connections between them. The functional meaning of Atlas is to give full and clear notion of the subject domain. Navigation in the hypertext area is also possible through these schemes. One of the schemes is presented on figure 2.

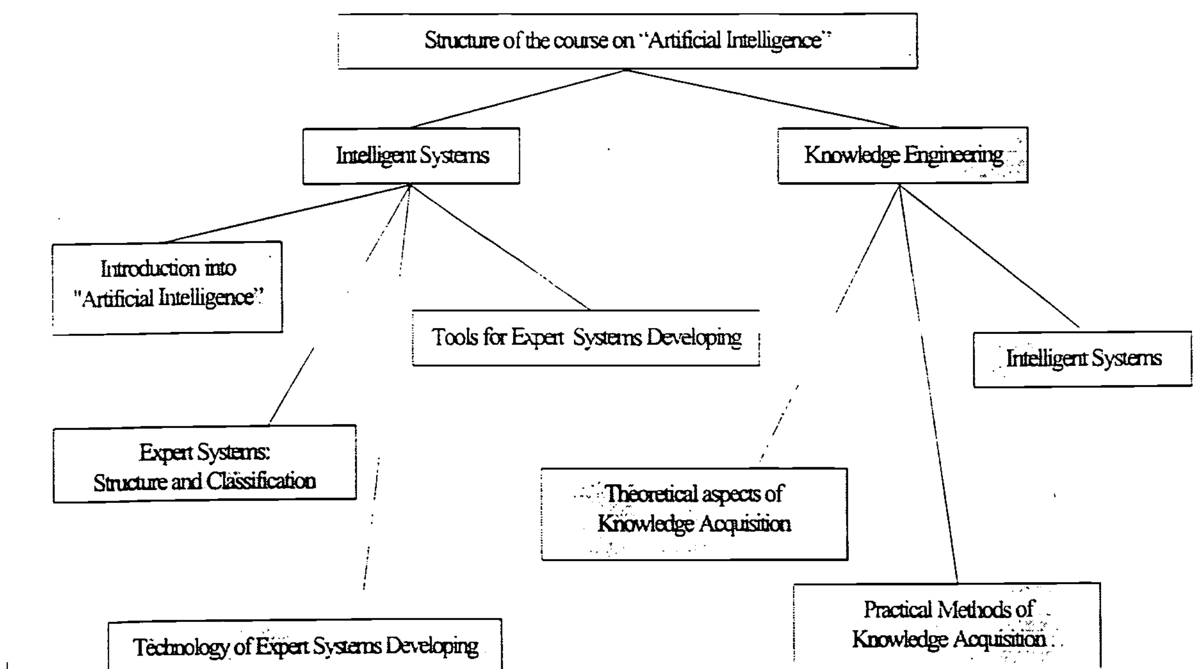

Figure 2.

But only the registered users ("students") can get access to the learning material. First of all the student must pass preliminary testing that reveals his characteristics and on it's basis indicates his level: "novice" or "professional". In dependence with its results the corresponding structure of the course is chosen.
After each part of the course he is given intermediate examination test. It may be close with several variants of answers or open. The system automatically sets mark and defines the further route of education. In the educational process the system dynamically gathers the following information about the student: performed

actions (login, logout, learning particular document, test passage) with their dates and time, test results. The student is provided with feedback to the teacher. So he is able to address the teacher for explanation some incomprehensible parts of the learning material. Each time when the student finishes the educational session the system remembers the address of the last visited page. Therefore beginning the next educational session he finds himself on this page.
In case of successful overcoming of all the tests the learning course is finished.

Program implementation

Intelligent Distance Learning Environment IDLE developed and implemented for creating and management of the adaptive DL system. is a three-layer 100% Pure Java toolkit which provides all the necessary functionality for developing, maintaining and using adaptive courses. Java application makes possible for the users of the system to fulfill their functions from any point in the Internet.
The lower layer of the system is SQL (structured query language) DBMS (database-management system) with the database. It contains structure of the course graph, rules for passage between it's nodes, student models and protocols of educational sessions, some administrative information.
Middle tier - application server is a Java application which provides its services through RMI. It is connected to the database using open interface JDBC (java database connectivity) API.
Client software – higher tier - never modifies the database directly, only through the high-level API. This standard approach guarantees the portability of the environment between different SQL servers. Client software are the Java applets running inside any standard modern browser having JDK-1.1 compatible JVM.
For specifying rules used in the course graph, the Scheme language is used. The mature, pure Java implementation SILK/JLIB (http://www.norvig.com, http://www.cs.brandeis.edu/~tim) is incorporated into the system as a scripting language, so course developers can write rules of any complexity. Each rule comprises the expression which result is considered as a weight ot the corresponding course link. Largest value gives the link which the system chooses for the further movement.
For developing test subsystem XML (Extensible Markup Language) is applied. The DTD (Document Type Declaration) and example describes all the possible types of tests which IDLE can manage. Using XML in the system provides general flexibility and extensibility. It is the most flexible way to handle student model.
Atlas of the subject domain is presented with the use of tool Pegas developed in the Laboratory of Artificial Intelligence of the Institute for High Performance Computing and DataBases (http://www.csa.ru/ailab).

Conclusions

The work is now in progress. The approach described in this paper may be implemented for different disciplines, not only for artificial intelligence (for example, course on cognitive sciences - psycho-linguistics and neuro-psychology - is being in progress parallel to the course on artificial intelligence). It allows to adapt structure of the learning material presented to the student.

Further directions of work are the following:

1. Today the system uses link-level rules (i.e. rules associated with particular course links) for specifying the strategy of the educational process. This is not a problem for small tutorials, but for large courses, higher level of methodical knowledge should be used. The most important goal of the project is to reach the ability to define some course-level rules for the adaptive behavior of the system.
2. The concept of student model should be reviewed. At present it is completely static, the only really dynamic variables in rules are ones from student protocol. The system should provide the ability to change parameters of the student model dynamically. Moreover, this model can be used for changing not only the content of the course but also the user interface of the system. The interface should reflect student's progression using advice, for example.
3. Developing multi-agent system – developing several agents that will communicate and help both teachers and users.

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Virtual-Real Lab: an Electronics Laboratory Using Real Devices and the Internet

Humberto Gomes, Rita Pivetta, Luigi Carro
Departamento de Engenharia Elétrica – Universidade federal do Rio Grande do Sul
Av. Osvaldo Aranha 103 – Porto Alegre – Brasil - 90035-190
carro@iee.ufrgs.br

Abstract: This paper presents the design and utilization of an Electronics Laboratory, physically available through the Internet. One of the greatest advantages of this project is to offer to many students the possibility of achieving practical experiments in the electronics field without the need of their presence in the laboratory room. This paper shows the hardware used to develop the system and the frontend web page with the required security involved.

Introduction

Computers have been extensively used in Electrical Engineering education, thanks to the available graphical interface and to programs able to solve a set of differential equations. Actually, there has been reported a large number of software tools and their use in a real or a virtual classroom (Oakley 1996, Canizares 1997, Mehta 1996). Distance learning using the Internet has bloomed (Coleman 1998), but one of the main resources of learning has been almost always forgotten: the laboratory. Simulation, although helpful, by no means can replace real experimentation. On the other hand, it is very hard to offer a real laboratory for all students, open any time of the year and near his/her home. There has been some effort to allow students the access of a virtual lab in some specific niches like power systems control (Patton 1996) and control engineering (Aktan 1996).

This paper presents our contribution to allow access to a basic laboratory useful in electronic disciplines. Our main goal is not to substitute the presence of students in a real laboratory, since this is still required to develop their manual ability with components, to feel temperature of burning resistors and the like. The goal is to work as a complementary laboratory, working round the clock, where the student can achieve experiments without leaving home, getting further motivation to frequent regular laboratory classes.

There are other related advantages in using our proposed Virtual-Real laboratory. First, a lot more students can use some rare components, difficult to find or even expensive ones in security. Moreover, like simulation, the Virtual-Real Laboratory enhances the concept of active learning (because it allows easy modifications) and data collection facilities.

In the Virtual-Real Laboratory the student can assemble a real circuit and check its behavior through a web page. This page shows the set of available components and the student chooses which of these components will be used in his experiment. After the circuit is completely defined, its specification is sent to a microcomputer (in a real lab) physically connected to the protoboard where all components stay. Based on the specification received, the computer controls component selection and switching on the protoboard. A configurable board placed between the computer and the protoboard, in fact, carries out component switching. A control software running in the host computer is responsible for the correct working of the configurable board.

After component switching is done, signals read from the circuit are sent to the student who is now able to analyze them with a visualization tool, available from the Virtual Real Laboratory home page. This tool simulates an oscilloscope, so that the student is provided with the same resources found in a real laboratory. Since this project has an academic goal, a new circuit can be proposed to the students on every week, so that they can make experiments and take conclusions in a practical and comfortable way, through the Internet.

This paper presents all the hardware and software developed to support the Virtual-Real Laboratory. Section two presents the configurable board, developed to support circuit component switching. Section three describes the Virtual-Real Laboratory home page from which the student can make his experiment. The visualization tool is described in section four. Finally, section five presents our conclusions and future work.

The configurable board

The configurable board developed for this work, also called ASA matrix (from Analog Switching Array), is based on the MT8816 integrated circuit by Mitel Telecommunication. Each of these ICs is an array of 16 programmable analog switches connected by 8 connection nodes. Four MT8816 were used to obtain a matrix of 32 switches and 16 connection nodes as shown in Fig. 1.

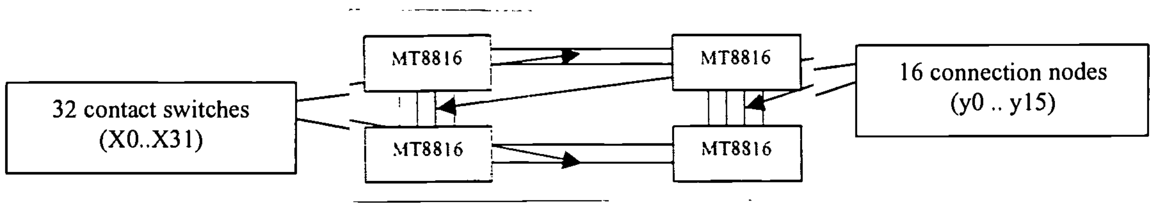

Figure 1: Configurable board.

All connections keep their state until a new addressing process is done or the RESET signal is activated. In this last case all switches are opened. Besides that, the CS (chip select) signal for the IC must be active when an addressing process is taking place. The control and addressing signals are common to all 4 ICs except for the CS signals, which have individual wires to enable the identification of which IC will receive the addressing data. Control signals come from an auxiliary board (control board) which interfaces to the computer. This board is connected to the computer parallel port and controls the ASA matrix board. It also has the connection terminals to the signal generator and to the analog to digital converter that captures data read from the electronic circuit. The control board processes data received from computer to send them to the ASA matrix. Then, the ASA matrix executes the operations to connect the correct electronic components in the circuit. Fig. 2 shows a snapshot of the actual system. From left to right one can see the control board, responsible for computer interfacing; the ASA matrix and the protoboard that contains the electronic components that will make up the circuit.

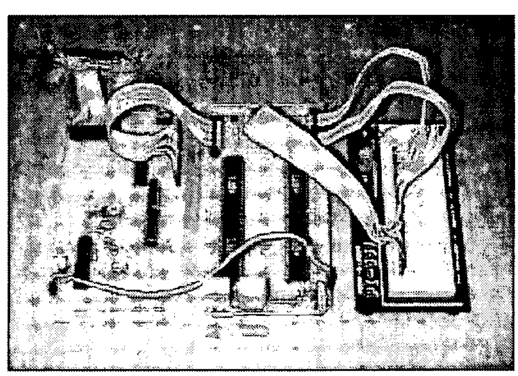

Figure 2: photo of the system

The virtual-real laboratory home-page

Fig. 3 shows the virtual-real laboratory home page (NCSA 1999) which shows the electrical schematics of the circuit to be tested and the available component values. These values are previously set by a lecturer according to the type of exercise to be implemented and to the circuit characteristics to be exercised. Through this page the user also sets the excitation and measurement points. This page, still in beta testing phase, is available at http://www.lvr.iee.ufrgs.br

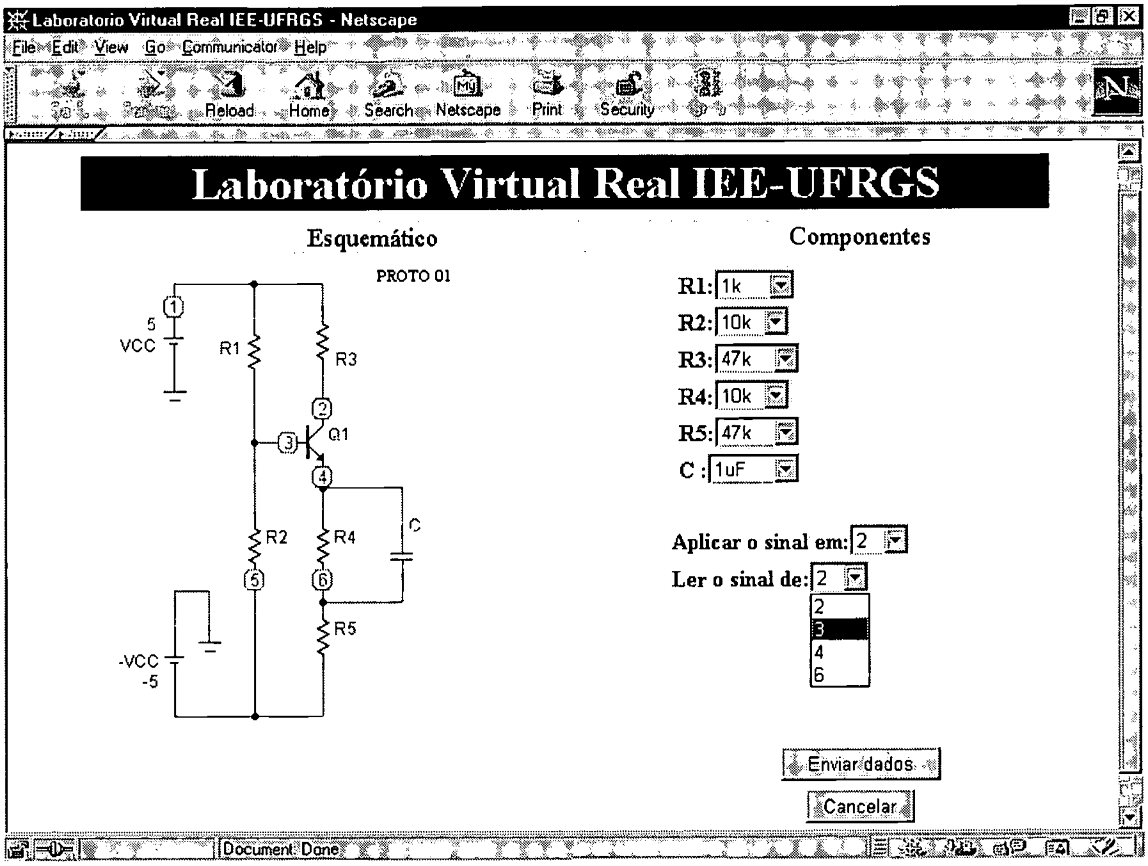

Figure 3: Virtual-real Laboratory Home-Page

The Virtual-Real Laboratory has a dedicated HTTP server (Sambar 1999) that makes the page available to the Internet. To test the circuit the user sets, in the page, all needed information, particularly choosing those components that will be used in his experiment. These information are forwarded to the HTTP server, which in turn, starts a CGI program on the computer that has the board, sending to this program all information set by user. The CGI program is responsible for direct communication with the board control software, and sends the received information to the control software, which will execute component switching, and, by consequence, final circuit set up. After the switching process is done, circuit response signals are stored in a data file whose name is informed to CGI. Then, this program builds a result page from which the user can save the data file in his local disk and analyze it *a posteriori,* using the visualization tool described in the next section.

Remote access to the page is granted to all students at any time. Since two students should not be allowed to execute experiments at the same time, there must be an access control. Access blocking is done when CGI gets running. If a student tries to begin an experiment when another is already in place the CGI associated to the second student informs him that the board is busy. When the CGI program is started by the HTTP server, it verifies if another user is already using the board. If so, the CGI program sends an error message to the user indicating that the access was unsuccessful. Otherwise, circuit information from the page is stored by CGI program in a switching file that is read by the board control software. The CGI program goes to a wait state until switching is finished and data read from the electronic circuit is available. With all data read and stored in a file, the CGI program makes the file available for download and notifies the board control software that access is enabled again. The board control software always begins execution after verifying the existence of the switching file created by CGI program. If the file exists the software proceeds with circuit switching, response signal capturing and data storing. After that it informs the file name to CGI, waits for the end of CGI program execution and re-enable board access.

The visualization tool

The visualization tool simulates the functions of a digital oscilloscope with all the resources generally found in this equipment. This way, the user can work with the wave forms read from the electronic circuit via Internet as he would view them in real-time at laboratory. The oscilloscope also has a spectrum analyzer to introduce some basis of frequency spectrum to the Fundamental Electronics students. The resources of this software can be seen in Fig. 4, which shows a snapshot of full oscilloscope program screen.

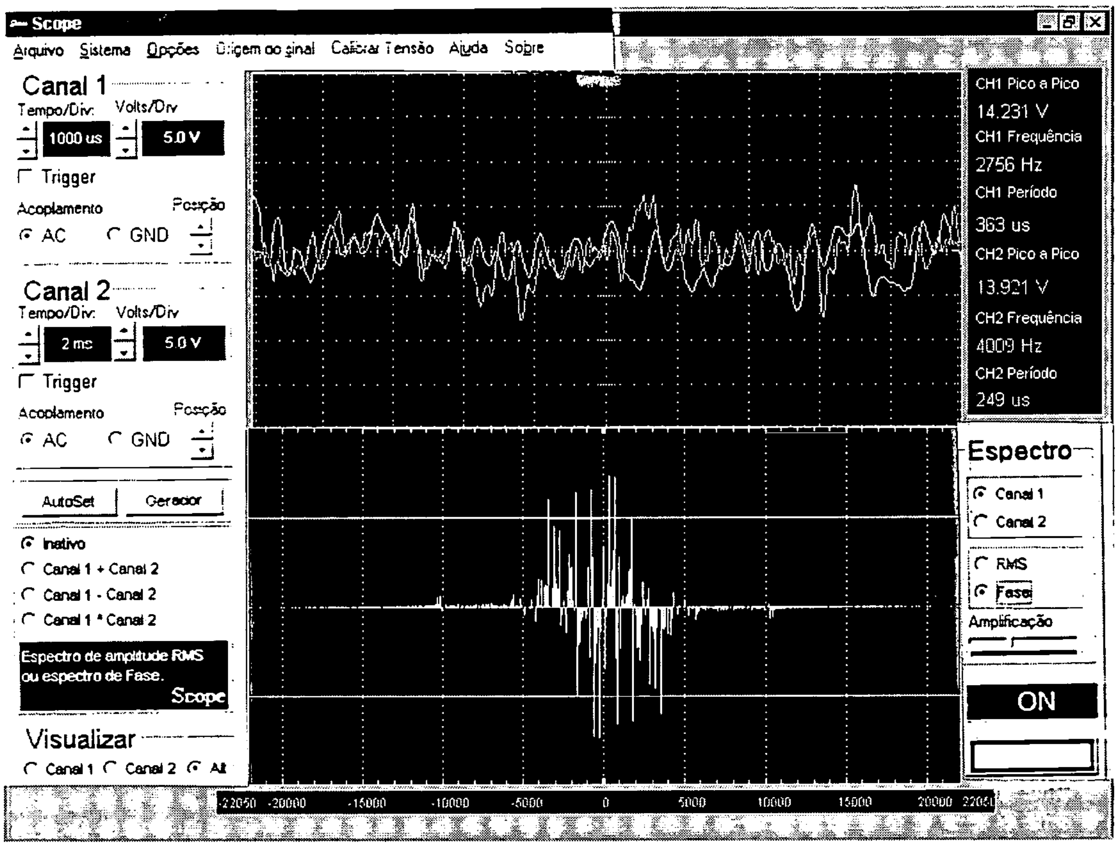

Figure 4: the visualization tool

In the top half portion of screen one can view the waveforms read from the electronic circuit. These signals keep moving on screen exactly as they do in a real lab oscilloscope. There are 2 signal channels, one of them is the signal applied to circuit and the other is the read response. The oscilloscope offers visualization resources such as time and voltage division. All controls work independently for each channel. Trigger options can be selected to force the beginning of waveforms at left screen limits. Autoset feature allows the automatic adjust of waveform on screen accordingly to its frequency and amplitude for the best view. There are also math operations such as channel multiply, addition and subtraction as well as channel visualization controls. The measurements panel shows frequency, period and peak-to-peak voltage amplitude of each wave form (channels 1 and 2). In the bottom half portion of screen one can view the signal frequency spectrum in RMS or phase mode. User can select the channel whose spectrum is to be shown, having the option of amplifying the amplitude to observe minor intensity harmonics.

Conclusions and future works

The number of services provided via Internet is growing fast. This is due to several reasons, among them the easy access to information and the low cost for installation of these services. More and more people are using this important tool for a variety of purposes: shopping, fun and specially education. There are no doubts about the importance of the Internet for scientific and technological development. The number of Internet sites dedicated to education and knowledge forwarding is enormous, but on the other hand, this is not enough to implement a distance learning program. These sites just make the access to information easier and don't free the student from going to the educational institution, since concepts must be explained and exercised, and doubts eliminated.

This project does not intend to substitute a real electronics laboratory, but to make possible to many students the access to practical experiments at a relatively low cost, using a simple and effective work method, in which students interact with real circuits instead of just consulting databases. All of that makes Virtual-Real Laboratory an important learning tool for all those people interested in upgrading their knowledge in fundamental electronics. Future work includes some more sophisticated security systems to allow student evaluation. In this case there would be a lot of possibilities such as automatic exercises correction and different ways to effectively implement a circuit.

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Mathematical Modeling within a Technology Based Learning Environment: Some Principles for Adaptive Instruction

Neal Grandgenett, Elliott Ostler
Neal_Grandgenett@unomaha.edu, Elliott_Ostler@unomaha.edu
University of Nebraska at Omaha

Art Zygielbaum, Scott Henninger, Char Hazzard
aiz@unlserve.unl.edu, scotth@cse.unl.edu, hazzard@unlserve.unl.edu
University of Nebraska at Lincoln

Abstract: This paper describes a set of research based instructional plans being developed by a multidisciplinary team of researchers at the University of Nebraska within a National Science Foundation Proof-of-Concept Grant. The project is seeking to establish a prototype effort for teaching mathematical modeling within a technology based learning environment, which includes components of adaptive instruction for the student. Seven curriculum based design principles for the adaptive instruction that are being followed in the development of the project are described in the paper as they relate to research on effective mathematics instruction, and in particular the enhancement of mathematical modeling activities.

Why Mathematical Modeling?

This paper describes seven design principles, and related development plans, being integrated into a curriculum design project within the context of a NSF Proof-of-Concept grant. The project is targeting mathematical modeling as a content area within the project, because mathematical modeling is both an important topic in today's mathematics classroom, and an unusually difficult process to teach in the traditional classroom. Mathematical modeling can be defined as a mathematical process that involves observing a phenomenon, conjecturing relationships, applying mathematical analyses (equations, symbolic structures, etc.), obtaining mathematical results, and reinterpreting the model (Swetz & Hartzler, 1991).. It is essentially a systematic generalization process, where the mathematical model (such as a mathematical expression or algebraic formula) attempts to describe the mathematical relationships for a group of problems or situations, and is refined over a period of time with additional testing or use of the model.

Mathematical modeling can be difficult to teach in traditional formats, such as lecture, and often requires considerable student involvement. Part of the difficulty in the instruction of mathematical modeling, is that considerable flexibility and feedback is often needed to work with the student (Smith, 1997). As a student's understanding evolves, their conceptual model may go through many different evolutions, hopefully becoming more refined over a period of time, and with more instruction and feedback. Often, if a formula can be used to represent the model, the formula evolution itself may somewhat represent the evolution in the modeling process. Mathematical modeling is in essence a "scientific inquiry" process for mathematics, and can be thought of as being undertaken in a series of four stages, which become cyclical as the model refines. Four stages can be considered within the mathematical modeling process typically undertaken (Swetz & Hartzler, 1991). These stages include: Stage 1 - Observing and Discerning (observe the phenomenon or problem); Stage 2 - Conjecturing (proposing a mathematical or symbolic representation of the problem; Stage 3 - Applying Mathematical Analysis (converting relationships within the data based model to mathematical equations or expressions); and Stage 4 - Interpreting Results (test the model, and obtain results and interpret them in the context of the original problem).

The Teaching of Mathematical Modeling

Mathematical modeling is a key process for the complex problem solving that takes place in businesses and industry, and applied mathematics in engineering, as well as other fields. Due to the applied focus of mathematical modeling, there are lots of real life problems lending themselves to mathematical modeling, such as predicting wildlife populations, costs of long distance phone calls, irrigation flow rates, and even the fastest line to enter in a

check out stand at a grocery. From a classroom perspective, these problems often lend themselves well to interactive multimedia and technology based instruction, where a simulation might be used as part of the instruction, as well as a systematic questioning process involving student dialogue or discussion. The use of such interactive activity within an electronic course format can be a powerful mechanism for building the knowledge base of students, as well as assessing the individual skills of students (Richards, Barker, Meng Tan, Hudson, and Beachman, 1997); and such work has already been successfully integrated into limited knowledge transfer systems.

The effective instruction of mathematical modeling within a classroom context or related course format is often built upon several important assumptions or considerations (Ostler & Grandgenett, 1999). These include the following: 1) Students have some control over how they approach the problem, 2) Good modeling activities are adaptable to many different ability levels, 3) Good modeling activities are scalable to different grade levels, 4) Problem solving and mathematical modeling are retained as different but related processes, 5) Mathematical modeling is used to focus primarily on the general case, and 6) The mathematical modeling is assessed carefully within the learning process, since even a poor model may build student understanding as it is tested, and then discarded by the student.

Adapting Instruction for Effective Mathematical Modeling

The designed project undertaken within this NSF Proof-of-Concept project is initially targeting the instructional topic of acceleration, which is a common topic covered in a variety of developmental mathematics and science courses. Especially relevant to the choice of developmental math for the prototype design effort is the fact that developmental math courses are taught in 72 percent of four-year institutions of higher education in the U.S., and nearly every (99 percent) two-year colleges. Students in these remedial classes are often nearly on their own, left to work their way through a textbook with only a graduate student instructor available to answer questions and offer assistance. Many universities, including the University of Nebraska system, are not able or willing to use scarce and expensive instructors in what are essentially seen as remedial courses. Using the instructional approach being planned within the design process, if expanded, would provide the advantage of more interactive and personalized instruction than what is usually now available in such developmental math courses.

The overall vision for the technology based learning environment that is being designed in this NSF Proof-of-Concept endeavor is one which is consistent with the vision of new technology based resources as recommended by documents such as the 1996 NSF document "Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology." In addition, the use of a technologies that assist individual learners with different instructional styles and educational opportunities is a key design consideration. Within this context, the project is also striving to develop technology-based applications which can help illustrate the utility of "learning communities" within such instruction, that can provide a flexible and extended learning process which might take place both inside and outside of the traditional classroom walls. The possible contribution to a student's individual learning process, as represented by such learning communities is just now being fully recognized. As described by the SRI International Center for Technology in Learning, in the report Future Visions by the United States Congress Office of Technology Assessment, the educational potential and utility is considerable: "the effective use of this technology could alter the relationships between homes, schools, and workplaces and in so doing assist the creation of new kinds of communities --- communities that have learning and teaching at their core and use digital technologies to foster higher levels of community participation, enable deeper levels of cognitive and social engagement, and structure new kinds of relationships that support education." (From Future Visions, Kozman and Grant, 1995, pg. 121)

In order to ensure that the project is designed with the individual student learning process as the priority consideration, research-based educational design principles are being carefully integrated into all aspects of the project development. In essence, the educational vision for the adaptive instruction to be used within the project is such that the instructional process will embody the following seven design principles.

Design Principle 1) The adaptive instruction will seek to be a use of technology that helps students learn through involvement with real life problems, real life data, and true examples of mathematical modeling as they apply to today's world.

The use of real life problems, data, and tools within the context of technology based mathematics instruction has long been recognized as a beneficial contribution to student learning (Corbat, 1985). The availability of the Internet has expanded the teacher's selection of such modeling resources and software, which are now available to a much greater extent than they were even five years ago (Harvey and Charnitski, 1998). It is this new

networking capability that promises to provide teachers everywhere with an enhanced opportunity to incorporate mathematical modeling activities into existing curriculum and to give their students a chance to undertake modeling activities that are fairly realistic. For example, students might examine actual census data using new statistical tools to create their own predictive model of a societal trend. In addition, such new resources and tools also suggest the potential for a wider use of mathematical examples across grade levels, with greater flexibility in how a student might approach a mathematical modeling activity. For instance, real life examples related to optimization were normally not taught until Calculus, but with the appropriate graphing technologies, students at lower grade levels can learn to interpret and build mathematical generalizations based upon graphical information as well as the traditional calculus approach. This exposure in the lower grades (i.e. algebra or geometry) would set the stage for much more meaningful problem solving and mathematical modeling when the same students reach Calculus and study optimization as a formal topic.

Design Principle 2) The adaptive instruction will seek to actively rather than passively involve students, in deep conceptual questions and encourage them to be both dynamic and flexible in their thinking and problem solving.

A fundamental instructional idea behind mathematical modeling is that students, through modeling activities, discover patterns and consistencies in data that will allow them to test, refine, and build generalizations by creating a "mathematical machine" which represents a particular situation (Smith, 1997). This "machine" would provide them with a means for conjectures and predictions that might be tested using data sets, or systematic trials. Thus, the mathematical modeling process by a student typically goes through several modifications or refinements in order to produce a model which is more accurate, faster, or efficient. The creation of such a mathematical machine by a student, and its testing and refinement, is typically a very interactive process. Such systematic thinking within the mathematics field by a student is similar to they might undertake using the scientific method within a science class, and parallels that process closely. It also helps students understand that true mathematical application is much more than the mere routine application of formulas and strategies that they may have experienced in some mathematics instruction.

Design Principle 3) The adaptive instruction system will seek to be an additional resource to teachers and classrooms, rather than a replacement for these valuable assets to student understanding.

The design project being undertaken in this effort is striving to enhance rather than replace the important synergy that often happens between a teacher and student in the learning process. Within this context, the technology being designed seeks to facilitate the shared thinking between a student and their teacher, or a student and other students. The technology should also help organize and coordinate the technology based resources available to a student within the classroom environment, in addition to the teacher. For example, students often don't know what technology based tools might be useful for helping with a particular mathematical modeling task. How might they use a spreadsheet to help examine their data? How might they test some of their evolving ideas within a mathematical simulation? Where might they go on the web for additional information on a modeling topic? This third design principle then seeks to permit the student as much control as possible within the learning process, and still help the student structure their thinking, and coordinate the access of their classroom resources, so that they can work more efficiently and use their resources more effectively.

Design Principle 4) The adaptive instruction will seek to enhance human interaction, by connecting students more effectively with the teacher, their peers (other students), and appropriate mentors (professionals) during the mathematical modeling process.

Based upon the student level, interests, and local resources and professional availability, the system will also suggest opportunities for students and professionals to work together electronically and collaboratively to confront modeling challenges as a "affinity learning group". Similar to electronic special interest groups or listservs, but more focused on a particular task or set of activities, these affinity learning groups will move forward together to share ideas and activities occurring on the system. In this way, students can tap the thinking of other students, as well as designated professionals.

Enhancing the ongoing dialogue between students and their teacher, students and other students, and students and other professionals, within such affinity learning groups is an important component targeted in the project design. Cognitive coaching and affinity learning as proposed in this project, have already been used successfully online in several classroom focused projects. For example, the Electronic Emissary Project, from the University of Texas at Austin, was able to match a wide range of students with scientists and other professionals to assist in answering questions on-line and for engagement in focused problem solving (Harris, 1996). This project

would expand and add to such efforts by having the technology within the project assume a greater role in the facilitation of the structured dialogue process.

For extending student access to content expertise within the mathematical modeling process, the design team is targeting the development of something called an "Inquiry Garden" or "Knowledge Garden", where questions can first be asked by a student to an interactive system. If the system can understand and respond to the student question, it does so based upon a stored database of knowledge related to the question, providing immediate feedback. If the student wants additional information, or doesn't feel that the information is helpful, then the system can forward the student's inquiry to a peer group of learners, or to the teacher, or to an outside expert or professional. As these individuals contribute new content based answers to the student, the system might store this new response, and index it as part the existing knowledge stored within the system related to that type of question. Such an extended and systematic inquiry process should help the student organize their thinking a bit, and efficiently tap the important resources represented by the thinking and feedback of others, as they work through a challenging mathematical modeling activity. For this important design feature of the project, the project is building upon the previous work of Henninger (1997, 1996), one of the PI's of the project.

Design Principle 5) The adaptive learning system will help with the ongoing assessment of student understanding, through a systematic use of embedded assessments, as well as student self-assessment.

The systematic assessment of student understanding is a very important piece of the interactive technology being planned within the project. As educational technology continues to rapidly advance, new assessment opportunities and techniques are surfacing based upon these new technologies (Baker & O'Neil, 1995). Within this project, the use of assessments which are carefully integrated into the instructional environment, or "embedded" are targeted within the project design. For example, in an instructional activity where a student uses a spreadsheet to examine patterns of data within the mathematical modeling process, the system might record what variables the student is using within the spreadsheet, and perhaps the formulaic relationships between the variables. If key variables, or relationships have not been identified by the student, then additional instruction may be needed.

Drawing upon the potential of new technologies to store and index student information, an on-line student portfolio, or related student assessment profile, is targeted as a design feature. There is indeed a rich context of potential assessment information which often exists within an on-line or technology based learning environment, and the technology itself can indeed be a very useful tool in the organization of such information (Mathies, 1995). In fact, assessment variables which might be stored within the context of such a student profile are quite numerous. These variables can include a wide variety of student performance information. Some examples include the quality of the questions asked within electronic dialogue with the teacher or peers, the speed of response within a simulation environment, the approach used to set up on-line experiments to test data, the content information self-selected by the student to review. Student self-assessment can also be very rich within this context, and students might reflect periodically upon their own levels of understanding.

It is recognized within the design process being undertaken in the project, that any assessment will of course have some inherent degree of error in examining or predicting student understanding. An important component of the current prototype design planning in the project then is to try to identify potential "nodes" of student understanding, or related "nodes" of student misconception, within the content area of acceleration, based upon previous work of researchers in this topical area. We have defined a "node" to essentially be a key point within a student's understanding related to a particular content area or process. For example, within the acceleration content area, such a node may be something as simple as recognizing that the student now understands that velocity is changing over a period of time. It is recognized that some student presence at a particular node of understanding may initially be less defined or "fuzzy", until the system has adequate data from the student to determine whether a particular level of understanding or "node" has been truly achieved.

Design Principle 6) The adaptive instruction will assist students in a systematic learning process, by carefully targeting instruction based upon their current levels of understanding.

The design of the project seeks to ensure that students will work from current levels of understanding (or achieved nodes as mentioned earlier), and are able to access content information as they are ready for it. The ability to move easily and systematically through content is an important component of any successful online instructional endeavor, and particularly when faced with the mathematics discipline (Harvey and Charnitski, 1998). For this design component, the project is building upon previous successes and expertise already established within the CLASS project (Communications, Learning, and Assessment in a Student-centered System) underway at the University of Nebraska at Lincoln.

Design Principle 7) The adaptive learning system will strive to assist students in the learning process, by acting as a non-threatening coach or assistant, which patiently helps them clarify their thinking process, examine possible approaches to the problem, and test possible solutions.

Within the design philosophy and process being undertaken in the project, student control is perhaps the most important design feature being incorporated. The vision for the project is one in which the student helps initiate, monitor, and direct their own learning process. The independent nature of the mathematical modeling process makes this a key design feature needed for any system which strives to assist in the modeling process (Smith, 1997). In fact, as described by Smith, the first independent run through the modeling process is often the most difficult. The education design within this project is paying particularly attention to this typical difficulty. Thus, the project seeks to assist students in learning how to initiate a mathematical modeling endeavor by helping assist their choice of modeling subtask, presentating the subtask appropriately, and delivering their the appropriate tutoring, and relevant instructional intervention, as needed. Facilitating such a systematic control by the student is also one the most difficult design challenges that we are facing in the project.

The Challenges of Building a Prototype System

It is indeed a daunting task to build an interactive and technology-based instructional system that truly follows the seven educational design principals set out by the team, and described in this paper. Each principal is itself an individual design challenge, and inherent with its own set of individual challenges when trying to be operationalized within the context of one or more components of a working system. However, the design team is building upon a solid foundation of earlier work, a commitment to innovative instruction and learning, and an ongoing dialogue with numerous colleagues. We are in essence seeking to conceptualize and examine how such system might contribute to all areas of the achievement cycle in mathematics education: curriculum, assessment, instruction, and learning (Glatthorn, Bragaw, Dawkins, & Parker, 1998); a cycle which is becoming all the more important with the growing commitment to standards based curriculum and related student achievement within our country.

A Final Thought: The Importance of Work in This Area

As an instructional team, we have found that mathematical modeling is indeed an appropriate topic for the content and focus for the design of a new adaptive instructional system. It is difficult to teach mathematical modeling in traditional ways, and the importance of mathematical modeling within the mathematics curriculum is well recognized, and seemingly growing. In addition, mathematical modeling is a natural outgrowth of the reform efforts of many committed organizations, such as the National Council of Teachers of Mathematics, and the Mathematical Association of America. Although daunting, the design task we are addressing is also a very engaging and interesting one, and we are learning something almost every day about how students learn, and how we might better support them in that learning process. There is little doubt that good mathematical modeling instruction takes considerable effort by both the teacher and student; and that correspondingly, the development of instructional systems to support such a complex process will also take considerable design effort before a workable prototype or clear components to that prototype can emerge. However, it is also clear that in this situation, the design effort and energy to be expended is well worth it, as we seek to understand and help contribute to the exciting learning opportunities represented by new technologies, and new approaches to the learning process.

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Can the Same Results be Obtained Using Computer-mediated Tests as for Paper-based Tests for National Curriculum Assessment?

Greenwood, L., Cole, U.M., McBride, F.V., Morrison, H., Cowan, P.& Lee, M. (1998)
The Institute of Computer Based Learning
The Queen's University Belfast

Abstract This paper describes part of a research programme designed to explore the validity of using computer mediated tests as opposed to paper-based ones for National Curriculum testing in mathematics at Key stage 3. Previous research in this area has focused primarily on the comparison between computer-based and paper-based multiple choice questions while this research uses constructed response questions similar to those used at present in National Curriculum testing. A total of 127 pupils was tested using questions based on items selected from National tests in mathematics at Key stage 3. The study showed that where questions tested similar cognitive tasks there were no significant differences in outcomes. Questions requiring spatial awareness were more difficult when presented in a computer environment. Also the study illustrated that constant care is required to ensure that computer-based questions do not change the level of cognitive tasks of paper-based examples. The paper demonstrates the potential and limitations of a shift to computer based assessment.

Keywords: **Computer-based assessment; National Curriculum assessment; Computer-mediated assessment, Assessment of mathematics, Constructed response.**

Introduction

The research described in this paper is part of the ATOM (Adaptive Testing Of Mathematics) project, a co-operative project between the Institute of Computer Based Learning and the Graduate School of Education at the Queen's University Belfast. The ATOM project has been designed to look at the utility of Computerised Adaptive Tests (CAT) in mathematics with particular reference to the National Curriculum assessment. For an account of CAT see Cowan (1997) and Green (1983).

This paper analyses whether it was possible to obtain similar results in National Curriculum Tests (NCT) in mathematics at Key Stage 3 (14 years). The computer mediated tests used in this research were not adaptive as when comparing results between computer-based and paper-based tests, it was necessary to ensure that all questions were attempted by all participants.

There are advantages in assessing students using computer-based tests rather than the traditional pen-and-paper tests. The advantages may include:

- automation of test results;
- automatic generation of progress reports for each individual student;
- saving in teacher time;
- minimal cost of individual tests compared to paper-based tests once the tests have been created;
- test security - computerised question banks can be made much more secure than paper-based tests;
- reduction in the time spent in assessment rather than in constructive learning;
- reduction of opportunities for copying;

Although the present advantages of using the computerised tests are mainly administrative and represent an economy in the use of the teachers' time there are other factors that can to some extent contradict the positive impact on testing. These include:

- the need of teachers to be confident with the technology
- the availability of computers
- the lack of a working record of the pupil's work
- The time taken to computerise and trail the questions

Nevertheless research into computer- based testing may help clarify the direction NC assessment may take in the future.

Review of the Literature

In a comparison of paper-based tests (P & P) with CAT, Lunz & Bergstrom (1995) found that the mean ability estimates, standard deviations, and pass rates were comparable across modes of administration. However, this comparison was made using tests delivered in multiple choice format rather than in the constructed response format mainly used in NCT. See Green et al (1994) for guidelines in assessing CATs. The present research seeks to establish whether results from computerised tests using constructed responses can be comparable to those results obtained from traditional pen and paper tests.

In the United States, CAT testing is gradually replacing paper-based tests as the principal method of assessment in a number of subject areas. However, these CAT systems involve mainly multiple choice questions rather than constructed response. While it is possible to assess a number of the National Curriculum attainment targets with multiple choice questions, there could be problems associated with a complete change to this format. Gipps (1993), Murphy (1982) and Wood (1978) argue that multiple choice testing gives boys an advantage over girls whereas extended writing favours girls. However, short answer, constructed response type questions have not been found to be biased in favour of either sex. In particular, Nuttall (1987), in examining the literature to explore the effect of context in tests, has concluded that "assessment (like learning) is highly context-specific and one generalises at one's peril" (p. 115). Traub (1993) concurs with this view; having searched the literature for studies of equivalence of testing methods and reviewed nine studies in detail, he concluded that there was too little evidence to decide whether multiple choice and constructed response questions measured different characteristics (p. 38).

Braswell and Kupin (1993) indicate in their article 'Item Formats for Assessment in Mathematics' that "multiple-choice examinations are frequently criticized because the task posed requires students to recognize a correct answer rather than to generate one" (p. 167). They emphasise an additional advantage of the constructed response question over multiple choice format in that it is possible to analyse incorrect responses to identify students' misconceptions and thus enable the teacher to improve pedagogy. This certainly concurs with the aims of NCT not only to analyse pupils' performance but also to assist in their further development.

In view of

- the concerns expressed by Gipps (1993) re gender differences,
- the uncertainty as to whether multiple choice and constructed response questions measure the same characteristics (Traub 1993),
- the ability of constructed response answers to be used for the identification of student misconceptions as identified by Braswell and Kupin (1993),
- the need to maintain validity with the present paper-based NCT,

it was decided to maintain the constructed response format of the paper-based tests in both modes and not to allow open responses that could not be assessed objectively in a computer environment.

The Research Programme

This research investigates the implications for test construction in a computer-based testing environment. There are several questions that need to be answered in this context. Among the most important are the following:

- do the questions presented on a computer lead to similar conclusions as the same questions in pen-and-paper tests?
- do the questions presented on a computer test similar mathematical skills and concepts as the same questions in pen-and-paper tests?
- does lack of computer experience, e.g. in keyboard or mouse skills, adversely affect scores?
- do questions which require the use of pen and paper for calculations or planning an answer, pose more problems when working on a computer than they do on paper?
- will questions which are logically structured and sequentially presented on the computer effect performances?
- will the fact that pupils no longer have the opportunity to revise answers at the end of the test affect the results?

Method

In this research, tests involving a wide range of response types used in NCT of mathematics for Key Stage 3 were administered to a group of Year 8 and 9 pupils in both paper-based and computerised format. Healy et al

(1995) describe how these mathematical tests were calibrated using more than 1000 experienced teachers and 13,000 pupils using a multi-session Angoff (1971) procedure.

Two tests of 12 questions[1], spanning the levels 4, 5 and 6 were constructed. Each contained 5 questions from Level 4 , 3 from Level 5, and 4 from Level 6 (the expected level of the pupils lay between levels 4 and 5). The Level 6 questions were included in order to examine a wider range of response types than was possible using Levels 4 and 5 only.

A computerised version and a paper-based version of each test were produced. In a few cases the questions had to be changed slightly for the conversion to computerised format but in the main the items have face validity - i.e. they seem equivalent in both the presentation and the response handling of the item; viz. typing a response instead of writing it, using a mouse click to select an item instead of marking it. However, the computerised tests used progressive revelation i.e. multi-part questions were revealed sequentially. Also on the computer test, while pupils could review and change their response while answering each question, they could not review the entire test at the end as they could on the paper-based test. A CAT system, due to its adaptive nature, does not support a review facility.

A total of 127 pupils (four classes from each of Years 8 and 9) was tested in the four tests, which were held on consecutive days. The pupils were almost equally divided between Year 8 (62) and Year 9 (65) and there were 70 males and 57 females. All the classes tested were of mixed ability. Half of the students in each year did the computer-based test first and the remainder did the paper-based test first. This order was reversed for the second test.

Analysis of Overall Results

Effect of computer experience

None of the students could be classified as complete novices since they had all completed a one year course in IT (one hour per week). Over 80% said they had no difficulty using keyboard or mouse and the remainder had only slight difficulty - this was associated with a scale drawing question which is discussed in detail later.

Comparison of scores

The results were analysed using the statistical package SPSS® 7.0 for Windows™. shows the overall frequencies: of the total of 127 pupils, 124 sat computer test 1, 121 sat paper test 1, 116 sat computer test 2 and 108 sat paper test 2. The mean percentage marks for each version of the test vary from 56.61% for paper test 1 to 36.89% for computer test 2, with a relatively large standard deviation. In both cases the result for the paper-based test is higher than that of the computer-based test.

	N		Mean% mark	Std. Deviation	Minimum % mark	Maximum % mark
	Valid	Missing				
computer 1	124	3	52.79	16.50	17.86	100.00
paper 1	121	6	56.61	14.92	10.71	92.86
computer2	116	11	36.89	18.00	.00	83.33
paper 2	108	19	45.29	19.16	4.17	95.83

Table 1: Overall results

Considering the possible effect of the testing order first, it was found that while those who did the paper-based test first obtained better results on both tests than those who did the computer-based test first, this result was not significant.

Further analysis of the overall results, using a paired samples t-test (see **Error! Reference source not found.**) shows that the difference in mean scores on the computer-based test 1 compared to paper-based test 1 is significant at the 1% level ($p \leq 0.001$), while the difference is more significant for computer-based test 2 compared to paper-based test 2 ($p \leq 0.0001$). Thus, while results obtained using the different media are broadly similar, the significant difference between them suggests further analyses be made of individual questions

[1] Copies of the Tests may be obtained from the authors at ICBL, The Queen's University of Belfast

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	computer test 1 - paper test 1	-3.12	9.86	.91	-4.91	-1.32	-3.436	117	.001
Pair 2	computer test 2 - paper test 2	-7.84	11.64	1.16	-10.14	-5.54	-6.767	100	.000

Table 2: Analysis of results from computer-based and paper-based tests using paired samples t-test

Comparison of results by NCT level of attainment

When each NCT level of attainment is considered separately, there are 10 questions from Level 4, 6 questions from Level 5, and 8 questions from Level 6. Table 3 shows that the mean mark is approx. 69% on the computer-based level 4 questions and 72% on the paper-based version. A cut-score, as defined by Healy et al (1995), is the score below which a pupil can be declared a non-master of a particular level and above which mastery of the level can be assumed. The cut-scores on the original standard assessment tests vary from 66% to 78% with a mean value of 70%. While it is not possible, without using an Angoff (1971) standard-setting procedure - a rigorous reappraisal of all the questions included in these tests by a large number of experienced teachers - to establish the true cut-score for these tests, it may be worth while to examine those who obtained more than 70%, the mean cut-score, and those who obtained more than 65%, i.e. just below the lowest cut-score of the pen and paper tests. From this analysis it appears that the majority of the pupils are performing at level 4 or above. While there is a strong positive correlation ($r = 0.77$) between the results from the two modes of test for Level 4, there is a significant difference ($p \leq 0.01$).

		Mean	Number	Std. Deviation	Std. Error Mean
Pair 1: Level 4	Computer	68.77	103	19.53	1.92
	Paper	72.22	103	16.56	1.63
Pair 2: Level 5	Computer	24.19	103	19.85	1.96
	Paper	23.79	103	17.64	1.74
Pair 3: Level 6	Computer	34.02	103	17.97	1.77
	Paper	43.69	103	19.77	1.95

Table 3: Comparison of results by NCT level of attainment

With all students who did not complete all 4 tests omitted from the analysis and those students obtaining more than 70% on Level 4 questions classified as masters at this level, and the rest as non-masters then Table 4 shows that 49.5% would be classified as masters using both media, 34% as non-masters using both media, but a number of pupils (16.5%) would be classified differently depending on the mode of testing. Of these, almost 10% scored higher in the paper-based test and the remainder (7%) scored higher in the computer-based test.

Level 4 Questions			
	Frequency	Percent	Valid Percent
Above 70% on both media	51	40.2	49.5
Above 70% on paper, below on computer	10	7.9	9.7
Above 70% on computer, below on paper	7	5.5	6.8
Below 70% on both media	35	27.6	34.0
Missing some values	24	18.9	
Above 65% on both media	60	47.2	58.3
Above 65% on paper, below on computer	12	9.4	11.7
Above 65% on computer, below on paper	5	3.9	4.9
Below 65% on both media	26	20.5	25.2
Missing some values	24	18.9	

Table 4: Analysis of results of NCT level of attainment 4 questions

By taking the lower cut-score of 65% similar results are obtained - while a larger percentage is classified as masters (58.3%) on both media, 16.5% of pupils are still classified differently depending on the mode of testing. The presence of a significant difference between the results suggests the examination of results on an individual question basis.

The means for both the other levels were low, (see Table 3) approx. 24% achieved Level 5 for both modes of testing, 34% achieved the computer-based test for Level 6 test and 44% for the paper-based version. Since the vast majority of the pupils were non-masters at these levels it is not possible to analyse the results as has been done for Level 4.

Times taken to complete tests

The average time taken for each test was roughly similar (see Table 5) - the means varied from 15.45 minutes for the first computer test to 17.79 for the second and 18.74 for each of the paper-based tests. In each case, the mean time taken for the computer-based tests was shorter than for the paper-based.

Despite the relatively small difference in times taken to complete the tests using computer compared to paper, many students cited "It's quicker doing tests on a computer" as a reason for preferring computer-based tests to paper-based ones. Perhaps the immediacy and novelty of the medium contribute to this impression. Shorter completion time has obvious benefits for the teacher as well, in that less class time is spent in assessment.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Time for Computer test 1	15.45	109	4.16	.40
	Time for Paper test 1	18.74	109	6.10	.58
Pair 2	Time for Computer test 2	17.79	101	4.30	.43
	Time for Paper test 2	18.74	101	4.45	.44

Table 5: Differences in times taken for the different modes of test

Students' Opportunity to Review the Test

While a few students (4 out of 117 respondents) mentioned the inability to review work at the end of the test as a disadvantage of the computer-based test, observation showed that the review, when it took place, consisted of a brief glance back through the pages. The mean time taken for paper test 1 was 1.5 minutes and for test 2 only 0.8 minutes. Forty-eight percent (48%) of pupils did no review for test 1, and a further 20.5% spent less than 1.5 minutes on the review. In only a few cases did a child use the review to attempt to answer a question that had not been answered previously, and in all of these cases the answer given was incorrect. During the review, no pupil changed an answer that was already written. These findings were unexpected, as most teachers assume that the possibility of reviewing answers is important and that many students do avail of it.

Conclusions

From an analysis of the work of students in both test modes, it was shown that changing from free response to multiple choice altered the level of abstraction within the cognitive task. However this change did not always result in different outcomes in the two test modes. When results differed, it was normally easier for students to obtain correct responses in the computer test. This need to alter the form of responses will become redundant as more powerful computers become available and as expertise grows in task setting in a computer environment.

As will restrictions on students review. Although this research illustrated that 14-year-old students did not review their work and review restrictions did not affect their results.

When questions were similarly presented in both modes, similar results were obtained (see example page). However, in questions where spatial awareness was required differences occurred even though the questions were similarly presented and the level of the cognitive tasks was similar. These questions proved to be more difficult for students to obtain a correct answer when working on a computer

In conclusion this study showed:

- Spatial awareness questions presented on a computer are more difficult than on paper.
- Care must be taken if changing from free response to multiple choice questions
- Students tended not to review their work
- Students having to use pen and paper to plan their work when using a computer test did not affect results.
- More research is necessary to further clarify the similarities and differences between test modes.

The growth and increasing complexity in National Curriculum testing with increasing demands on teachers' time necessitates renewed interest in assessment. The computer can provide a timesaving and efficient mechanism for scientific assessment. Well-chosen and carefully graded batteries of mathematical examples could significantly simplify and reduce the commitment of teachers to the process of assessment. However the computer is purely the means of monitoring such tests. It is not in itself the answer but a means of creating efficient and effective means of assessment.

This paper has illustrated some potential for the computerisation of NCT. It has identified some weaknesses in a shift from purely pen and paper tests to a computerised test. The potential of such a shift is enormous but there are many problems to be addressed before a complete change is contemplated. Nevertheless, none of the problems illuminated in this project is insurmountable and although still theoretical, CAT plots a direction that NCT may take in the not so distance future.

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Evidence of College Students' Graphic Decoding Gaps During Use of a Computer Simulation of Photosynthesis

Phyllis Baudoin Griffard
Department of Natural Sciences
University of Houston-Downtown
Houston TX USA
griffardp@zeus.dt.uh.edu

James H. Wandersee
Department of Curriculum and Instruction
Louisiana State University
Baton Rouge, LA USA
jwander@lsu.edu

Abstract: Twelve college science majors enrolled in introductory biology participated in two in-depth clinical interviews in which they verbalized while working with an award-winning computer simulation of a complex biochemical process, photosynthesis (Logal Corporation 1994). Their verbalizations during this and other cognitive tasks led to the identification and categorization of gaps that exist in their conceptual frameworks. Gaps fell into two major categories: propositional gaps and processing gaps. The graphic decoding gaps discussed in this paper comprise one category of the processing gaps. Graphic decoding gaps included gaps in *icon-decoding* and gaps in *graphic literacy skills*. Icons in the simulation for sugar output, photorespiration, oxygen production rate, flow lines, Calvin cycle and the radiolabel button were erroneously decoded. Gaps in participants' graphic literacy skills included design convention gaps, orientation gaps, and representation gaps.

Introduction

This paper discusses our findings about gaps in graphic decoding habits of college biology students. It is part of a larger study of gaps in conceptual frameworks for a complex biochemical process, photosynthesis. We define gaps as sites in a learner's conceptual framework in which concepts are not meaningfully linked, and therefore propositions fail to form. Gaps that hinder meaningful knowledge building may also reside in the declarative knowledge that underlies more automatized procedural skills such as one's skill in decoding graphic representations. The ultimate objective of this research was to elucidate how learning about biochemical processes occurs so that instruction can be adapted, especially instruction which addresses salient visuospatial aspects of learning. This study is also significant in that it utilized a novel approach to studying learning with computers: elicitation of participants' explanations and predictions during their interactions with an acclaimed computer simulation of a scientific phenomenon (Griffard & Wandersee 1999). Twelve students participated in two in-depth clinical interviews in which they interacted and verbalized while working with an award-winning computer simulation of photosynthesis (Photosynthesis™ , Logal Corporation 1994). Their verbalizations during this and other cognitive tasks led to the identification and categorization of gaps that exist in their conceptual frameworks. Gaps revealed by verbal analysis (Chi 1997) fell into two major categories: propositional gaps and processing gaps. The *graphic decoding gaps* discussed in this paper are one category of the processing gaps.

Photosynthesis is a biochemical topic taught in most introductory college biology courses, and it has the reputation of being difficult to learn. Biologists consider photosynthesis to be the most important biochemical reaction on Earth (Campbell 1996) because it fixes carbon from an inorganic form into an organic form needed by all living things. Meaningful understanding of photosynthesis requires integration of knowledge about light, thermodynamics, organic chemistry, plant anatomy, plant cytology, cellular ultrastructure and stoichiometry. All of these require abstract thinking about structures and processes—with limited macro-scale, visual referents. It is possible that some learners' difficulties with the topic are due to weak visual literacy skills. This can prevent their meaningful understanding of spatial orientation and multiple, nested frames of reference in which the process occurs. Poor visual literacy skills seem to hinder exploitation of potentially powerful instructional graphics such as those employed by simulation software. A study of these cognitive and visuo-spatial gaps seems necessary if teaching scientists who employ graphic representation are to improve the learning that occurs in introductory science courses.

The overall theoretical framework for this study is based on the Human Constructivist learning theory (Mintzes, Wandersee, & Novak 1997). Traditional instructional materials and the computer simulation used in this study depend heavily on graphic representation of selected organismal and biochemical aspects of photosynthesis. Thus visual literacy and the ability to decode the related graphics probably influence the degree of meaningful learning that occurs. For this reason the study was also informed by theory about the visual aspects of cognition, including visual literacy and Paivio's Dual-coding Theory of memory (Braden 1996).

Design and procedures

This qualitative, multiple case study involved 12 college biology students at a major state university, six of whom were "above average," and six of whom were "average or below" according to grade point average. Half were enrolled in Dr. Corey's section and half in Dr. Reese's section of "Bio 101." To aid the reader, pseudonyms indicate professor (first letter C or R), ability (second letter H or A), and ethnicity. Primary data were drawn from videotape recordings of cognitive paths taken by participants completing specially designed tasks during two clinical interviews conducted before (Phase 1) and after (Phase 2) instruction. Each interview lasted from one to two hours.

Participants explained aloud as they completed the tasks (Chi 1997), which included item sorting, term sorting, and co-concept mapping, and a significant set of tasks based on the computer simulation of photosynthesis. The tasks based on the simulation had the participants explain and predict events depicted in outputs, graphs, and icons in the simulation's leaf and mechanism windows as the result of actions they took. One such task was to obtain the maximum photosynthesis rate possible and to think aloud while doing so. Tasks that provided data for this paper are explained in more detail in the context of the findings. These tasks yielded valuable insight into the cognitive processing of the information in the graphics as well as clues as to how uninitiated students working alone with this simulation software decode these graphics in order to encode propositions about photosynthesis.

Instantiations of all gaps were identified in multiple passes through the interview transcripts, and were indexed into an emergent typology. The identified gaps were categorized over numerous iterations until a full typology of the gaps emerged. Only the graphic decoding gaps in that typology are discussed in this paper. The qualitative data analysis package, NUD.IST™ (1994), facilitated transcript and multiple datastream management, and supported theory building during analysis (Richards & Richards 1994).

Findings

Graphic decoding gaps fell into two categories: gaps in icon decoding, and gaps in graphic literacy skills (Fig. 1). *Icon decoding gaps* were evident when participants made erroneous assumptions about the meaning of individual icons and their positions in the windows of the simulation. These were especially evident when participants responded to the recurrent task of explaining what was happening in the window. Gaps in *graphic literacy skills* were evident when participants relied on fallible graphic decoding habits that led them to make erroneous assumptions about the process represented in the simulation.

Icon decoding gaps

Icons in the simulation windows included those for stomates in the leaf, membrane channels, the Calvin cycle, oxygen, carbon dioxide, light, water and proton flow, and radiolabels. Also represented graphically were a leaf cross-section, gauges for sugar output and oxygen output, and sliders to change light conditions, humidity, temperature, water input and carbon dioxide input.

Icons representing photorespiration, Calvin cycle, oxygen production rate, sugar output, flow lines radiolabel and ATPase block were decoded in error (Tab. 1), which caused them to make erroneous inferences about photosynthesis. Although photorespiration is a wasteful side-reaction of photosynthesis (represented in the simulation's mechanism window as an input of oxygen into the Calvin cycle), all 12 participants failed to recognize this when they identified the icons representing photorespiration as the location where the (required) oxygen is coming into photosynthesis. This is incorrect since oxygen is a product (not required reactant) of photosynthesis. The participants frequently decoded graphics in a way that indicated the graphics had elicited their constructs for aerobic respiration instead of photosynthesis. The simulation's icon for photorespiration and its prominent position in the mechanism window exacerbated that misretrieval.

Figure 1: Categories of graphic decoding gaps.

Another icon that was improperly decoded was the sugar output gauge. Its position at the edge of the leaf suggested to nine of the 12 participants that it represented where sugar is excreted from the leaf to the environment (Tab. 2). A cartesian graph of photosynthesis was also misunderstood. The title of this running graph was written as "O2 Production Rate." These six participants merely read it as "Production Rate," not understanding the significance of O2 until the researcher suggested that the 2 should be subscripted. Once read as "O_2 Production Rate," all participants understood that oxygen production was being represented. This gap is directly due to a flaw in the graphic design. A fourth misunderstood icon was the circle in the gauge windows representing radiolabel buttons. This circle, when clicked, simulated radioactive tagging of the molecule with an isotope of a carbon or oxygen atom. Five of 12 participants believed this circle represented an O for Oxygen. This was evident when they repeated the statement, "water and oxygen are going into the leaf." The significance of the dark blue background of the Calvin cycle and the black and white flow lines were also misunderstood by a significant number of participants.

Icon	Frequency
Photorespiration	12/12 (100%)
Sugar secretion	9/12 (75%)
Oxygen production rate	6/12 (50%)
Radiolabel button	5/12 (42%)
Calvin cycle	5/12 (42%)
Flow lines	3/12 (25%)

Table 1. Types and frequencies of icon decoding gaps.

It is acknowledged that many of the icon decoding gaps identified were simple processing errors that participants would have self-corrected upon more careful, persistent engagement with the simulation. However, that they made these inferences at all in their first encounter with the simulation indicates a responsibility on the part of graphic designers and instructors to monitor how users decode icons. Some of the icon-decoding gaps can be attributed to poor design by the software developer (e.g., O2 production rate), and some might be considered unavoidable due to constraints of graphic design and space use (e.g., position of photorespiration in window).

Charles	I'm still not happy with what the sugar is doing...because it looks like it's leaving the leaf through the....leaf.
Cheryl	I really don't know what the sugar would come in the form of if it's on the outside.
Carlos	The sugar is...I don't think they're excreted. Like they don't drop a sugar pellet! It's stored in the leaf.
Caroline	It looks like it but I don't think they are.
Cathy	The sugar is coming out. It looks like the top of the leaf but I've never noticed sugar coming out of a leaf before.
Rhea	It's taking in water and carbon dioxide, and, hmph, it's giving off sugars and it's giving off oxygen.
Raul	...Sugars leaving the leaf, this seems bizarre...I would have thought it would have been kept there.
Randy	I see water pouring into the leaf, carbon dioxide coming in through the right bottom corner. Sugars look as though they're exiting to the left, and oxygen is also exiting to the upper right.
Rashad	...It's leaving. ...Where, I do not know.

Table 2. Participant decoding of sugar output in Phase 1 interview.

Graphic literacy skills

This category of graphic decoding includes graphic-use habits that hinder meaningful learning from graphics. Gaps in graphic literacy skills fell into several categories: design convention gaps, representation gaps and orientation gaps. Participants exhibited *design convention gaps* when they expected design features such as shape, color and position to apply consistently throughout the simulation. When Chanda tried to decode the ATPase block icon, she was reluctant to say it was a channel because she expected the proton flow line to switch from the ATPase to the new channel, which was a reasonable expectation.

Chanda	Well I was going to say that, but then they're [hydrogen ions] still not moving out, so...
Researcher	You would have expected what to happen?
Chanda	The hydrogen ions to go through that [new channel].
Researcher	For the black and white [flow] line to be able to move?
Chanda	Yeah.

Caroline's difficulty with orientation also may have been related to her expectations of consistency in graphic design. In the simulation's "A Delicate Balance" task, she had trouble inferring that carbon dioxide, like oxygen, can enter and exit plants depending on light conditions. However the graphic was inconsistent because it showed separate input and output flow lines to and from the oxygen meter, whereas only one flow line was shown for the carbon dioxide meter which merely changed direction according to the net direction of carbon dioxide movement. Raul also expected consistency in Phase 1 when trying to infer the significance of the proximity of the relative humidity meter to the oxygen input meter in the mechanism window. At the bottom of the same window, the proximity of the water input to the oxygen output is significant. He was misled by trying to apply the same rule when inferring the other could be significant too: "Ah! the relative humidity might control the O_2 up here." Charles inferred that the elongated oval at the bottom of the mechanism window represented the stem instead of the thylakoid membrane. This suggested that he thought it defensible for a graphic designer to mix scale within a single

graphic without providing a referencing tool, like telescoping, to guide the user.

Participants exhibited *representation gaps* when they assumed that the model or graphic they encountered faithfully represented the true number and spatial arrangement of the biological phenomenon under consideration. One manifestation of such face value inferences is the icon decoding gap discussed later in which participants assumed because of the position of the output meter that plants secrete the sugars they produce. Similarly, Randy said "the carbon dioxide is inputted through the side of the leaf, somehow through the layers of the leaf," and that inputs and outputs entered and exited only on the sections of the leaf where arrows in the graphic were pointing. In Phase 2, Rhyan made an assumption that because carbon dioxide and oxygen were illustrated entering and leaving different stomata shown on the leaf surface that this could mean that stomata can somehow be specialized to allow in or out only one of the gases. Likewise, Cheryl's choice of words when explaining the mechanism window indicated she may have viewed the positions of the cycles to be fixed where they are in the representation.

Cheryl	OK, this is the thylakoid. What's happening is, OK, you've got light coming in and you're beginning your light reactions, and in your light reactions you make ATP here that's going in, and you make NADPH which is coming in this way. So they're coming in from opposite ways, they're going to the Calvin cycle...

One kind of representation gap was designated a *single representative gap*. inferring that a single representative icon means there is but one such structure/event in the real phenomenon. Although each icon may be intended to represent hundreds if not hundreds of thousands of the structure it represents, participants do not always make this inference. In Phase 2, Caroline assumed that each thylakoid has "its own ATPase," implying only one per thylakoid. Rhyan and Charles gave evidence that they did *not* have this gap. Rhyan understood that light entering the plant cell is "hitting all around" but it's [only] interacting with the pigments. Charles readily assumed that a single icon for NADP represented hundreds of thousands of that molecule in a chloroplast. The following interchange shows that he understands that light is hitting the entire leaf surface and that oxygen exits all over the surface of the thylakoid, not only at the site of the output meter.

Charles	Well the light's going right here [points with cursor to light arrow in mechanism window] but I mean presumably it's not all happening right here for the entire leaf.
Researcher	So you think that this right here [thylakoid] represents the surface of the leaf?
Charles	Yes but just because it looks like this doesn't mean that it's happening like this you know. I'm sure oxygen is coming off here [at output meter] but I'm sure it's coming off here and here [points elsewhere], all over when we saw the whole leaf picture...I mean [switching to leaf window] they have oxygen coming off here [at oxygen meter] but I wouldn't think it would just come off there.
Researcher	Where else would it come off?
Charles	There, there, there, there, there [points cursor to many places on leaf surface] same place.

In the above interchange Charles showed he had no single representative gap, but he did give evidence of an *orientation gap* when he thought the elongated thylakoid was the leaf surface. *Orientation gaps* were defined as the inability to process information provided in a graphic or between graphics so as to mentally place the interacting structures and processes in a workable arrangement in 3-D space. Cathy also misunderstood the thylakoid membrane representation in the mechanism window. Her attempt at visual correspondence between the leaf and mechanism windows led her to believe it represented the stem of the plant. Rhea believed the mechanism window was an overlay of the leaf window, as evidenced by her explanation that the mechanism window portrayed "the same cycle [as the leaf window], it's just very....thorough now." When trying to get oriented in the mechanism window she looked for an icon that would orient her: "Where's the O_2 that it gives off?" Before Raul identified the photosystem icons in the thylakoid membrane with a popup, he thought that they represented stomata in the leaf surface. All the participants showed evidence at some point in the interviews that they were not properly oriented. One particular kind of orientation gap relates to how the participants perceived the structures and processes represented in the simulation to be *nested*. Randy's attempt to visually nest the structures was evident in Phase 1 when explaining where light interacts with the parts of photosynthesis.

Randy	I figure that this [Calvin cycle] is more inside than this is [thylakoid space]. [incorrect]

Researcher	More inside what?
Randy	More inside the leaf. Just because it's a little boxed in area. I don't know if that's any good reason, or logic or not.

The text of the simulation in Phase 2 explains how the compartments of the cell and chloroplast are nested in living plants.

Simulation	The chemical substance which gives the plant its green color, the chlorophyll, is concentrated in the chloroplasts. The membranes in the chloroplasts are arranged in pocket-like structures called thylakoids. The light reactions take place in the thylakoid membrane. Each chloroplast contains many thylakoids.

After reading the passage aloud, Cathy admitted, "That part's confusing. I have to like write it on paper, everything is inside everything, you know what I mean?" Rashad made an error seen frequently with students that may indicate failure to regard levels of nestedness. When explaining proton pumping in Phase 1, he said "Protons, I think they are pumped out of the cell." A similar careless error was made by Chanda when she described protons as being found "in the nucleus of the cell." Rhea also called protons "parts of the cell that are positively charged." It seems likely that this misretrieval across scales is due to a cue common to both the cellular and atomic frames of reference ("nucleus"). Students do not seem to attend to nestedness when leaping across scale. When Rhea was asked where in the leaf is the mechanism of photosynthesis occurring, she was charting new cognitive territory.

Researcher	Can you tell me where this [mechanism] is going on relative to the leaf window? Where is this?
Rhea	Where is it in the leaf?
Researcher	Or where is it happening?
Rhea	In the leaf.
Researcher	In the leaf? OK, just anywhere in the leaf?
Rhea	Um...I've never thought about any of these questions before...

After leading questions she was able to say that the mechanism window portrays cellular events. Rhonda, who had the lowest photosynthesis literacy level of all participants, showed her inattention to scale and nestedness when she summarized events in the mechanism window as "all just working together, [ ] they just went back to what the plant was." "The plant" does not identify her level of organization, just as "in the body" fails to identify scale when less mindful students say "where" a particular physiological process occurs.

Summary

The above results suggest numerous heretofore unrecognized graphic decoding gaps that exist in college biology students' conceptual frameworks. Icon decoding gaps and gaps in graphic literacy skills such as orientation and representation were observed and analyzed. This study also furthers the use of computer simulations to elicit data that can be used to understand conceptual frameworks (Griffard & Wandersee 1999). It begins to raise awareness of visuospatial learning gaps and moves the profession toward a comprehensive typology of gaps in conceptual frameworks.

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STeam- Designing a Framework for New Forms of Cooperation in Education

Thorsten Hampel
Computers and Society
Heinz Nixdorf Institut
Germany
hampel@uni-paderborn.de

Abstract: The explosion-like distribution of worldwide data networks has changed and formed our life with lasting results. Surely the education sector at our universities and schools is substantially affected by this development. Unfortunately the development and distribution of cooperation supporting systems, i.e. tools that are not only like the WWW geared to the passive consumption of information, is still in its infancy. Following, the research project STeam (structuring information in a team) of the Heinz Nixdorf Institut deals with the conception and development of new learning scenarios and infrastructures which are adapted to the advanced "interactive" level of the WWW, enabling the user to explore and design their learning materials cooperatively.

The WWW- More Than a Library Without Index ?

At the turn of the ending twentieth century new media as well as learning- and information systems are widely spread over training and further education programs of the most different disciplines. "Virtual universities" and "multimedia" were the declared slogans for countless offensives against the education system.

The most of the learning- and information systems are characterized by a passive spread of information, e.g.: WWW, printing on demand. This development is based on the idea of individually learning persons that with the help of the new technology are enabled to explore studying units from at home according to their own pace and predilection. Thus most of the hypermedia systems are designed either as printing on demand service (WWW) or as simple repository for the execution of animations (CD-ROM). Even the structure and the assignment of learning materials to each other is in a static way determined by the authors of the web pages.

As learning mostly takes place within social context the use of technology has to make special contributions to this aspect of the learning situation. Furthermore on the part of the learner the perceiving and storing, that is to say the understanding and acknowledgement of meanings, conditions, descriptions and models is accompanied by the process of relating these different aspects. Students must develop the ability to approach a problem from individual points of view; they have to discover them for themselves, understand them and relate them to each other. This process is supported by the intensive discussion about different sources of knowledge including the active work on them, for instance, the marking and the comment on passages of the text or their personal summary.

The communication of the learners' with each other is enabled and formed by the most different infrastructures. Hypermedia databases, the approaches of computer supported cooperative learning (CSCL) or even internet technologies like e-mail, WWW, etc. can serve as transport layers for the hypermedia flow of information. It is the objective of the work-group "Computers and Society" to establish an infrastructure which is as efficiently and intelligently designed as possible to guarantee the new media support for this cooperation. The quality of an infrastructure is represented by its usability, its every-day suitability and its level of reducing occurring discontinuities in the use of electronic media. These discontinuities in the transport of multimedia contexts, e.g. the technologically caused change of a used media into another media has to be reduced under all circumstances. Discontinuities in the use of media especially appear while attempting to blend synchronous communication forms into asynchronous interaction techniques.

Learners use a broad spectrum of tools and methods while tele-working or even in learning situations that require their presence to transfer lecturing papers, like documents, transparency sheets or offers of the

WWW into their own context of learning. At the same time the learners communicate with each other, thus conveying contexts, interchange them or reach an agreement on certain posed questions.

This process is made more difficult clinging to the existing concepts, because all systems that are used on a large scale, like classical WWW servers show a document structure which can be absolutely called flexible on the part of the author, but on the part of the user they appear rigid. Following on from the described problems, the vision of using "Collaborative Virtual Environments" (CVEs) in teaching and the connection of document oriented systems with event oriented systems was and will be an object of research for some time. (see Masinter, L. & Ostrom, E. (1993), Dieberger A. (1997), Benford, S. D., Greenhalgh, C. M. & Lloyd, D (1997) and MITRE (1999)). The respective approaches take the most different directions and take on diverse shapes: If, e.g., primary synchronous abilities are stressed, the realization of a Shared-Whiteboard-Metaphor would provide a solution (see Roseman, M. & Greenberg, S. (1996a) and Roseman, M. & Greenberg, S. (1996b)). Other approaches connect avatar worlds, like active worlds with internet information systems like the BSCW-system (see Huxor, A. (1998)). Finally the interest of research is concentrated on the process of learning, i.e. the transport of learning information within MUDs[1] itself, like for instance the learning and adventure worlds of A. Bruckman or B. Slator (see Bruckman, A. (1997), Slator, B. M. & Hill, C. (1999)).

Within the STeam system standard web technologies are combined with the possibilities inherent in MUD technologies. Web technology is characterized by the use of large, worldwide distributed and connected document stocks. Some advanced but purely asynchronous systems, like for instance, Hyperwave (see Andrews, K., Kappe, F. & Maurer, H. (1995)) make it possible for the user to establish personal access to these documents as well as to put them at somebody else´s disposal. A further dimension of flexibility is offered by MUDs which enable the user to design and change the working-places and conditions while the system is operating. The STeam idea as a CVE consists of a room oriented world (see Henderson, A.J. & Card, S.A. (1985)), which is subdivided into public as well as private areas. Public areas serve as storage and exchange places for freely available information and documents; the private areas form the actual group working environment. The rooms are equipped with the most different objects, which depict for instance other users, documents or further references. It is possible to manipulate these objects and to structure them newly. An administration of user rights ensures that all objects and rooms are at the disposal of a defined user group. This important central idea constitutes the basis for the establishment of virtual working environments in which groups can meet each other about particular subject areas. Thus real existing social contacts between students are reflected by the work with the system. For this reason the connections between the rooms are not organized in a real-world metaphor but reflect the semantic structure of the subject area. Building the heart of the STeam architecture an event oriented and object oriented server in connection with a database administrates information about changes within the rooms. Therefore a person who enters the room is informed about the documents and objects which are located in the room. Furthermore the server has to store the manipulations regarding the objects. The document access within the server is realized via HTTP, the protocol of the WWW as well as the FTP. Consequently the implementation of a STeam integrated modified HTTP server was necessary.

Tools were designed for the user (e.g. the STeam-Client) that allow an easy and comfortable interaction with the server. A graphical interface which visualizes the relevant room with all its objects for the user, is developed by the use of the platform independent programming language Java. The upload of new or modified documents into a room on the server is made possible in most different ways, both over the STeam-Client and over any extern tools (FTP). Based on an initial feasibility study the STeam approach was subject to a complete redesign and to a consequent further development in the last years.

The STeam Architecture – Learning Media and Subject of Learning All In One

On the sides of the system architecture the STeam system is subdivided in the STeam-Client, the STeam-Server and a database. In this connection the STeam-Server is regarded to be the heart and control center. Within the STeam-Server user and room structures are administrated, the communication between users is

[1] MUDs are network-able programs, which are based on a client-server-architecture. Thus many users with different computer systems at various locations are able to participate in the games. MUDs can on the one hand be accessed by any number of users, on the other hand the exclusive access variant restricts the number of users; here authorized players, so called wizards, limit the participation to a defined user group. The communication flows are free, but they can be controlled as well as manipulated by the game leader, as far as the course of the game requires it.

synchronized and different object types are provided. Documents, reference structures, i.e. objects that are administrated by the STeam-Server are saved in a relational database[2] of free choice.[3]

The most important component which in comparison with classical systems requires the most differentiated solution, is surely the architecture of the STeam-Server. The STeam-Server has an event oriented organization, meaning it emphasizes the communication between different users.

As mentioned before the STeam-Server itself is organized in a sequence of layers. Based on the classical MUD-server, Dworkins Generic Driver (DGD)[4], the object-oriented interpreter language LPC[5] is implemented. LPC is specifically adapted to the needs of a multi-user-system. It is based on a minimal concept and allows beside of the instantiation of existing objects during the run-time period also a dynamic generation of new objects without interrupting the interpreting process. This is the most important precondition for the provision of individual user objects. In this way all mechanisms that are responsible for the supply of communication channels and for the event oriented administration of persons and objects in virtual structures are implemented in the programming language LPC. Objects and persons are assigned to rooms. STeam rooms are hierarchically organized, each room has its own individual environment, i.e. is connected to the neighboring rooms. The documents are arranged in the rooms. The documents themselves can be hierarchically structured by the use of container objects. In the course of this the reference structure between the documents is uncoupled from the documents′ position in the room.[6] Besides providing for a room hierarchy as well as for most different object types the STeam-Server distinguishes itself from all others by a differentiated individualized system of rights. User groups are hierarchically structured – each group inherits the rights of its superior group. User rights, like reading, moving, writing or executing may be free specified for each STeam-Object. Each STeam user may arrange personal user groups. Each STeam-Object, like scripts, rooms or even persons are structured by a variety of attributes but also by the users′ or individual clients′ choice of free define-able characteristics. Within STeam the open attribute concept is realized to give the user the possibility to adapt the objects to specific requirements by choosing individual extensions. For this purpose mechanisms are implemented which allow the programming and execution of individual STeam-Objects while the server is in run time mode. This possibility to program individual STeam-Objects and therewith to create rooms whose functionality is adapted to a certain learning situation, is going to be consequently developed in future versions of the STeam system. In the long term it is our goal to provide an increasing number of previously designed objects and methods.

In this way, the programming which on the side of the server is necessary to create synchronous tools and group editors, shared-whiteboards or voting tools is reduced to a tolerable extent. A large part of the expenditures is allotted to the design of the actual applications user interfaces and semantics. To realize the rather universal embedding of the STeam-Server and its services in the typical intranet/internet landscape, we set great store by providing mostly established standards.[7] For this purpose STeam rooms are mapped onto a FTP typical directory structure. For the user the STeam-Server appears in its usual working environment in form of a directory hierarchy, in which he/she can add or move any documents. In this way larger data files, such as HTML-sites , papers or presentations can be added to the server and can be individually arranged even without the help of a specific client. Each STeam-Object is immediately inserted in the database by the uploading process. Eventually existing links are extracted and are administrated as dynamic logical reference. This concept guarantees a permanent link consistency within the STeam-Server.

Furthermore each document of the database is, depending on the right to read, by its name and respectively by its object number reachable as a WWW address. The moving, copying and deleting of

[2] At the present moment because of the lack of implemented high-performance standardized database interfaces the adaptation of the STeam server, exactly the SQL interface to the respective database is necessary. In later versions of the STeam system standardized database interfaces like JDBC and ODBC will be used.

[3] Object-oriented databases are still little spread and little standardized. For this reason the intern object-oriented models and objects of STeam are mapped onto a relational database concept. This approach is advantageous because of the possibility to adapt the STeam-Server quite universally to specific multimedia databases, like e.g. special video databases.

[4] The DGD implements the LPC language. Further LPC interpreters are, e.g. CD, LPC4, LPMuD (Amylaar), MudOS, Shattered World.

[5] LPC is the acronym for "Lars Pensjö C" and was specified by Lars Pensjö.

[6] In the opposite to conventional Web servers the reference- and document structures are stored independently from each other in the database. I. e. the shifting of a document does not lead to inconsistencies in the link structure.

[7] A STeam-Server can among other protocols be accessed using the common HTTP and FTP protocols.

documents leads through consequently separated documents and references (links) to no inconsistencies of the document structure.[8]

The STeam-Client is structured in four basic components. On the one hand in form of a hierarchical structure the order of the STeam rooms is displayed. Rooms are subject-oriented, i.e. each user is positioned in a room after accessing the STeam-Server. On the other hand the second section of the STeam-Client depicts the persons which are actually present in a room. To a large extent we dispensed with the implementation of complex avatars. Instead the persons were symbolized by simple graphical pictograms (icons). The information about the presence of persons in the respective rooms is of essential significance for the initiation of various processes like the cooperative work on documents or the discussion of room related subjects. The third section realizes the communication of the participants in a room. Like in a conventional chat window participants can be addressed personally or as groups of STeam users. The last, for the cooperative document structuring and design essential section, includes the presentation and administration of the documents which are placed in a room as well as their first planar order on an individually chosen background graphic. In STeam documents are attached to a room in accordance with a chosen room metaphor. Users may (in case corresponding rights are existing) change documents with each other, shift them to their so called personal "rucksack" (a filing tray that every user owns) or copy them and store them in other rooms. In this way the user is free to design the order of documents in respect to the rooms.

Documents can be uploaded interactively via STeam-Client on the server in a room which grants the user the right to write. The STeam-Client is developed in the programming language Java. An important component is the STeam-API. This communication layer forms the needed connection between the graphical user interface and the STeam Server. Through the implementation as Java interface the compulsorily realization of certain important methods of the APIs is guaranteed. The possibility of later enhancement, the adaptability to specific application contexts and an easy redesign are to the fore concerning the conception of the STeam-Client.

The STeam-System and the Teaching Process – a Scenario

The most apt description of the central idea of STeam, namely the establishment of virtual working environments in which groups can meet about different subject areas and cooperatively construct and develop their own structures of understanding, can be presented by the help of a typical learning scenario. Already for some years the teaching of the work group "computers and society" at the University of Paderborn emphasizes the concepts of cooperative exploring and working on teaching materials.

It is the aim of the STeam concept further to ease and support the process of cooperative design and structuring of learning materials. STeam rooms on different subjects are opened to accompany an exercise or a tutorial.

This process can be initiated by a teacher (supervisor) but also by the students themselves. Every student is individually entitled to access writing or reading processes within a room. The next step is to equip the respective subject-oriented rooms with the most different documents; this can be references to documents, to common intranet- or internet servers, web pages or extern multi-media hypertext databases.[9] Accompanying the classical exercises and tutorials the students are asked to structure their learning materials according to their own preferences. Concretely, the student is advised to add his/her own electronic notes to the script which later on are to be discussed within the framework of a classical meeting or over the net. In this connection synchronous phases, e.g. coordinated by a Shared Whiteboard that is integrated into STeam are alternating without a transition with individual phases of materials structuring as well as with the inquiring and collecting of information in the net. One of the most important central ideas of the STeam project is the initiation and maintenance of a discussion which is lead as independently as possible between the students themselves and which accompanies tutorials, exercises and later examination preparations.

In the actual tutorial or exercise situation the composed materials are directly referred to. Here the concept of reducing discontinuities in the use of media immediately takes effect. Students are able to fall back upon their personal papers, structures and notes and should the situation arise revise them while attending exercises, discussions and tutorials. The elaborated subject is transferred to be the focus of the reflection,

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[8] References (links) are realized as STeam objects.

[9] Also this process of "equipping" the room with documents, scripts, graphics, animations or sound information may be realized by the students at most different locations where learning takes place.

different views on the papers are able to be presented to a group of students and once again to a wider group for discussion.

Conclusions

The primary goal of the STeam concept is the development of individual comprehension structures on the side of the students' by using tools that support as well as accompany the cooperative learning process. With regard to this STeam functions as a communication media for fellow students and lecturers and as a collection- and structuring system for all materials that accompany the learning process. The conceptual approaches of the STeam-system concentrate on the above mentioned aspect of the establishment of cooperative and individual link- and navigational structures which might be described as paths or trails over the materials (see Bush, V. (1945)). First implementations of specific editors for the establishment of individual reference- and navigation structures (semantic cards) will be soon integrated into STeam. Here an interesting perspective would be the cooperative editing of these semantic orientation- and structuring aids (see Klemme, M., Kuhnert, & R., Selke, H. (1998), Hampel, Th. & Selke, H. (1999)).

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Making Movies On the Web Accessible to People With Disabilities

Eric G. Hansen
ehansen@ets.org

Douglas C. Forer
dforer@ets.org

Louis S. Mang
lmang@ets.org

Educational Testing Service
Princeton, New Jersey
United States

Abstract: This paper describes basic requirements for making movies on the Web accessible for people with disabilities. The paper focuses on important alternative content that needs to be added to movies, such as captions, auditory descriptions, and collated text transcripts. It also describes a prototype system for delivering movie-using test questions accessibly over the Web. Resources for going beyond the basics are then presented.

Introduction

Problem

There is a great need to make movie clips accessible to people with disabilities. Movie clips are used increasingly in computer-based instruction and tests that are delivered via the Web. Yet movie clips are often partially or completely inaccessible to people who are have disabilities. For example, individuals who are blind cannot see the video portion of the movie clip and individuals who are deaf cannot hear the auditory portion of the movie clip. Individuals who are both deaf and blind (i.e., deaf-blind) can neither see the video nor hear the audio. Individuals with other disabilities (learning disabilities, cognitive disabilities, low vision, etc.) can also face challenges.

Purpose

The purpose of this paper is to describe basic requirements for making movies accessible over the Web and how Educational Testing Service is beginning to apply these requirements.

Basic Concepts

Let us consider some of the key concepts surrounding the accessibility of movies.

A Visual and Auditory Medium

Consider the fact that the Web relies heavily on visual and auditory presentations. The Web is first a visual medium and second an auditory medium. It is visual because it relies on visually displayed text, graphics, animations, and visual tracks of movies. It is an auditory medium because it often includes sounds, such as audio clips and auditory tracks of movies, as well as other sounds, such as beeps and click noises. The reliance on visual and auditory presentations causes particular difficulty for individual who have difficulty perceiving or processing visual or auditory information.

The Concept of "Equivalent"

If the primary content on a Web site is inaccessible, then some kind of accessible alternative must be provided. The accessible alternative should be functionally equivalent to the primary content. According to the Web Content Accessibility Guidelines version 1.0 (Chisolm, Vanderheiden, & Jacobs 1999):

> Content is "equivalent" to other content when both fulfill essentially the same function or purpose upon presentation to the user. In the context of this document, the equivalent must fulfill essentially the same function for the person with a disability (at least insofar as is feasible, given the nature of the disability and the state of technology), as the primary content does for the person without any disability. (From the definition of "Equivalent")

For example the words "The Earth as seen from outer space" may be considered an "equivalent" for a picture of the Earth as seen from outer space if the words serve the same function for a person who is blind as the picture does for the person who has no disability.

The Flexibility of Text Equivalents

Many of the most important equivalents are expressed as text and are called "text equivalents." Text is a highly accessible mode of representing information because it can be output in a variety of ways that are accessible to three major classes of sensory disability: (1) synthesized speech, which is accessible to individuals who are blind, (2) Braille, which is accessible to individuals who blind or who are deaf-blind, as well as (3) visually, which is accessible to people who are deaf. The W3C Web Content Accessibility Guidelines require that Web content developers provide "text equivalents" for all "non-text elements," such as audio, video, images, scripts, and so forth (WCAG 1.0 checkpoint 1.1; Chisolm, Vanderheiden, & Jacobs 1999). For example, in HTML an image should provide text in the "alt" attribute of the IMG element that describes the image so that its purpose and meaning will be clear when rendered to a Web user, regardless of whether the user relies on synthesized speech, Braille, or a visual display. "Non-text" equivalents, such as auditory descriptions, are also important, as discussed later in this document.

Assistive Technologies for Speech and Braille Output

It is important to know that many of the people who rely on speech synthesis and Braille to obtain information from computers already possess the necessary assistive technologies. For example, many people who rely on synthesized speech or Braille use "screen reader" software in conjunction with their Web browser. Essentially, screen readers interpret what is on the screen and output that information to speech synthesis or a refreshable Braille display. A refreshable Braille display raises and lowers dot patterns on command from the computer.

Important Equivalents for Movies

Now let us examine movies more closely and consider some of the kind of equivalents that must be provided to make a movie accessible on the Web. Recall that the primary content for a movie (or other multimedia presentation, such as an animation) is essentially the visual track (video track) and the auditory track (audio track), which, of course, are synchronized with each other. For any given movie, there are three essential equivalents -- captions, auditory description, and collated text transcript.

1. Captions

Captions are essential for people who are deaf or hard of hearing. Captions consist of a text equivalent of audio information (e.g., spoken dialogue) that is synchronized with the visual and/or auditory information. Captions are often displayed on TV monitors in airports to allow people in noisy environments to understand the sounds that cannot be heard.

2. Auditory Description

Auditory description is non-text equivalent that is essential for people who are blind or who have low vision. Auditory description is an auditory equivalent of the visual track that is synchronized with the regular auditory and visual tracks. Auditory descriptions are usually inserted in the pauses of the audio (e.g., spoken dialogue). The listener who is blind hears the spoken dialogue and, during the pauses in the dialogue, hears a description of the visual track of the movie (or animation). Auditory descriptions come in two major varieties.

a. *Synthesized-Speech Auditory Description.* This is an auditory description produced through synthesized speech, generally generated "on the fly" from a text equivalent of the visual track. Synthesized-speech auditory descriptions can potentially have great flexibility, user customizable voices (male, female), rate, spell-out of words, and so forth. Furthermore, they can be of any duration (presumably resulting in a pause in the presentation of the visual track if they exceed the natural pause in the regular auditory track). A key advantage of synthesized-speech auditory descriptions is that they can be automatically generated from text and synchronization information.

b. *Prerecorded Auditory Description.* This is an auditory description in prerecorded speech, usually in natural human speech. Prerecorded auditory descriptions, especially when using natural human voice, avoids the more mechanical or robot-like sound often found in synthesized speech. The most common way of implementing prerecorded auditory descriptions is by combining them with the regular audio into a second auditory track. Because this special auditory track, like the regular auditory track, is strictly synchronized with the visual track, the auditory descriptions themselves must fit within the natural pauses in the auditory track. When there is more essential description than can be spoken during a natural pause, some of it is spoken during an earlier or later pause; when expertly done, these overflowings from the proper natural pause do not necessarily weaken the message of the overall presentation. One of the disadvantages of this approach is that it requires very careful planning of the auditory description to see if it can fit within the natural pauses, and if not, then determining how to spread it into other pauses without compromising the effectiveness of the presentation. This kind of auditory description was pioneered at WGBH in Boston, where it is sometimes called "video description."

3. Collated Text Transcript

A collated text transcript is essential for individuals who are deaf-blind and is helpful for many others. A collated text transcript is a "text equivalent" of a movie. It is a collated combination of (1) a text equivalent of the auditory track and (2) a text equivalent of the visual track. For example, a collated text transcript of a movie dialogue would provide the snippets of dialogue interspersed by descriptions of visual elements such as actions, scene changes, etc. When accessed by a person who is deaf-blind, a collated text transcript is rendered in Braille, either on hardcopy through a refreshable Braille display.

A Prototype Accessible Movie System

In order to make movies accessible in practical settings one needs to address additional issues, such as how to ensure that the interface be made accessible for people with disabilities without overburdening it for users who don't have a disability?

The Approach

In approaching these challenges, we determined that, rather than having one display layout for all disability types, we would have several different layouts or modes. In other words, we opted against providing a single unitary presentation mode with options that could be turned on and off for people with certain accessibility requirements. Following are the three modes we chose to use.

1. Regular mode -- for nondisabled test takers and many others. In this mode, the movie's default setting is to run without captions and without auditory descriptions. The stimulus (movie) and the question are placed side by side for easy visual access.

2. Auditory Description mode -- for individuals with visual disabilities. In this mode, the movie's default setting is to run with auditory descriptions, meaning that in the pauses in the spoken dialogue, a "describer" tells (in prerecorded audio) what is happening visually. The stimulus (movie) and the question are arranged top to bottom, since that is easier for users to navigate using screen reader software.

3. Caption mode -- for individuals with hearing disabilities. The movie's default setting is to run with captions, meaning that the visually displayed transcript of the dialogue is synchronized with the video. The stimulus (movie) and the question are side by side for easy visual access.

4. Collated Text Transcript mode -- for individuals who are deaf-blind. There is no movie, but the collated text transcript can be navigated. The stimulus (collated text transcript) and the question are arranged top to bottom, since that is easier for users to navigate using screen reader software. Individuals who are deaf-blind use a screen reader and refreshable Braille display to access the information.

Using HTML and the Microsoft Windows Media Player (version 6.4) technology, the system allows a researcher to select of the four modes and administer the questions in that mode.

One design decision that we made involves auditory descriptions. We found that in several instances the prerecorded auditory description was longer than the natural pause in the auditory track. In those cases, we decided to pause the visual presentation to allow that auditory description to play to completion before proceeding with the visual presentation. Thus, the movie that normally took about 1 1/2 minutes to play took about 3 minutes to play in auditory description mode.

We expect to evaluate how well this approach works for individuals with disabilities over the next few months.

Moving Beyond the Basics

In this paper we have only considered the basics, with particular focus on the major classes of alternative content and their usefulness for people with a few classes of disability. For additional resources, consult the following.

- The *W3C Web Content Accessibility Guidelines* (Chisolm, Vanderheiden, & Jacobs 1999) provides guidelines for developing accessible content.
- The *W3C User Agent Accessibility Guidelines* (working draft) (Gunderson & Jacobs 1999) provides guidelines for developing accessible user agents (Web browsers, media players, etc.). At this point, media players and Web browsers provide only some of the capabilities needed for achieving a high degree of accessibility for movies on the Web.
- The *W3C Authoring Tool Accessibility Guidelines* (working draft) (Treviranus, Richards, Jacobs, & McCathieNevile 1999) provides guidelines for developing authoring tools that are both accessible and can produce accessible content. Improved authoring tools will facilitate the development and integration of alternative content.
- The *W3C Synchronized Multimedia Integration Language (SMIL) 1.0 Specification* provides some support for the capabilities required for accessible movie but further advances are needed (Hoschka 1998; Koivunen & Jacobs 1999).
- The National Center for Accessible Media (NCAM) at WGBH in Boston provides tools and techniques for creating accessible media. (www.wgbh.org/wgbh/access/)

Notwithstanding the great progress that has been made in setting standards for accessibility, much more work and creativity is needed to facilitate the creation and rendering of accessible movies on the Web.

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Real Education from Virtual Objects: Active Learning in Science On-line

Roy Hawkey, Head of Education, The Natural History Museum, UK, r.hawkey@nhm.ac.uk

Abstract: This paper describes, analyses and evaluates an on-line science education project – *QUEST* – that was designed to develop a constructivist approach to learning by enabling students to carry out a series of investigations on a range of natural objects, by applying virtual tools, and to share their findings. It examines the project and explores the effectiveness of such an approach to learning science on-line, which is focused on the search for solutions rather than on the solutions themselves. Particular emphasis is given to issues relating to interactivity, the representation of scientific methodology and the role of names in the natural world.

Introduction

QUEST (Questioning, Understanding and Exploring Simulated Things) is a project developed by The Natural History Museum, London, UK and can be found on the Internet at www.nhm.ac.uk/education/quest. The aims of the *QUEST* project, which are made quite explicit on the site itself, are to attempt to provide opportunities for students on-line to…

- explore natural objects
- investigate in the manner of a scientific expert
- discuss findings and their interpretation

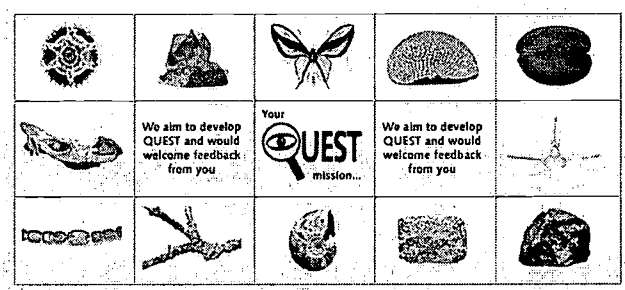

Figure 1: *QUEST*'s twelve objects

The opening screen (Figure 1) presents twelve disparate objects – rock, mineral, animal, plant, fossil, micro-organism – carefully chosen to represent not only the diversity of the natural world but also the range of the Museum's scientific work. While teachers may wish first to read the supporting explanatory material, which explains the rationale and intended learning outcomes and provides practical advice, students quickly select an object. This is then displayed full-screen. A feature of this first image is that it carries no supplementary information, not even an indication of scale. Tools selected from the visual menu can then be applied in turn. (Figure 2)

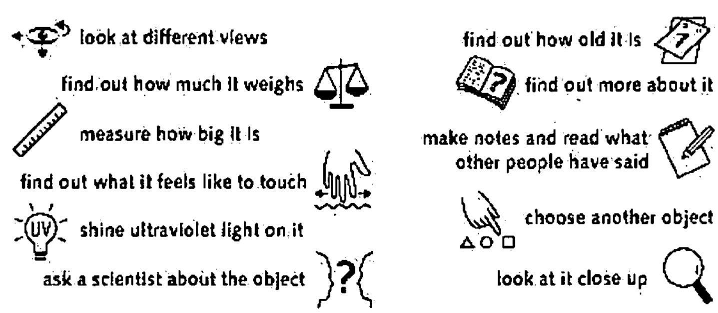

Figure 2: the range of tools

Students can click to select any or all of the tools from the set of icons; there is no fixed order. Similarly, an 'object bar' – a series of thumbnail images – makes it possible to apply a given tool sequentially to a variety of objects. Application of the tools makes it possible for a student to build up her/his data set about each object, to interpret this data and to hazard inferences about it.

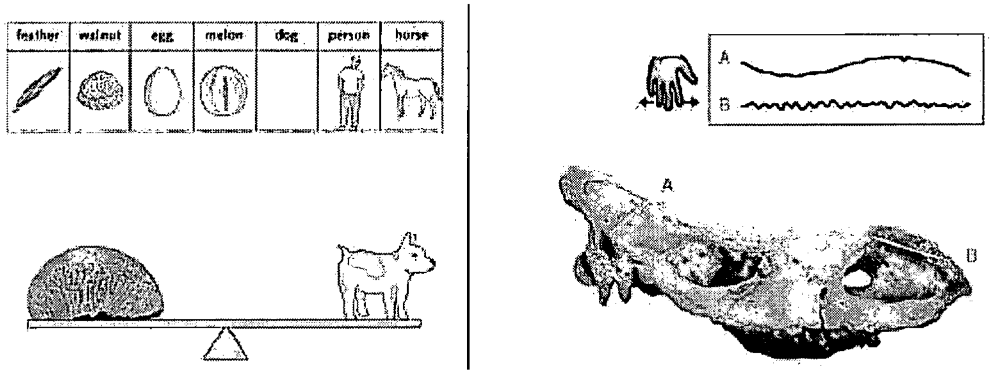

Figure 3: weight and touch tools in use

While the majority of tools represents observation aids or measuring instruments (Figure 3), three are significantly different. 'Ask a scientist' provides advice or prompts – further questions rather than answers – from an expert. The on-line notebook enables students to record their findings and thoughts and, crucially, to share those of others. Finally, the information page – accessible only from the notebook – gives background and further information, usually in a questioning style. Each of these elements will be explored further in later sections.
Earlier studies have reported on observation of the pilot version of *QUEST* in use in the classroom (Johns & Sanger 1998) and on some of the underlying educational issues (Hawkey 1998, 1999a). The focus of this paper is a more detailed examination of several of the claims made by the project, with particular regard to its philosophy, its pedagogy and its perspectives on science, under five headings:
'Constructivism', 'Interactivity', 'Science as enquiry', 'Debate' and 'What's in a name?

Constructivism
Conventional approaches to displaying objects in museums rely heavily upon the expert knowledge of curators and researchers. In this respect, traditions in museums of science and of natural history are not particularly different from those in other domains. Beyond the objects themselves may come their contextual frameworks, their associations with each other and with other materials, the provision of additional interpretation and, of course, their names. All of this is the province of the expert. Similarly, in school science teaching, the predominant mode of discourse is the provision of expert knowledge and its transmission from teacher to student, a tradition reinforced by content-laden curricula. Underlying both situations are implicit assumptions, both epistemological and pedagogic, in which the hegemony of teachers and curators and of their expert knowledge predominates.
In complete contrast are approaches generally identified as 'constructivist'. Hein (1995) has highlighted frequent confusion and contradiction over notions of constructivism. His model clearly distinguishes between perceptions of knowledge – from revealed truths to best-fit paradigms – and perspectives on learning – from *tabula rasa* to personal sense-making.
From the outset, *QUEST* was designed to be constructivist on both of these dimensions. This makes it unlike other approaches to presenting and learning science at The Natural History Museum – both in the exhibition galleries and in other on-line products – and in most school science, too. For example, Hawkey (1997) has identified many of the Museum's Life Galleries as primarily didactic, the hands-on Discovery Centre as heuristic and the on-line Science Casebook (www.nhm.ac.uk/sc) as behaviourist – figure 4.
It is worth examining in more detail this claim of constructivism. Wild & Quinn (1998) have pointed out the importance of being cautious when applying labels such as this to multi-media products. However, their arguments dismiss Gagne's matching of pre-determined instructional goals with artificially constructed learning events in favour of supporting different learning styles in multi-media – by providing multiple paths for navigation that let the learner choose. *QUEST* further meets their plea for a coherent model of multi-media design in enabling the learner to

'engage, explore and build', by providing information resources, deliberately facilitating cognitive processes and

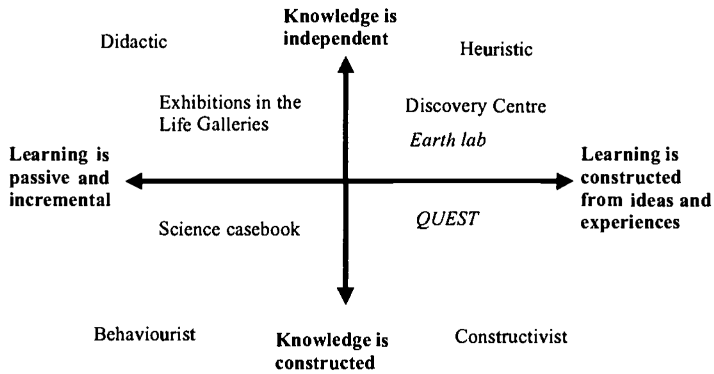

Figure 4: Hein's (1995) model applied to The Natural History Museum

Interactivity

As there has with constructivism, there has been much recent debate about what exactly is meant by 'interactive', and the relationship between interactive and 'hands-on' and 'minds on' (Hawkey 1999c). Caulton (1998) has highlighted the difficulty that is posed by each of these concepts (both individually and severally) and the further complication introduced by the inherent assumption that all computer multi-media is *ipso facto* interactive. He suggests that, 'A hands-on or interactive museum exhibit has clear educational objectives which encourage individuals or groups of people working together to understand real objects or phenomena through physical exploration which involves choice and initiative.' Key criteria, he asserts, certainly include those of physical interaction, clear learning objectives and a multiplicity of outcomes depending on the visitor's individual explorations.

Although its 'physical' interactions are in the virtual realm, *QUEST* claims to be genuinely interactive, and, furthermore, that this makes it unlike many on-line science learning resources, which, lacking choice or feedback, are best described as 'operand' (Miles at al 1982). When engaged in *QUEST*, students are involved in a series of active decision-making steps, such that the choice of routes using thousands of hyper-links – while not actually infinite – is enormous. It can be strongly argued that it is mental activity – from asking questions through collecting data to interpretative decision-making – leading to clearly defined learning outcomes, rather than the clicking of a mouse, which makes *QUEST* interactive.

An additional layer of interactivity is provided by the exchange of ideas and information between students in the on-line notebook. Here, each child's contribution can be valued for its own sake, even if it is subsequently contradicted, and shows the potential for such sharing of ideas to lead to enhanced understanding. (This is examined more fully in 'Debate', below.)

Science as enquiry

The Natural History Museum's education policy highlights active learning in terms both of learner participation and of the learner making his or her own sense of experiences. Emphasis in all programmes, both real and virtual, is therefore given to observation and enquiry, to exploring and investigating.

Science teachers in the UK are very familiar with the notions of exploring and investigating, for they form the basic tenets of a major element of the National Curriculum for science (DFE 1995). The idea that the processes and methods of science should form an essential component of the school curriculum is, however, far from new. Darwin's champion, T H Huxley, was a strong advocate:

> ".... the true teaching of science consists, not merely of imparting the facts of science, but in habituating the pupil to observe for himself, to reason for himself on what he observes, and to check the conclusions at which he arrives by further observation or experiment." (Huxley 1875)

Many of these fundamental scientific processes are possible with museum objects and are reflected in *QUEST*: observing, measuring, identifying patterns, formulating and testing hypotheses, evaluating evidence, recording and communicating.

QUEST assumes that learning prospers if students are encouraged to ask questions and then attempt to make sense of what they discover. Testing ideas – against those of others and against further evidence – is a critical part of this process. So, although the 'expert' view is available, it is accessible only from the notebook and avoids simply

Emphasis on the processes of investigation and enquiry mean that an officially sanctioned 'right answer' is certainly not given prominence. In some cases, no approved data is provided, and some objects are not named at all – and never at the full-screen stage. One definite advantage of the virtual system over the classroom teacher or the explainer in science centre or museum is that it cannot be persuaded to become a mere transmitter of knowledge. This contrasts with Russell's Liverpool study where staff tended 'to view their function as being predominantly to provide information rather than stimulate conjecture' (Russell 1995).

QUEST's approach fits well with Jenkins' (1996) assertion that the cognitive deficit model of scientific literacy, in which science is portrayed as an unproblematic body of knowledge, is generally inappropriate. Certainly, if students are to develop their own enquiry skills – and value their own findings – then opportunities are needed such for learner-controlled exploration that can begin to negate their students' apparent preference for asking an expert over first-hand investigation (Hawkey & Clay 1999).

In *QUEST*, the 'Ask a scientist' function provides advice, encouragement or provocative questions from a specialist. However, the aim of this element is not to provide an expert answer but rather to promote thought and to guide the learner. Students may expect expert knowledge, but instead find themselves being asked whether they can think of other objects with a similar shape or whether they have looked at an object under ultra-violet light or in close-up. Or, perhaps, they may be asked to speculate on how an object may have been formed.

Debate

It is characteristic of scientific investigation and enquiry that there is often a complex mixture of evidence, interpretation, guesswork and assumption, yet this aspect of science – sharing findings, discussion and debate – is all too often absent from conventional learning resources. It is rarely, if ever, included as a significant component of formal science education. *QUEST* 's powerful notebook function allows users to record their thoughts on the object, to share those of others and respond to them. This represents the exchange of views and ideas parallel to those of the scientific paper, poster or conference presentation.

Careful examination of students' comments in the on-line notebook suggests three broad categories:

a) Statements, suggestions or guesses of a 'what is it?' nature, such as:
   'Is this a diatom?' 'I think it is a Coconut seed.' 'I think it's a kind of mineral probably Quartz.'
b) Observations, evidence and interpretations. For example: 'Lighter than a feather No idea what it is yet
c) Discussion and debate between learners. Some sample exchanges:
   i) – 'I believe this [fossil skull] is a Palaeolithic horse skull'
   – 'I thought so too at first glance, but it is much too large and heavy'
   (later) 'It appears to have the same shape as a horse's head, but in that time period, they would have been smaller. It could be a relative of the woolly mammoth.'
   ii) – 'There's something wrong! This butterfly's much too heavy!'
   – 'But have you seen how big it is?'
   iii) – 'It [pollen grain] is very small - about the size of a grain of sand. It is very light. It is green so it might be something to do with plants. It is spiky on the outside and there seems to be a hole in the top. I think it might be a small sea anemone.'
   – 'I don't think there are any that small. I think it is a microscopic organism like a diatom for example.'
   iv) – 'I know that this is older than the earth it probably came from the meteors or part of the fragments of the

   – 'There was no such thing as the big bang because if there was nothing, no Earth, then how could there be a

   – 'When was the first human alive? ... Maybe this rock knows cause it was around before then!'

In each case, the right answer – on the information page – can be obtained with only a few clicks of the mouse, but the challenge of discovery, and of thinking and of communicating, seems to overcome this. Given such potential indicators of children's thinking, the right answer (even from another student) comes as something of a disappointment: 'I think it is a meteorite that is older than the Earth.'

Evidence of shared learning in such on-line dialogues provides some indication of students' own evaluation of *QUEST*. We may speculate that it is the excitement of not knowing and the vitality of the challenge of searching for solutions that may provide stimulus and motivation for the scientists of the future.

What's in a name?

The experience of staff working in The Natural History Museum's Discovery Centre – a hands-on activity area aimed at children of primary school age – suggests that knowing the name of a biological specimen may well actually inhibit close observation and enquiry. It is evident that adults, in particular, regard naming as a critical outcome (often the only significant outcome) of an encounter with a natural object. Staff in the centre work very hard to persuade visitors that a child is not simply 'fiddling' but is making thoughtful observations and that 'to tell her the name so that she'll stop' is not a strategy conducive to learning. Because of the potential limitation of students equating learning with the knowing of names, *QUEST* makes further information available only through the notebook. After offering an additional opportunity to carry out further tests this function gives background details, including a category or common name for the object and/or an image of the object in context.

Given that The Natural History Museum is one of the world's leading institutes for taxonomy and systematics, it may appear to be a supreme irony that *QUEST*, as one of its products, relegates the names of objects to such a lowly position. However, as Feynman (1989) has pointed out, knowing the name of something normally says more about people (the namers) than about things (the named):

> 'You can know the name of [a] bird in all the languages of the world, but when you're finished, you'll know absolutely nothing about the bird. You'll only know about humans in different places, and what they call the bird. So let's look at the bird and see what it's doing – that's what counts. (I learned very early the difference between knowing the name of something and knowing something.)'

This is especially true for natural objects – rocks, mineral, fossils, animals, plants and
name is not a property of the object and can never be deduced by observation or experiment.

Summary

It has become axiomatic that it is in the nature of on-line learning resources to be either information rich or goal- and reward-orientated. *QUEST* is neither of these, and yet it appears to be successful in providing a real representation of a field of scientific enquiry and in developing its philosophy, pedagogy and perspectives on science.

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Hypermodels: Embedding Curriculum and Assessment in Computer-Based Manipulatives

Paul Horwitz

The Concord Consortium

One of the more fruitful innovations in science education has been the use of computer-based manipulatives (herein referred to as CBMs) — open-ended, exploratory environments within which students can solve problems and conduct investigations in a particular scientific or mathematical discipline. The name is derived from Montessori theory, whereby through manipulating objects to learn their behavior or to achieve certain extrinsic goals students learn to reason about a particular model of the world.

Traditionally, CBMs have been neutral with respect to specific curricular goals or pedagogic approaches. This has been a significant source, in fact, of their power and charm. There is something wonderfully elegant about a general purpose environment like the Geometer's Sketchpad which enables an elementary school student to investigate how the area of a triangle varies when one drags one of its vertices about, while a more advanced user may discover a new theorem in plane geometry[1].

This begs an obvious question. Why should we *want* to embed curriculum and assessment into a general purpose tool like a CBM? We wouldn't think, for example, of embedding curriculum and assessment into blackboards or notebooks — we leave it up to students and teachers to use them to good effect. Why should computers be any different?

For one thing, the more powerful and universal a software tool is, the more complex its interface has to be. The time students spend learning how to use the software is time they could have spent learning the content[2]. Moreover, there is no way to customize the software to a particular student or developmental level. It would be useful, for example, to be able "turn off" some of the more advanced features until a student is ready for them — or even to turn them off at the beginning of an activity, and

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[1] As one high school student actually did, see http://forum.swarthmore.edu/epigone/geometry-forum/27.

[2] A properly designed CBM can sometimes turn this problem around and use it to good effect. By designing the interface appropriately, one can force students to think about a domain in fruitful but counter intuitive ways (Horwitz, in press). In this situation, learning how to use the CBM may guide students to learn the underlying concepts.

then turn them back on once the students have worked through a preliminary exercise. It is very difficult to do this in the classroom with a traditional CBM.

Once the students have learned how to use the software and are doing self-paced investigations with it, another problem of CBMs often manifests itself. One of the major goals of constructivist pedagogy is to lead students to those "teachable moments" when all of a sudden they break through a problem and finally "get it." These are the times when it is crucial for the teacher to intervene, to offer congratulations, to ask probing questions, but mainly to get the students to articulate and think about what they have learned. Absent such "metacognition," the learning students do may remain so closely associated to the CBM, and to the specific task they were assigned, that it will not transfer to other problems. The other side of this coin is that students often get stuck and may need nothing more from the teacher than a tiny hint to guide them through a difficulty. But in an inquiry-driven classroom every student, or group of students[3], traverses a slightly different route through the investigation, and it is difficult even for a very experienced teacher to identify the right moment at which to intervene with any particular group.

Students who learn with CBMs often become adept at solving problems and completing investigations on the computer, but fail to connect what they are doing to the science underlying the model. In effect, they gain skill at the "videogame" without really learning the associated concepts. To avoid this problem, it is very important to make explicit for the students the connections between the CBM and the real-world scientific phenomena that it models. This need not be done, of course, entirely on the computer. Off-line curriculum materials, such as books, videotapes, or lab experiments are also very useful. But offline presentations and activities are temporally separated from the computer-based investigations — often by several days . They typically take place at a different location (e.g., in the classroom, rather than the computer lab) which makes it difficult to associate them in students' minds with the CBM activities[4]. For this reason, it would be very useful to link the computer model to appropriate multimedia materials.

The implication of this discussion for software design is that it would be helpful to give the teacher, or other curriculum developer, the ability to set up a semantic context for student work with a CBM. Within such a context the software would "know" what the students were trying to do at any given moment and could assess their performance online. The computer could then use this input to identify appropriate moments for teacher intervention, and could link student investigations to examples taken from real world science. We are currently building an example of a learning

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[3] When we use CBMs we try to have pairs of students work together so that they can communicate and articulate their thought processes.

[4] Of course this problem is not restricted to computer-based investigations. As every experienced science teacher knows, it is just as difficult to get students to recognize the connections between the concepts they are taught in the classroom — and on which they will be tested — and the hands-on experiments they conduct in the science laboratory.

environment that can do these things. Adopting a term we coined a few years ago[5], we call it a "hypermodel." It effectively combines a CBM with a multimedia engine, linking the too through scripts that embody the curriculum. We are adapting this hypermodel idea to the study of biology, starting with the subfield of genetics.

Description of BioLogica

BioLogica is a hypermodel designed to help students learn genetics. This is a particularly difficult topic to teach because it involves complex interrelationships of processes that occur at different levels. To make matters worse, many of these processes are not directly observable because they take place too quickly or slowly, or on a scale that is too small or too large. BioLogica contains a CBM that presents the many linked, multi-level processes of genetics visually and dynamically to students, making explicit the causal connections and interactions between them. This CBM consists of five distinct levels.

At the **organism level** BioLogica displays the organisms' phenotypes (the collection of their physical traits), but gives no direct information concerning their genetic makeup. Using a specific tool, however, one may move to the **chromosome level** to observe a pair of chromosomes. BioLogica represents these chromosomes schematically, with the genes marked at their respective locations, very much as textbooks — and research articles — do. However, in BioLogica students can change the genes from one variant, or "allele," to another. Such changes may be accompanied by changes in the appearance of the organism to which the genes belong, as decreed by Mendel's famous Laws. We have observed students as young as fifth graders figure out for themselves the rules governing the behavior of dominant, recessive, and incompletely dominant traits simply by manipulating the various genes in this way.

Seen at the chromosome level, genes are simply "markers" of some kind — their exact nature remains as mysterious to students as it was to Mendel himself. The true nature of the genetic mechanism resides, as we now know, at the molecular level, and BioLogica enables students to drop down to this level to explore the DNA molecule that is contained within each chromosome. At the **DNA level** students can alter the DNA of a gene, using an interface reminiscent of a word processor. Such changes will be reflected in the organism just as though the gene had been altered directly on the chromosome. Mutations created at the DNA level are treated as new alleles. Their default effect is to mimic the recessive allele, but BioLogica includes pre-programmed mutations that show up as new phenotypes at the organism level.

At the **cell level** students can create gametes via meiosis, select which ones to fertilize, and directly control the movement of chromosomes during meiosis as well as the crossover of DNA between them. In nature, of course, these processes are entirely

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[5] The term "hypermodel" as used in Horwitz, 1996, implies only a linkage of a computer-based model to relevant real world information. In our current usage the term is considerably more ambitious.

random, and this randomness, which is not always manifested in observable traits, can make the inheritance pattern of a given phenotype difficult to interpret. At BioLogica's **pedigree level** students create "family tree" structures of related organisms in order to observe and investigate such inheritance patterns.

BioLogica's interface is *activity-driven:* the layout of the screen, the affordances made available to students, the representations available, all these are idiosyncratic and determined by the particular activity that is in progress. BioLogica cannot be run by itself, but requires the presence of a *script* – a short executive program that tells it what to do. The script embodies both the activity and the indicators that can be used to judge students' performance. Here is an example of such a script.

The Horns Dilemma

One of the early "mysteries" that students of genetics encounter is the fact that physical traits may be acquired by offspring even though the parents do not possess them. Blond children are occasionally born to brown haired parents. To pick a more poignant example, children can inherit a recessive disease like cystic fibrosis from parents who not only do not have the disease but are unaware of any family members who ever had it. How is such a thing possible?

As Gregor Mendel was the first to point out (Mendel, 1866), the answer lies in the fact that each organism[6] carries two copies of each gene, and these "compete" with each other in determining the organism's physical traits. In the simple case that a single gene controls a particular trait – and adding the further simplifying assumption that the gene can exist in only two forms, or *alleles* – the typical pattern is that one of these alleles, dubbed the dominant one, "wins the fight" over the other, or recessive, allele. Thus, if an organism has two dominant alleles (a condition denoted "homozygous dominant") it will have the dominant trait, if it has two recessive alleles ("homozygous recessive") it will have the recessive trait, and if it has both alleles (in which case it is said to be "heterozygous") the dominant allele will "win" and the organism will have the dominant trait. Cystic fibrosis is a recessive trait, so the child with cystic fibrosis must have had two heterozygous parents, and had the misfortune to inherit the recessive allele from each. There was a one-in-four chance of that happening.

The "Horns Dilemma" is a BioLogica-based puzzle that involves the inheritance of recessive traits. Using a fictitious dragon species, students are asked to predict and then construct the genotype of two horned parent organisms such that they may produce offspring who will not display the horns trait. (Since horns are dominant in this species, both parents must be heterozygous if they are to have a hornless baby.) The students must then run meiosis on each parent, inspect the eight gametes so produced, and select one with the recessive horns allele from each parent. Combining these gametes through fertilization will produce a baby with the recessive, hornless trait.

[6] Technically, each *diploid* organism.

In order to solve this little problem, the students must understand many things. They must be aware of the relationship between phenotype and genotype and know that horns is a dominant trait. They must understand that offspring get half their genetic information from each parent, that both parents could be either homozygous or heterozygous for horns in order to display the trait, but both must in fact be heterozygous in order to have hornless offspring.

The BioLogica script for the Horns Dilemma is designed to operate on its own, without the need for a paper handout. It starts by posing the problem, then it sets up the BioLogica interface, choosing which levels and tools to make available, for example, and setting up the screen layout. It also activates "listeners" — software agents that, in effect, "look over the shoulders" of the students, so as to make it possible to intervene at propitious moments. Here is what the activity looks like to the students and how we can use it to assess what they have learned. The text messages that the students see are in **bold.**

Good morning! Your task for today is to mate two dragons with horns and make sure the baby dragon has no horns. Before we begin, do you think it can be done? Students choose from "Yes," "No," and "Not sure." The script records their answer, but does not use it for assessment. The purpose of the question was to get them to think about the problem.

Screen shifts to: **OK, make your first dragon** and places a button on the screen reading "**New Dragon**." When the students click on this button, a female dragon appears. The script has ensured that she is heterozygous, so naturally she has horns. The script gives them the message: **Good. Now make another.** The students click on the same button. This time the dragon is male, horned, and homozygous dominant. The chromosomes of the dragons are not visible, but they the students can see them simply by clicking on a dragon. The text gives them a gentle reminder of that fact. **Note that your two dragons both have horns. Your job is to give them a hornless baby. You can inspect the genes of the two parents, and modify them if you wish, but they must have horns.**

The "**New Organism**" button changes its label to "**Run Meiosis**." If the students choose to examine the genes of the dragons that fact will be noted but not commented on. If they attempt to change any of the genes they will be allowed to do so by the script, as long as the change does not make either dragon hornless, because that would violate the condition set forth in the problem. If they make the male dragon heterozygous for horns, as is required for the activity, that fact will also be remembered, but not commented on. In fact, at this point the computer effectively "goes away" while the students (1) run meiosis on a cell from each dragon, making four gametes from each; (2) select one gamete from the mother and one from the father; and (3) start to run fertilization.

When the students start to run fertilization the script halts the process and puts up a text box asking, **How sure are you that the baby you are about to create will not**

have horns? It gives four choices, **Really sure, Pretty sure, Not so sure,** and **Actually, I think it will have horns.** After the student has answered the question, fertilization is allowed to proceed. There are various possibilities:

- The students have examined the parent dragons' genes, altered the father's to make it heterozygous, and selected an ovum and sperm that contain the recessive allele. This series of actions indicates that they understand the problem completely.
- The students have examined the parent dragons' genes, but have failed to alter the father. However, they have stated that they think the baby will have horns, indicating that they know something is wrong. The script will allow fertilization to proceed, and once the baby dragon is born it will say, **You're right! Do you think that these parents can ever have a hornless baby dragon?** If the students answer "Yes" they will be told to try again, if they answer "No," they will be given a hint **You can alter the parents' genes if you like.** If they do this and then succeed at the task they have shown that they now understand what is going on. If we are scoring the item, we can give them 90% credit.
- The students have failed to examine the parents' genes, but they have examined the genes on the gametes. They are given the same sequence of hints as before, but lose points for not realizing the importance of the parental genotypes.
- The students fail to examine the genes on the gametes, essentially randomly selecting an ovum and sperm to fertilize. They will be walked through the exercise until they succeed, but for scoring purposes they will lose almost all credit for the item.

No matter what happens on this question, eventually the students can be led to produce the desired hornless baby dragon. When that happens, in all cases the script displays a brief textual description of the process they have just gone through, and then presents an "extra credit" question involving a human recessive trait, such as cystic fibrosis. The new question is presented in "passive" mode, just as though it were on a paper-and-pencil assessment. Its purpose is to determine whether the students can apply their knowledge of the inheritance of horns in dragons to a real life situation involving humans, and whether they can do so outside the context of the CBM. It is also useful for preparing the students to take conventional paper-and-pencil tests.

Conclusion

The idea of joining of scripting technology to computer-based manipulatives is a simple, but powerful one. It enables us to create hypermodels that are cognizant of student goals and able to respond to student actions. As we have seen, such hypermodels can add real world verisimilitude to students' investigations. They can scaffold students' attempts to make sense of a complex system, and they can alert a teacher to propitious moments for intervention. As of this writing (December, 1999) they have yet to be tried out with real students in a classroom. Thus, the jury is still out on their educational effectiveness and appeal. Our challenge for the immediate future will

be to create scripts that combine the power and appeal of open-ended exploratory environments with the realism and explanatory power of multimedia materials. On our ability to rise to this challenge rides the ultimate utility of the hypermodel paradigm.

Changing the Rules: Children, Creativity and Computer Games

Celia Hoyles and Richard Noss
Mathematical Sciences Group
Institute of Education
London, UK
choyles@ioe.ac.uk; rnoss@ioe.ac.uk

Abstract: Computer games are important in children's culture. They afford opportunities for fantasy, challenge, collaboration and competition, all essential elements of play and learning. Yet their relationship with learning remains tenuous. This paper will present some work that seeks to build computational 'playgrounds' where children will learn about rules, by designing, building and playing their own computer games.

Introduction

Computer games are important in children's culture. Yet many computer games achieve very low thresholds of accessibility at the price of considerable restriction in terms of what can be done. Current computer games typically cast children in the role of game-player, playing according to rules programmed by someone else - a situation which, however motivating, sets strong boundaries around what might be learned. We claim that the fascination of children with computer games is entirely at the level of interface. That is, manipulation of the game objects is fun, expressive and engaging. But for the most part, the interface is all there is: the level below the interface is the preserve of the programmers and designers, not the user. The aim of the Playground project is to place children in the role of producers as well as consumers of games, and in so doing change their relationship with the rules of the games. In this endeavor we are building on the work of Papert (1998), Kafai (1995), Harel (1988), Klawe (1995), and Rubin (1995). As far as learning is concerned, we build on our own work in developing microworlds for mathematics to explore students' meanings (Noss and Hoyles 1996), as well as others: in particular in relation to facilitating links across representations (Clements and Sarama 1995, Kaput and Roschelle 1999, and Hoyles et al. 1999).

The Playground project is a 3-year collaborative project, funded by the European Union, which has been working since November 1998 to build 'playgrounds': computational worlds in which children can play games, take them apart, reconstruct and share them. The project partners are the Institute of Education, University of London, UK; Logotron, Cambridge, UK; CNOTINFOR, Portugal; Royal Institute of Technology, Sweden; and Comenius University, Slovak Republic.

Playground is developing two platforms on which children can create and play their own games: an animation-based computing formalism called ToonTalk (Kahn 1999), and a new, concurrent object-oriented version of Logo. Our research has progressed simultaneously on three levels: questionnaire and interview survey of the games 5-8 year olds like to play on and off computer; case studies of children designing, building and changing games, the resources they use, the meanings they evolve and share, and the understandings they develop; and analyses of how children come to understand the implications of the rules that they program into their games. Our preliminary work has revealed the need for a clearer distinction between children's strategies for building games and for taking apart and reconstructing them, and a more precise specification of our learning objectives.

We have developed two types of resource: playground fragments (play objects such as bouncing balls, noises and pictures) and control components (such as dice and timers) that can be used to make games; and a collection of different types of games composed of simple modular reconstructable elements. A preliminary identification of the most useful categories of games, the tools available and the aspirations of our children have led us to distinguish action games, strategy games, and school games. Prototype examples in each of these categories have been built.

The latter concern has led us to define more clearly what we mean by *rules* in this context. In any game, the rules may model 'real' laws (the way a ball bounces), specify constraints (this place is out of bounds) or simply define how the game is played (if a certain object is hit 10 points are scored). If children

design their own games all these types of rules are necessarily raised to a more overt plane, they become objects of reflection, something else with which to play creatively. A central part of our development work has been to identify the right grain-size of the objects that children will want to manipulate to specify the rules and goals of their games: the appearance of the play objects, the sounds they make, their behaviors and the rules that underpin interactions between them. Our achievement to date is that we have built simple games in such a way that the children have come into contact with deep ideas: how motion can be decomposed into components, the symmetry of events such as 'hitting', how different scoring mechanisms work and their implications for the fairness of the game.

In this paper we will focus on game evolution and how two children changed a simple game, its appearance and how they modified its rules so it fitted more closely what they wanted to play.

From Pong to Underwater Fishing

We wrote a very simple pong game in ToonTalk which we gave to two girls, Harriet and Roberta (age 7 years) to play, redesign and change as they wished. Harriet and Roberta had both been working with ToonTalk in an after-school computer club for about three months, so were relatively familiar with the metaphor and the simple tools available. This original pong game was a two-player game, where one player controls the top paddle using the keys SHIFT and CTRL to move the paddle left and right, and the other uses the mouse to move the bottom paddle left and right (see Figure 1). The ball bounces around and the players must each try to hit it with their paddle. The score (bottom right hand corner) increases by 10 points whenever the top paddle hits the ball.

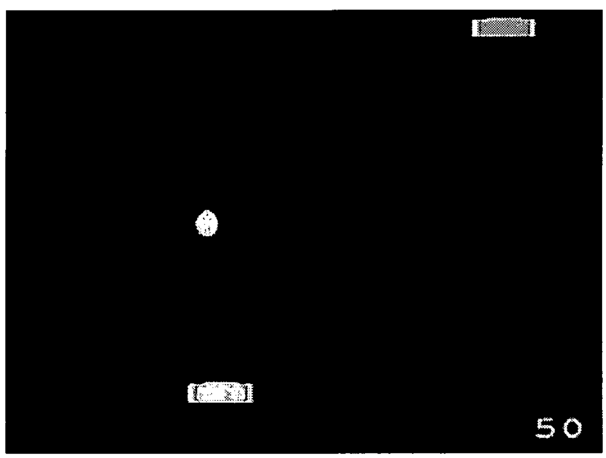

Figure 1: original pong game

At first the two girls simply treated pong like a 'sport': as they put it, "it's like tennis". As they played, they soon worked out that the score was changed by the top paddle. They thought the game was rather boring, so we added more inducements to carry on playing - playing against the clock, trying to get the most points in 30 seconds.

Changing the Appearance to Bammers and Birds

We wondered if the girls wanted to change the game, which took us to the first phase of game evolution:

I: How can you change the game?
H: Could have two scores, one for bottom one for top.
H: Make it more colorful… it's a bit dark.
H: You could have… like the paddle as a fish.

R: I've got an idea: Bammer hits the thing down and hits the ball.

Out of these ideas they first implemented the change in color - to light blue. This is trivial in ToonTalk and is achieved by hitting the space bar. They had decided to make the paddles look like Bammer - a special animated mouse in the ToonTalk world, so we asked:

I: How will you get Bammer to behave like the paddle?

H&R: I know — you stick the paddle on the back.

The two girls were referring to a general method for exchanging behaviors in ToonTalk. On the back of any picture are its behaviors (as illustrated in Figure 2).

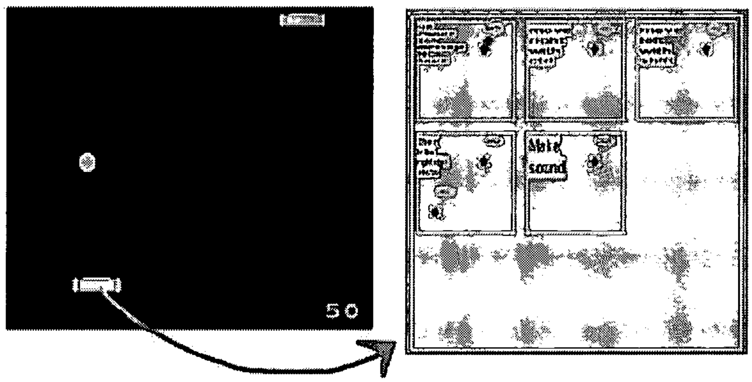

Figure 2: the paddle and behaviors on the back of it

The girls knew that if you flip over a new picture, flip over the paddle, and put the paddle on the back of the picture, then the picture will inherit the paddle's behaviors.

Next they changed the ball to look like a bird.

I: That's horrid! [i.e. the bird is being hit by a hammer!]

H & R: No, no it's flying up and down, up and down — it's OK.

This was achieved exactly in the same way as the change of appearance of the paddle. They also changed the color of the background at the bottom to be yellow (see Figure 3).

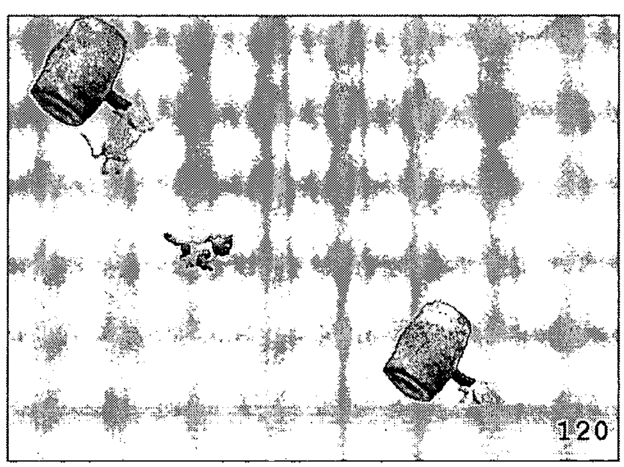

Figure 3: changing the appearance to Bammers and Birds: Bammer is the animated mouse with a *large* hammer

The changes in color stimulated more ideas, and it seemed to support the girls' inclination to build an underwater narrative which they had mentioned earlier when they said they wanted fish. They decided how far they were willing to suspend conventions of reality; a tacit agreement or compromise, both parts of make-believe play.

H: I know… that's like the sea and he's [Bammer] running down into it! Cos that's like there's a hill and there's sand going down.

R: There's a problem! He's walking on… the water!

H: It doesn't matter.

The new game is no less boring in terms of playability than the first version. Yet the girls found it far more compelling because *they* had made it. They also became less concerned about the scoring aspect of all their ideas for development but we only encouraged them to implement the (simple) picture changes at this point. This indicates the importance of the interactions with a more capable other (such as a teacher) who is able to judge what is possible as well as desirable in computer interactions at a particular time and for a particular group of children. It was clear that Harriet and Roberta needed extra playground elements such as pictures of fish and sounds. We developed these and stored them in libraries of play objects and control components for them to access later.

Going underwater

In the next session, we gave Harriet and Roberta some new pictures of fish and they picked out the shark picture for the paddles. They discussed more ideas: Roberta wanted to have lots of fish bouncing up and down, (an idea she had picked up from the boys who had made multiple balls for their game).

H: But if the fish reach the top or bottom then they make another fish?

R: And also they take away from your score.

This latter suggestion is a different sort of transformation incorporating a penalty scheme in addition to the scoring one. In fact they simply changed the paddles to sharks, now an easy maneuver as they had already changed the paddle to be Bammer. The girls were changing the appearance of the game and programming at what we term 'the picture level'. They simply put the paddle on the back of the shark picture. They also changed the ball to a fish by putting the 'ball with all its behaviors' on the back of a fish, reducing its size with a ToonTalk tool called Pumpy (an animated bicycle pump which makes things bigger and smaller), and then copying it many times with another tool, Wandy (which copies objects and all their inherited behaviors). Their game now looked like Figure 4.

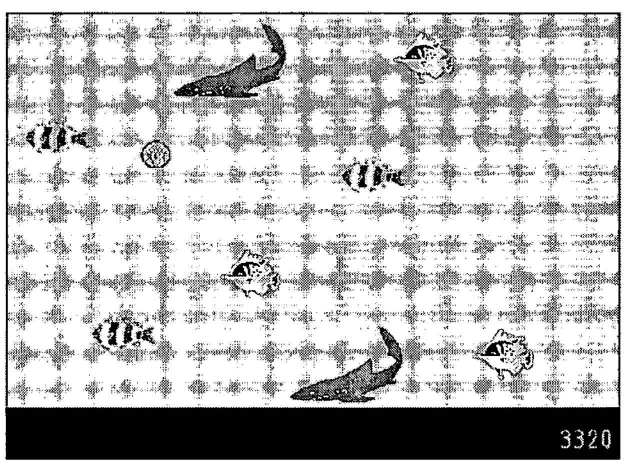

Figure 4: changing the appearance to sharks and fish

From hitting fish to eating them

Once Harriet and Roberta played with the shark and all the fish, they immediately wanted to make more changes - changes in the rules of the game as well as its appearance.

R: The sharks are the paddles. And if one of those hit the sharks -

H: - any of them -

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R: it goes like this [R chomps]
H: No it doesn't.
I: That's what you want?
H: This is what we want.
R: We really want to make more of the balls and when it comes they go [chomp] and if you press a button it spurts out again.

So the girls wanted a new sound that would be played whenever the shark hit the fish. This was rather harder to manage: they needed to get further into the system, to reprogram a robot which is the mechanism for making a behavior and lives on the back of a picture so it made the noise 'crunch' rather than 'beeyaw' if the shark and fish collide. They managed this since all they had to do was find the right robot and change its 'input box' to have the noise they liked, as illustrated in Figure 5.

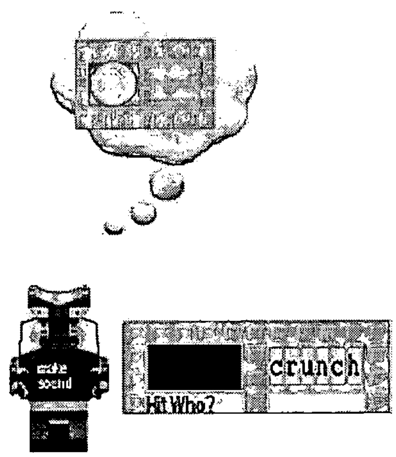

Figure 5: 'make sound' robot and its new input box

Next, the girls tried to build a game that was more realistic by changing another rule: every time a fish hit a shark, instead of bouncing off, it would be eaten. This idea made the pair think of new ways to win - which shark eats the most fish!

In this paper it is not possible to illustrate all of the next phases of their game evolution. We simply summarize: first they made the shark eat the fish by making a 'disappear when hit by shark' behavior; then they made many fish and changed the scoring system so the game had two scores, one for each shark. After help with this final phase, their game looked like Figure 6.

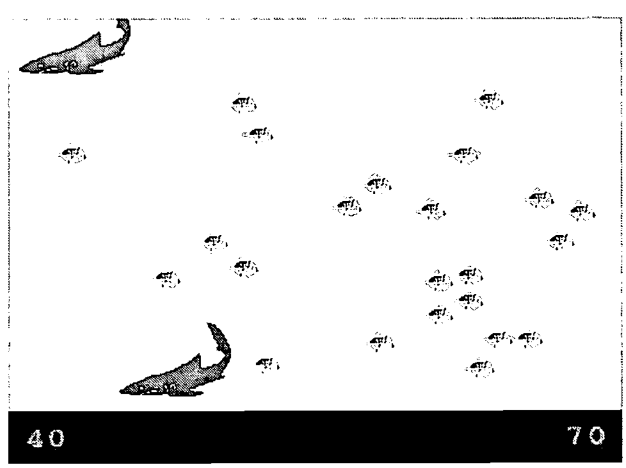

Figure 6: shark game with two separate scores

Conclusions

What this brief paper illustrates is how two girls were able to transform a game and the rules by which it was both played and won. It shows how they were able to program at the level of pictures, noises and behaviors: that is, swap these attributes and functions in ways that satisfied their own goals. In the next stage of the project, we are seeking to investigate in more depth the meanings that the children are attributing to their interactions in our playgrounds, and what exactly they see as the rules of their games. We know they are largely unaware of the rules of the computer games they play at home and school, and we know they are very aware of the events they wish to see and hear in their own games. What we have yet to discover is how far they are able to articulate these rules to others - face to face or over the web.

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Predictors of Class Use of Computers

Johan van Braak
Department of Education
Vrije Universiteit Brussel
Belgium
Johan.van.Braak@vub.ac.be

Abstract: A survey was performed to investigate the influence of personal factors on class use of computers. Subjects were 236 secondary school teachers who were using computers, either for teaching or non-teaching purposes. A logistic regression technique was used to examine differences between class users and non-class users of computers on a set of personal characteristics: age, gender, computer attitudes, computer experience, technological and general innovativeness. Results indicate that only technological innovativeness and computer experience accounted for significant variance in explaining class use of computers.

Background

Many studies and meta-analyses have reported gender differences in the field of computing. In general, males have more computer experience and more favorable attitudes towards computers than females (Whitley, 1997; Kirkpatrick & Cuban, 1998; Liao, 1998).

Also age is often perceived as being correlated with computer use and attitudes (Dyck & Smither, 1994; Durndell et al, 1995; Parry & Wharton, 1995). Dyck & Smither (1994) showed that older adults were less computer confident, and at the same time more computer anxious. Durndell, Glissov, Siann et al (1995) found boys to have more favorable attitudes towards computers and to be more computer experienced. Parry & Wharton (1995) showed that younger people are more likely to use computer networks. Age differences however, showed little power in explaining differences in network use.

Research literature on computer attitudes is well documented. Several attitude scales have been developed (e.g. Loyd & Gressard, 1984; Kay, 1989, Panero, 1997) and used in different populations. However, research literature on the relationship between computer use and innovativeness is limited. Rogers (1995) describes innovativeness as a personality characteristic indicating how early an individual is in adopting an innovation relatively to others in a social system. In Rogers' view innovation refers to a specific change and can designate an idea, a method or a technology. Hurt, Joseph & Cook (1977) define innovativeness as a normally distributed, underlying personality construct, which may be interpreted as a willingness to change. Marcinkiewicz (1993-4) stresses the importance of innovativeness as a predictor of computer use for teaching.

Method

The subjects were 236 computer using teachers in Dutch-speaking secondary education in Brussels (Belgium). The respondents filled out a questionnaire. Demographic variables were gender and age. A classification was made taking into account the subject taught and the fact that the use of new technology was a priority (technology courses, informatics, sciences, economics). It could be assumed that the content of the taught subject was a main predictor of computer use in class. To assess the amount of computer experience, a distinction was made between more and less than four years of computer use for personal and/or occupational means. Computer attitudes were assessed using a self-developed *Attitudes toward Computers in Education Scale*. The scale consists of twelve Likert items which assessed the attitudes towards the impact of computers on education and the necessity to integrate computers into the teaching practice. Item scores could range between 0 (totally disagree) and 4 (totally agree). Innovativeness was assessed using a similar Likert-scale. A distinction was made between *Technological Innovativeness* (eleven items) and *General Innovativeness* (five items).

Results

Demographics

In the sample, ages ranged from 23 to 62 years, with a mean of 41 years. Exactly half of the respondents were female. This proportion is consistent with gender and age distribution within the total population of teachers in secondary schools in Brussels (N=1757). Only 41.5 % of the respondents stated having used a computer in the classroom at least once. The other 58.5 % of the teachers mainly used the computer as a support tool (lesson preparation, evaluation purposes...). Of the sample, 43 % taught a subject in which the use of technology is seen as a priority.

Computer attitudes and experience

One way analysis of variance (ANOVA) showed that class users have more favorable attitudes towards the use of computers in education than non-users ($F = 9.35$, $p < .01$). Table 1 highlights mean scores at item level and differences in item means between the two groups of teachers. (Mann-Whitney tests are employed to calculate differences in means.

	Z-value	p-value	class use M	class use SD	non class use M	non class use SD
The introduction of computers is a necessity in modern education (9)	-2.93	.0034	3.01	.89	2.65	.96
Computers improve learning outcomes (1)	-2.77	.0056	2.76	.89	2.45	.87
A future teacher should get substantial computer training. (12)	-2.66	.0078	3.17	.86	2.85	.95
The computer as a learning tool raises the motivation of children. (3)	-2.65	.0081	2.61	.93	2.29	.87
Computers increase the creativity of learners. (4)	-2.53	.0113	2.38	1.06	2.04	.94
Computers raise learning efficiency (2)	-2.51	.0120	2.43	.90	2.13	.88
Computer knowledge and experience should be implemented in the curriculum. (8)	-2.38	.0172	3.03	.83	2.74	.92
Computers are effective to differentiate between children (6)	-1.94	.0519	2.80	.87	2.58	.80
Due to the computer, children learn to produce better texts. (7)	-1.80	.0712	1.65	1.08	1.38	1.03
At risk students benefit by the possibilities of computers. (5)	-1.56	.1193	2.51	.85	2.33	.88
It is essential for children that they learn to handle computers from primary education. (11)	-.75	.4528	2.83	1.14	2.72	1.13
The operation of a computer is an essential object of study. (10)	-.19	.8496	2.80	.94	2.77	.95

Table 1: Class users (n=98) and non-class users' (n=138) attitudes towards computers in education.

Several observations can be made from Table 1. First, the data on the *Attitudes towards Computers in Education* items indicates that class users reported a higher mean score on all items. Differences between groups are statistically significant for seven of the twelve items.

Second, the scale items can be subdivided in two categories: adjectives that describe instructional benefits of computing in education (items 1-7) and adjectives that gauge the overall need to introduce new technology in education (items 8-12). The distinction between both categories is confirmed by principal component analysis (Appendix A). Data in Table 1 reveals that both class and non-class users have a lower mean score on all instructional benefits items. This clearly indicates the gap between the perceived need to introduce computers in education and the perceived educational results.

Concerning the amount of computer experience, 75.5 % of the class users reported to have been using the computer for more than four years, as compared to 45.6 % of the non-class users. Differences between groups were strongly significant ($X^2 = 21.65$, $p < .000$).

Innovativeness

Principal component analysis with a two-factor solution was performed on a 16-item Innovativeness scale. This statistical technique confirmed the structure of two different constructs (appendix B). The 11 items loading high on the first construct are a measure for the belief that technology is a necessary educational innovation, linked to the personal willingness to introduce new technology in the classroom. This construct is labeled *Technological Innovativeness*, with a high internal consistency of $\alpha = .93$. The five items loading high on the second component,

measure a personal degree of *General Innovativeness* (α= .79), which refers to the general willingness of teachers to introduce new methods and ideas into their teaching practice.

One way analysis of variance showed statistically significant differences in means between the innovativeness scales and class use of computers. In Table 2, results of the one way analysis of variances are presented with some descriptive statistics. Scales scores range between 0 (totally disagree on all items) to 100 (totally agree on all items).

	F-value	p-value	class use M	class use SD	non class use M	non class use SD
technological innovativeness	34.01	.0000	75.32	15.90	62.98	16.12
general innovativeness	15.05	.0001	75.41	15.87	67.14	16.32

Table 2: Technological and general innovativeness: one way analysis of variance and descriptive scale statistics for class users (n=98) and non-class users (n=138).

Class users of computers not only reported a significantly higher degree of technological innovativeness ($F = 34.01$, $p < .001$), but a higher degree of general innovativeness as well ($F = 15.05$, $p < .001$). The relationship between the innovativeness scales and class use of computers is clearly demonstrated on item level (Table 3).

	Z-value	p-value	class use M	class use SD	non class use M	non class use SD
Technological innovativeness						
I highly value the introduction of new technology such as computers (6)	-5.94	.0000	3.18	.83	2.43	.92
I have realized that the introduction of technological innovation represents an added value to my work practice (2)	-5.22	.0000	3.00	.82	2.40	.83
I find technological innovation beneficial for my teaching practice (4)	-5.09	.0000	3.15	.76	2.60	.78
I believe the need for the introduction of new technologies in my practice (5)	-4.66	.0000	2.86	.91	2.26	.93
Our fast changing society requires the introduction of technological innovation into the work practice (7)	-4.38	.0000	2.96	.91	2.46	.85
I personally realize that the time is right for introducing technological innovation into my educational practice (3)	-4.16	.0000	2.67	.95	2.13	.95
New technology is not a high priority in the subject I teach (11)*	-4.04	.0001	3.13	.93	2.64	.96
I think that introducing technological innovation can be very beneficial to my profession (8)	-3.68	.0002	3.10	.77	2.70	.81
I have a positive attitude towards a broader introduction of computers in secondary education (9)	-3.59	.0003	3.22	.74	2.86	.73
I want to integrate new technologies in my work for their impact on society (1)	-2.89	.0039	2.83	.84	2.44	.95
I believe a progressive introduction of technology into education responds to our society's changing needs (10)	-2.76	.0057	3.03	.95	2.79	.77
General innovativeness						
I'm suspicious against the use of new educational methods until I notice they are successful to my colleagues. (14)*	-3.50	.0005	2.81	1.00	2.34	.99
I seldom trust new ideas until I see the majority of those around me accepting them (12)*	-3.28	.0010	3.02	.87	2.65	.82
I'm aware I usually accept ideas later than people around me (13)*	-3.04	.0024	3.40	.70	3.07	.80
I am generally very careful about accepting new ideas (16)*	-2.06	.0394	2.59	1.05	2.30	1.01
I do not seek change in my teaching practice (15)*	-1.76	.0776	3.27	.77	3.07	.81

Table 3: Class users (n=98) and non-class users' (n=138) degree of General and Technological Innovativeness. * Scoring mode was reversed for negatively stated items.

Class users of computers recorded significantly higher mean scores on all general and technological innovativeness items (expect one). For most of the items, especially the technology ones, the differences were strongly statistically significant. Class users are more convinced of the value of technology for education in general and for their own teaching practice in particular. It strikes the attention that non-class users display the lowest mean score on the item '*I personally realize that the time is right for introducing technological innovation into my educational practice*'. On

average, not only class users are convinced of the value of technology in education, but non-class users obviously feel inhibited by time constraints. The concept of time is probably one of the most important factors in understanding the process of technological innovation in education.

Predictors of class use of computers

In a next step, forward stepwise logistic regression was used in order to analyze the predictive value of the set of independent variables on the dichotomous, dependent 'computer use' variable.

Variable	Regression coefficient B	standard error	Wald coefficient	Statistical Signif. of B	R
Constant	-4.618	.771	35.843	.0000	
Technological Innovativeness	.043	.010	17.803	.0000	.222
Technology Relevant Subject	1.216	.308	15.568	.0001	.206
Computer Experience	1.218	.322	14.322	.0002	.196

Table 4: Results of the stepwise logistic regression (n = 236). Model $X^2 = 66.51$, $p < .000$. -2 Log Likelihood = 253.84. Nagelkerke $R^2 = .33$. Variables not in the equation: gender, age, attitudes toward computers in education, general innovativeness.

Table 4 shows that three variables contributed to the prediction of class use of computers: technological innovativeness ($R = .22$, $p < .001$), teaching a technology related subject ($R = .20$, $p < .001$) and computer experience ($R = .20$, $p < .001$). Although Table 1 showed a significant relationship between *Attitudes toward Computers in Education* and class use of computers, the effect disappeared if controlled for technological innovativeness. In other words, the predictive power of the attitudes scale is absorbed by the technological innovativeness scale. The other independent variables (gender, age and general innovativeness) did not contribute to any increase of explained variance of the model.

Discussion

In this study, some data is provided on the relationship between personal factors and class use of computers by secondary school teachers. Results suggest that class use of computers is mainly dependent upon the personal willingness to change teaching through technology, teaching a technology related subject and computer experience. Although evidence is provided that computing is more a male than a female activity (Whitley, 1997; Kirkpatrick & Cuban, 1998; Liao, 1998), in this study gender did not seem to have any power in explaining differences between class users of computers and non-class users, as neither did the age variable.

Teaching a technology related subject. As one might expect, teaching a technology oriented subject such as informatics, technology education or sciences, is a good predictor of class use of computers. However, no previous studies could be located that suggest the impact of curriculum-based factors in explaining differences in computer use. Based on the results of this study, we hypothesize that the integration of computers in classroom will be facilitated only when school curricula become more technology-oriented. As distinct from the impact of technological developments on society, the introduction of technology in school curricula is still a matter of secondary importance for curriculum designers. Still, changing school curricula is a vital condition for the increase of technology adoption in schools.

Technological innovativeness. The use of computers with learners within the classroom can be analyzed in terms of organizational factors such as availability of computers in schools, computer access and technical support. However, findings in this survey suggest that personal factors such as technological innovativeness are crucial in relation to teachers' class use of computers. Marcinkiewicz (1993-4) too confirmed the predictive effect of innovativeness on computer use. In this survey however, a clear distinction could be demonstrated between general and technological innovativeness, with the latter having the strongest predictive power for class use of computers. Dispositions of teachers towards technology are seemingly acting as a bottle-neck for the adoption of technology in school practice.

Computer experience. A teacher who is not self-confident concerning his technological abilities is less likely to implement computers with learners than a teacher who feels computer competent. Computer competency increases with computer experience over time. Therefore, ensuring more (computer-)focused professional

development possibilities through in-service training appears necessary if an increase of class use of computers is to be seen as a priority for schools. Through in-service training, teachers refine their computing abilities and learn to transfer their knowledge and skills into teaching situations. Not hardware delivery, but professional development of teachers is a key issue in the adoption of computers in teaching practice.

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APPENDIX A Principal component analysis on the Attitudes towards computer Scale

Attitudes towards computers in education Scale	Factor (1)	Facto r (2)
1. Computers improve learning outcomes	**.795**	.243
2. Computers raise learning efficiency	**.777**	.274
3. The computer as a learning tool raises the motivation of children	**.729**	.261
4. Computers increase the creativity of learners	**.705**	.294
5. At risk students benefit by the possibilities of computers	**.683**	.225
6. Computers are effective to differentiate between children	**.599**	.267
7. Due to the computer, children learn to produce better texts	**.594**	.240
8. Computer knowledge and experience should be implemented in the curriculum	.243	**.749**
9. The introduction of computers is a necessity in modern education	.159	**.738**
10. The operation of a computer is an essential object of study	.290	**.640**
11. It is essential for children that they learn to handle computers from primary education	.273	**.624**
12. A future teacher should get substantial computer training	.382	**.593**
eigenvalue	**5.491**	**1.066**
% total variance	**45.76**	**8.89**

APPENDIX B Principal component analysis on the Innovativeness Scale.

Innovativeness Scale	Factor (1)	Facto r (2)
1. I want to integrate new technologies in my work for their impact on society	**.844**	.036
2. I have realized that the introduction of technological innovation represents an added value to my work practice	**.826**	.249
3. I personally realize that the time is right for introducing technological innovation into my educational practice	**.819**	.157
4. I find technological innovation beneficial for my teaching practice	**.798**	.284
5. I believe the need for the introduction of new technologies in my practice	**.776**	.254
6. I highly value the introduction of new technology such as computers	**.733**	.228
7. Our fast changing society requires the introduction of technological innovation into the work practice	**.733**	.030
8. I think that introducing technological innovation can be very beneficial to my profession	**.702**	.338
9. I have a positive attitude towards a broader introduction of computers in secondary education	**.705**	.269
10. I believe a progressive introduction of technology into education responds to our society's changing needs	**.646**	.131
11. New technology is not a high priority in the subject I teach*	**.565**	.168
12. I seldom trust new ideas until I see the majority of those around me accepting them*	.039	**.814**
13. I'm aware I usually accept ideas later than people around me*	.109	**.762**
14. I'm suspicious against the use of new educational methods until I notice they are successful to my colleagues*	.199	**.734**
15. I do not seek change in my teaching practice*	.349	**.670**
16. I am generally very careful about accepting new ideas*	.213	**.582**
eigenvalue	**6.325**	**3.088**
% total variance	**46.50**	**12.33**

* Scoring mode was reversed for negatively stated items.

Problem Solving with the TI-92: A Report on a Problem Seminar

Clifford Johnston
Department of Mathematics
West Chester University of Pennsylvania
United States of America
cjohnston@wcupa.edu

Abstract: The paper will report on a graduate level Problem Seminar offered at West Chester University that focused on using technology, particularly the TI-92, to assist problem solving. The course merged the traditional problem seminar with an introduction to computer algebra systems and their applications. Traditional and non-traditional problems that required the use of technology beyond routine numerical computation were the focus of the course. In particular, problems from the fields of number theory, algebra, calculus, geometry, probability, and statistics were used to investigate the role of technology in problem solving.

Introduction

In the past decade, two issues have greatly influenced curriculum reform in mathematics education—an emphasis on problem solving and the inclusion of technology, particularly graphing calculators (NCTM, 1989). Many authors including Polya (1957) and Krantz (1997) have shared their insights on problem solving over the past century. Several strong programs such as the T^3 program from Texas Instruments have been developed to prepare teachers for the inclusion of technology in the classroom. With regard to problem solving, however, most programs on the inclusion of technology in the classroom focus on how *students* might be directed to solve problems with the technology. While the problems presented often require a calculator or computer for the solution, the teacher is usually aware of the method that ultimately solves the problem. In short, the teacher rarely encounters a problem where, according to Polya's structure (Polya, 1957), the teacher needs to "understand the problem" or even "devise a plan," but rather they can jump right to "carrying out the plan." By offering a graduate problem seminar emphasizing the use of graphing calculators and computer algebra systems in solving problems, we intended to provide *teachers* with the whole experience of problem solving much as their students encounter it.

To give a more specific example, consider the problem, "Determine whether or not the sequence $\{(n^2e^{-n})\}$ converges as n goes to infinity" (Hollister, 1993). Presented as a discovery problem in a typical reform calculus course, the student is expected to evaluate the function at increasing values of n until it is clear that the sequence converges to 0. This is obvious to the teacher. The teacher knows not only the answer but also the method by which this problem is attacked. The student, however, has no such foreknowledge, and it seems reasonable to suspect that the student might not see the role of the technology in solving this problem until presented with a similar solution by the teacher. By engaging teachers with problems for which they have no foreknowledge of the appropriate use of the technology, we intended to increase their insight into the role of technology in problem solving and their awareness of student difficulties in using the technology.

The Course

The fundamental philosophy of the course was that "you learn to solve problems by *solving* problems" (Krantz, 1997). The format of the course followed *A Problem Seminar* (Newman, 1982); problems were assigned in sets with relevant mathematical content presented to add to the students' collection of problem solving tools. The course was targeted toward teachers, particularly those enrolled in the department's graduate mathematics program with a mathematics education emphasis.

Problems were chosen from the areas of number theory, algebra, calculus, geometry, probability, and statistics. While most problems used the technology for simple arithmetic or symbolic manipulation at some point, students were encouraged to investigate other uses of the technology in forming the solution. Uses of the technology in problem solving were categorized into the following areas of application: arithmetic, symbolic manipulation, trial

and error computations, approximation, visual representation, generalized algorithms, and pattern recognition. A significant emphasis was placed on mathematical programming. Problems ranged from those whose solution relied almost entirely on abstract arguments to those that asked the student to develop and implement algorithms. Successful problems mixed both abstract and computational elements in a non-trivial way. For example, to solve a problem involving sequences of consecutive natural numbers all divisible by a perfect square, the class learned the Chinese Remainder Theorem, implemented the algorithm on the technology, and then calculated the sequences.

The TI-92 calculator from Texas Instruments was chosen as the primary technology for the course for several reasons. It was readily available and inexpensive to the students and the school because of the Texas Instruments Workshop Loan Program. It was portable, allowing students flexibility while maintaining a common platform throughout the course. Moreover, the TI-92 contains all of the basic elements of a computer algebra system including a comprehensive library of operations and the ability to program. Finally, it was felt that a course using the TI-92 as opposed to computer-based systems would be attractive to the target audience of the course. The disadvantages of selecting the TI-92 included the lack of power compared with most computer-based systems, a non-standard keyboard, and a small display. Students were encouraged to use computer-based systems such as *Mathematica*, in cases where the TI-92 would not perform well.

The course was offered during the first summer session at West Chester University. It met four days a week, two hours a day, for five weeks. Twelve students were enrolled in the course. The course began with a two-day introduction to the technology. The students were expected to learn aspects of the technology needed to solve the problems by using the manual, asking the instructor, or asking another student. After the introduction to the technology, each class meeting was divided into four segments: presentation and discussion of solutions, lecture on related material, presentation of new problems, and small group work sessions. The ordering of the segments and the time given to each segment varied each day. The students decided among themselves with whom they would work in the small groups. During class, the groups were allowed to interact with each other if they so desired.

The Problems

Approximately 50 problems were assigned during the course. Most were solved and many were generalized beyond the initial question presented. In general, the students eagerly attacked the problems. During the first half of the course, the students usually used the calculator for arithmetic and were particularly hesitant when asked to program it. Several suggestions, reminders, and specific examples in class increased the students' familiarity with the technology. Throughout the course, hints were provided for more difficult problems on which students had made little or no progress after several days. Each student presented the class with the solution to at least three problems. In general, students who had done well in other mathematics classes solved more problems and presented clearer solutions than students with poorer backgrounds, who often found the course frustrating and overwhelming. There were exceptions, both on specific problems and throughout the course. One student in particular performed significantly above expectations based on prior course work. He worked well with his group, took a genuine interest in the problems, and was creative with the technology. All of these factors contributed to his success.

Sample Problem 1

The following problem was presented during the unit on number theory and was discussed shortly after several problems on prime numbers. By this time in the course, several of the students were using the technology actively in searching for solutions. This problem integrated the technology into a problem that ultimately relied on a theoretical result for a complete solution. The technology was used for pattern recognition and trial and error computation with algorithms generalized from previous examples. It also produced good subsequent questions and led to discussions on testing algorithms and limits of technology.

> **Problem:** A square-free number is a number that is not divisible by any perfect square. Describe these numbers in terms of their prime factorization. What is the largest string of consecutive integers that are square-free? What is the largest string of consecutive integers of which none are square-free?

The students began work on the problem by developing an algorithm to test for square-free numbers following the simple model that we had previously done in class for testing integers for primality. Most of the students found the solution to the first two parts of this question. The test consisted of a loop through a pre-formed list of primes, testing for divisibility by the square of each prime. Discussion of early attempts at solving the problem pointed out errors in the students' algorithms. This prompted a discussion on testing algorithms. Eventually the students realized that for long sequences of consecutive nonsquare-free numbers, they would need to look at large numbers. In particular, iterating through the integers and checking each number individually was not going to lead to a solution.

As part of this unit, the students studied the Chinese Remainder Theorem (see Appendix). With some direction, the students applied this theorem and found the general solution to the last part of the question. The problem then shifted from an existence question to a construction question. One of the students decided to investigate the size of the numbers generated by the solution and programmed the TI-92 with the solution. The longest sequence that the TI-92 could generate with this method consisted of five integers. The same student tried by trial and error to find sequences of size 5 or 6 that consisted of numbers smaller than the numbers guaranteed by the solution. He was successful in finding sequences of smaller consecutive numbers that were nonsquare-free, but a general solution for the smallest sequence of arbitrary length remained unsolved.

Sample Problem 2

The following problem highlighted the technology as a tool to recognize patterns leading to general methods of solution. It also pointed out that initial methods may not provide the solution, but may lead to more useful methods.

Problem: Which of the positive integers 101, 10101, 1010101, etc., can be prime?

Several students began attacking this problem by testing the numbers for primality and found that many of the numbers were not prime. Some of the students began factoring the numbers rather than testing for primality. It was quickly determined that 101 was a factor of those numbers in the sequence with an odd number of zeros. For those numbers in the sequence that had an even number of zeros, the factorization showed that 9091 was a factor of 101010101 and 909091 was a factor of 1010101010101. Once the pattern was recognized, students were able to prove that the pattern continued. The first attempt to generalize this problem was to look at other alternating digit patterns, such as 323, 32323, etc. Another generalization was to increase the number of zeros, such as 1001, 1001001, etc. The later problem lead to a similar solution for the numbers 1000001, 1000001000001, etc.

Sample Problem 3

Problems on probability and statistics were added to the course in response to the increasing number of school districts adding statistics courses to their curriculum. The solution to the following problem also provided the teachers with a useful tool should they teach statistics. The problem was presented immediately after reviewing the Central Limit Theorem. The technology was used to implement a student generated algorithm as well as verify the output by plotting the results of the algorithm.

Problem: Generate a random sample of size 20 from a standard normal distribution.

The students' first attempts applied the Central Limit Theorem by taking averages of large numbers of values generated with the random number function of the TI-92. Students were then asked if this method would work for other distributions such as a Chi-square or exponential distribution. The problem was left as an open question.

Sample Problem 4

The next problem was chosen to illustrate some of the limitations of technology. The problem was included on the final examination. Students had 3 days to complete the exam and were allowed to skip 3 of 10 problems without penalty.

Problem: Caesar's Breath: Approximate the value of the number $(1\text{-}10^{-22})^{10\wedge 22}$---the probability that in your next breath you will inhale a molecule of Caesar's last breath.

Neither the TI-92 nor *Mathematica* can handle this computation directly. On the other hand, the solution is straightforward if one recognizes that $(1\text{-}1/x)^\wedge x$ approaches $1/e$ as x approaches infinity. Three students chose to skip this problem and did no work on it. Four students tried to compute the approximation by having the calculator evaluate the expression as written and subsequently chose to skip the problem when they realized that the calculator would not produce a straightforward answer. Three of these students reported trying the calculation on *Mathematica* with one student concluding his work on the problem with the remark "I let *Mathematica* run for 4.5 hours and it did not find the correct decimal expansion." Four students attempted to solve the problem by calculating values of the sequence $\{(1\text{-}10^{-n})^{10\wedge n}\}$, n a positive integer. One of these attempts generated a sequence that began to diverge away from the solution, and unfortunately, the student did not recognize the error. Three students, including two that attacked the problem using the sequence, found not only a good approximation but also the connection with the exponential function.

Sample Problem 5

The next problem was part of a series of questions on geometry that used the Cabri Geometry™ software in the TI-92. The software allows for complicated constructions that would be extremely difficult with pencil and paper.

Problem: Given the focus, the directrix, and a point on a parabola, develop a straight edge and compass construction that determines for each point on the directrix, a corresponding point on the parabola. Do the same for the hyperbola and the ellipse being given the foci, a point on the conic, and an arbitrary point on the segment connecting the foci.

The students enjoyed the problem on the conics but had a great deal of difficulty with them. A few students found the solution to the parabola, and eventually one member of the class found the solution for the ellipse. Using the construction and the locus function on the TI-92, the students then generated the entire conic section.

In a similar problem, referred to as the Midpoints Problem, students were asked to determine the figure formed by the midpoints of the segments joining a fixed point outside a circle to the points on the circle. Having done the construction on the calculator, the locus function gave a clear answer (Fig. 1). This question was generalized to other planar figures and the students were asked to conjecture and prove which planar figures would produce a similar result under this map.

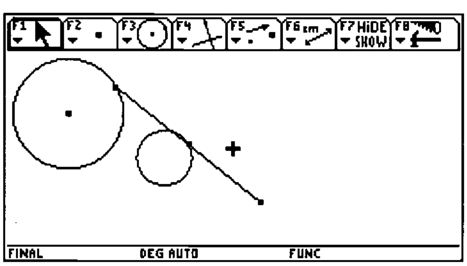

Figure 1: Construction for the Midpoints Problem

Evaluation and Conclusions

Each student completed an evaluation at the end of the course. The overall evaluation (Tab. 1) of the course was positive with 100% of the students indicating they believed the course should be offered again with little or no modification. Relevance of topics to a secondary school curriculum and difficulty of the problems were

ranked lowest on the survey. Increased knowledge of the TI-92 ranked highest. Students had mixed comments regarding the use of the technology. While they thought they had learned a great deal about the TI-92 and how they might use it for instruction, they were not confident that they would know how to use the technology in their own studies. Student performance on the final evaluation as compared to performance on the first problem set indicated that the students had improved their problem solving skills and had given more thought to using technology when formulating methods to solve problems. An informal discussion with 5 of the students approximately 15 months later indicated that the students still believed the course had been valuable to them. They stated that the course gave them a better understanding of problem solving and a good background in technology, particularly the TI-92. They had not dramatically increased their use of technology in the classroom because of the course.

MAT 595 Evaluation Summary	
On a scale of 1 to 5, rate the following statements with 1 *never*, 2 *hardly ever*, 3 *sometimes*, 4 *most times*, 5 *always* (for the lettered statements use: 1 *disagree*, 3 *neutral*, 5 *agree*).	
Average	**Question**
3.64	1. The material covered will be of value to me outside this class.
3.00	7. The problems were too difficult.
4.36	A. I would recommend this course to colleagues.
3.91	B. I feel comfortable using the TI-92 to assist in studying mathematics.
4.36	E. I gained a greater understanding of how I might use the technology outside this class.
4.45	G. My knowledge of the TI-92 has improved significantly
Do you think we should offer this course again?	
Frequency	**Response**
0	NO
0	Only with major revision
3	With minor revision
8	YES

Table 1: Excerpts from the course Evaluation Summary

The results on the course evaluation indicate that the students found the course valuable. They also indicated that they felt more confident with their ability to solve problems and to use the technology. The confusion about using technology beyond the problem seminar indicates a need to address that topic more directly in subsequent offerings of the course. The problems chosen for the course will also be reviewed, and problems more directly related to secondary school topics may be added to the problem list. Finally, a comprehensive plan for assessing the course will be developed and implemented.

Appendix: The Chinese Remainder Theorem

Theorem (The Chinese Remainder Theorem) Let $m_1, m_2, \ldots, m_r$ be pairwise relatively prime positive integers. Then for any a_i in $\mathbf{Z}$, the system

$$\begin{aligned} x &= a_1 \pmod{m_1} \\ x &= a_2 \pmod{m_2} \\ &\vdots \\ x &= a_r \pmod{m_r} \end{aligned}$$

has a solution. Any two solutions of the system are congruent modulo $m_1 m_2 \ldots m_r$.

The solution to the problem of a sequence of r consecutive positive integers none of which are square-free is provided by the solution to the system of equations

$$
\begin{aligned}
x &= 0 \pmod 4)\\
x &= -1 \pmod 9)\\
x &= -2 \pmod{25}\\
&\vdots\\
x &= -(r-1) \pmod{p_r^2}.
\end{aligned}
$$

Student Gary Yeager wrote a TI-Basic program, "cnonsqfr.92p," for the TI-92 that uses this method of solution to generate the sequences. The program is available in the Graph-TI archives at ftp://ftp.ti.com/pub/graph-ti/calc-apps/92plus/math/.

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FCell3D: A Central Example to Visualize Safety Critical Processes in the Construction and Control of Distributed Applications

Hans-F. Kötter
Department of Data Processing
FernUniversität Hagen
Germany
Hans-Friedrich.Koetter@FernUni-Hagen.de

Norbert Völker
Department of Computer Science
University of Essex
United Kingdom
NVoelker@Essex.ac.uk

Abstract: This paper reports on the design and implementation of a case study for the step-by-step development of distributed, safety critical control programs. The case study is a key ingredient in a new distance learning course for graduate students at the Electrical Engineering Department of the FernUniversitaet. It is implemented completely in VRML and Java and serves as a running, interactive example in our course. Via a variety of interfaces, students can model the control components and implement them in suitable programming languages.

Introduction

In recent years, the number of software control systems in safety-related applications has grown rapidly. A fault in such a system can lead to dangerous failures such as fatal accidents or serious damage to the environment. Erroneous assumptions and insufficient foresight during requirements analysis and design are known to be major causes of software faults. The hazards of safety critical systems oblige the developer to document the safety requirements precisely and to heed them during the entire development process.

In these and similar industrial application fields, engineers are traditionally employed. They are normally very familiar with application phenomena and proficient in techniques of component and process control as well as electronic communication. However, they often lack a sound software-specific training.

At the Electrical Engineering Department of the FernUniversitaet Hagen, this has led B. J. Krämer (see Krämer 97, Krämer 98), who holds the chair of Data Processing, to develop a new distance learning course on software engineering for distributed systems. The course is concerned with three characteristic features of computer based process control applications: reactivity, distribution and safety. Since the functional safety of the plants depends significantly on the correctness of the software, the use of formal methods is favored during development.

Our course is offered both in the traditional, written form as well as via the Internet. As a running example, it features a simple production cell whose electro-mechanical components are monitored and controlled by distributed programs. The task of the students is to formulate the requirements of the system and to design and implement the programs which govern the collaboration of the components. Since students in a distance teaching course have little access to real lab equipment, a visualization of the production cell is provided. This virtual control application allows students to experiment with different designs and to obtain feedback on erronous implementations.

The paper describes the design and implementation of a 3D visualization of the production cell using Java and VRML. The following section introduces the virtual manufacturing cell. Functional and architectural requirements of the visualization and the resulting design decisions are described in Section 3. Section 4 deals with the implementation stage, while the following sections report briefly on extensions of the system and the evaluation by students. Finally, the last section presents our conclusions and an outlook for future developments.

Concept and Structure of FCell3D

The manufacturing cell, called FCell3D, originates from a case study which compares the strengths and weaknesses of several formal methods for reactive systems (Lewerenz & Lindner 1994). In order to emphasize certain phenomena of distributed systems, we modified it into an open system. The FCell represents a simple industrial production line which processes individual blanks. It contains typical assembly line devices: two conveyer belts, a rotary table, a robot and a press. The blanks are inserted asynchronously from the environment of the cell onto a conveyor belt. The belt conveys these blanks to a rotary table at the belt's other end. Once a blank has landed on the table, the table moves up and rotates slightly so as to bring the blank into a position from where it can be picked up by the robot's first arm. After that arm is loaded, the robot rotates counter-clockwise into a position where the arm points towards the press. Then the robot deposits the blank into the press where it is forged until the press opens again.

In order to use the press optimally, the robot is equipped with a second arm. This arm picks up the parts forged in the press. Thereafter, the robot rotates counter-clockwise until the second arm points towards the deposit belt where the forged piece of metal is dropped. The deposit belt transports the processed parts from the loading area towards a gadget in the environment where they are removed. The two robot arms are mounted on different vertical levels and access the press while its movable cheek is on the corresponding vertical level. The arms can operate their grippers independently. They can also be extended or retracted in the horizontal direction independently, but must always rotate together as they are fixed on the robot's body. The load and unload zones of the conveyer belts are monitored by photo-cells, while switches and other types of sensors signal the horizontal or vertical position of robot arms, rotating table, and press cheek.

The simulation of this production cell was designed to allow for different implementations of press control. Particularly crucial situations, such as the violation of safety requirements, should be clearly recognizable. A purely 2-dimensional birds-eye model has the disadvantage that the upward movements of parts of the production cell are invisible. As a consequence, there would be no visible events corresponding directly to certain warnings or error messages during operation. For the distance learning course, we have therefore decided on a 3-dimensional visualization of the production cell (Fig. 1).

Requirements for the architecture and functionality of FCell3D

The manufacturing cell serves as a running example in our course. It illustrates many different issues related to the software engineering of distributed control systems. This includes such diverse tasks as the formulation of functional and safety requirements, the splitting of functionality into components, and the implementation of individual components.

Due to these requirements, the architecture of Fcell3D consists of three parts. The presentation module yields a 3D-visualization of the production cell and allows a faithful representation of the positions and movements of all mobile cell components. Component interfaces provide control and state information for each component of the production cell. These interfaces link the presentation module with the control part. The control module connects the component interfaces with a control which governs the behavior of the components. Control can be either manual or it can be a control program written by a student. The control module is event-based and does not rely on specific data types. This makes it possible to control the virtual production cell not only from a conventional programming language but also from executable specification formalisms such as Petri Nets or LOTOS.

Implementation of the System

The realization of FCell3D was determined by a number of requirements which are in part specific to distance education. Unlike students of classical universities, students of a Distance-Teaching-University do not normally have access to a software lab which contains designated hard- or software. Because of the heterogeneity of computers accessible to students, platform-independence is of paramount importance. This allows students to

run the FCell on different machines. Running the FCell should not require special software licenses. Instead, all necessary software should be free and widely available. The FCell software itself must be easily accessible to students. In addition to a distribution by CD-ROM, downloading from a server should be feasible. Furthermore, it should be possible to upload assignment solutions for processing on departmental servers. This allows the use of software subject to license restrictions or, for some other reason, not widely available. These requirements will be summarized under the notion of "network capability".

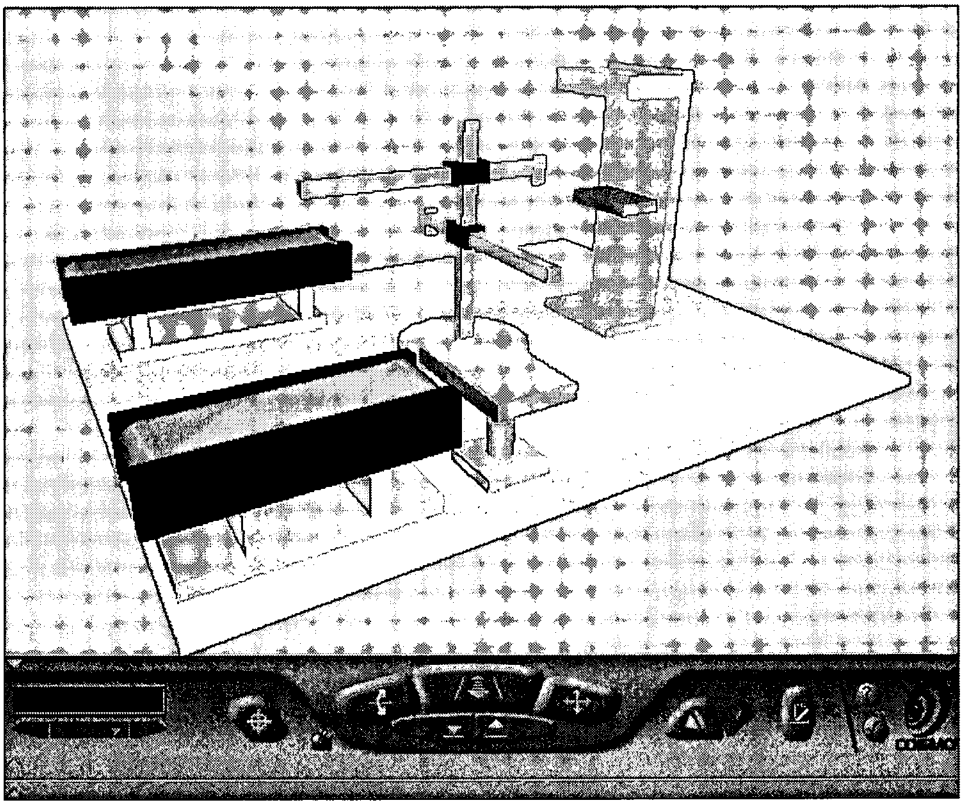

Figure 1: The Virtual Production Cell in the Cosmo Player environment.

The above-mentioned demands on the implementation of the production cell make Java an obvious choice as the implementation language (Flanagan 1998). Platform independence, network capability and broad availability are the characteristic features which have made Java so popular. Furthermore, Java offers a strong thread concept for implementation of concurrent processes and remote method invocation (RMI) for distributed programming. This corresponds to the concurrency processing in the production cell and allows a realistic simulation of industrial control processes.

The Java implementation of the FCell system reflects both the underlying architecture and the intended purpose of simulation. Each component of the model is implemented as a separate base class. These base classes implement the control logic of the components and abstract from the visualization. For each independent movement a base class uses one thread; for example the robot has separate threads for the horizontal movement of each arm as well as one thread for the control of the rotary motion. The specialized classes for each component are derived from the base classes. They implement low-level-routines for the visualization. A class BasicFCell3D instantiates the specialized classes and initializes the 3D-visualization. A main class FCell3D, derived from BasicFCell3D, exports the user interfaces. These allow selection of components. They can be invoked either from the control panel or a control program. Unlike the methods associated with the individual components, the user interface methods take the cooperation of components into account. For example, they produce warning messages if safety requirement violations occur. If required, the system can ignore events which lead to safety violations or

shut down the simulation with an error message. A virtual control panel provides manual control of the FCell3D components (Fig. 2). It is also implemented in Java.

As explained above, the implementation of the FCell visualization should support a 3-dimensional representation and be as platform independent as possible. For several reasons, we decided on VRML (Vacca 1996). VRML, the Virtual Reality Modelling Language, is a language standardized by the ISO/IEC 97 for the description of 3-dimensional scenarios. It allows the manipulation of objects in 3D space. It has the advantage of being both platform independent and manufacturer independent because major companies involved in 3D computer graphics (e.g. Sun Micro Systems, Silicon Graphics, IBM) have participated in its development. VRML is widely used in medical systems, mechanical engineering, military engineering, education, and other application domains. There are also commercial and cultural applications such as virtual markets, virtual museums and art galleries.

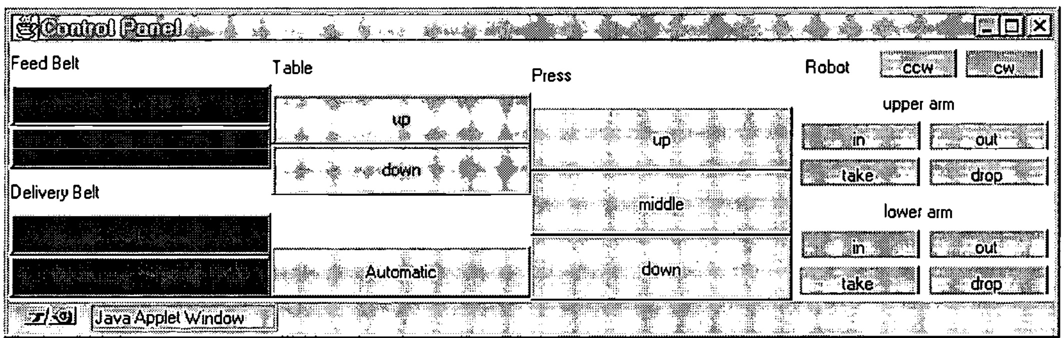

Figure 2: The Control Panel

For VRML, there are 3D editors and development tools which make it relatively easy to produce virtual scenes. The results are immediately available for inspection thus leading to a short developmental cycle. VRML worlds can be viewed using recent versions of the most popular browsers. This provides users with a familiar tool for viewing VRML.

Initially, we did not have the option to use Java3D as visualization language. At that time, Java3D was still in the specification and development phase while VRML was already standardized by the ISO. A visualization of another production cell in Java3D is currently being developed by an graduate student. This work should clarify how the use of Java 3D would have affected the development process and the final system. By means of a concrete example, it will shed light on the advantages and disadvantages of Java3D compared to VRML.

While VRML offers all mechanisms necessary for simple animations, it does not have all the functionality required for complex animations such as status information or non-linear interpolation. To prevent the extension of VRML to a programming language, VRML offers interfaces to existing programming languages in the form of Script nodes. These allow events to be exchanged between VRML objects and other programs. This can comprise both user events such as pointing to an object as well as events generated by other Script nodes.

An alternative to the use of Script nodes is the External Authoring Interface or in short EAI as proposed by Silicon Graphics. Instead of building a new product for the VRML visualization, it merely creates a standard for accessing Java from VRML. Above all, this has the advantage that available Java applications do not need to be reimplemented and that existing software can still be used.

The EAI is a browser interface for Java applets. It defines how a VRML browser and its contents can be manipulated by an Applet which is embedded in the same HTML page. The applet can send messages (events) to the browser or send requests for status messages from the browser, load new VRML files into the browser, and add or delete nodes in the 3D world. In contrast to Script nodes, the EAI offers general methods of accessing nodes and event structures from outside the VRML browser. While the definitions of a Script node consist of predefined fields and events, events and fields in EAI can be used and affected on a dynamic basis. We use the EAI to control FCell3D via the control panel (Fig. 1, Fig. 2). A disadvantage is that an EAI-conformant VRML browser is required. These browsers are not yet available for all platforms. Furthermore, it is not yet possible to implement a stand-alone application because no robust VRML viewers exist which both support EAI and can interpret Java code.

At the time of writing, EAI-conform browsers and/or PlugIns for Windows95, Windows NT, IRIX and MacOS are offered by companies like Intervista and CosmoSoftware.

Extensions

Our remote learning software engineering course also contains a section on middleware. In particular, it provides an introduction to CORBA (Common Object Request Broker Architecture) which is quickly becoming an important standard for industrial control applications. CORBA interfaces for FCell3D make exercises in middleware technology possible. To this end, the components of the production cell are divided into clients and servers, and we offer the stub and skeleton code on our departmental server. Students implement control programs based on prewritten functional stubs. By uploading these programs on our server, the students' work can be automatically validated. In case of syntactic failures, the code is directly rejected. Otherwise, the students' programs are stored on the server. The animation of the FCell3D, as controled by these programs, is made accessible to the student via a dedicated URL transmitted by email. If a safety exception occurs, visualization stops and the effect of the fault is shown. The student can then remedy the problem and repeat the simulation. This provides a concrete and illustrative introduction to programming with CORBA.

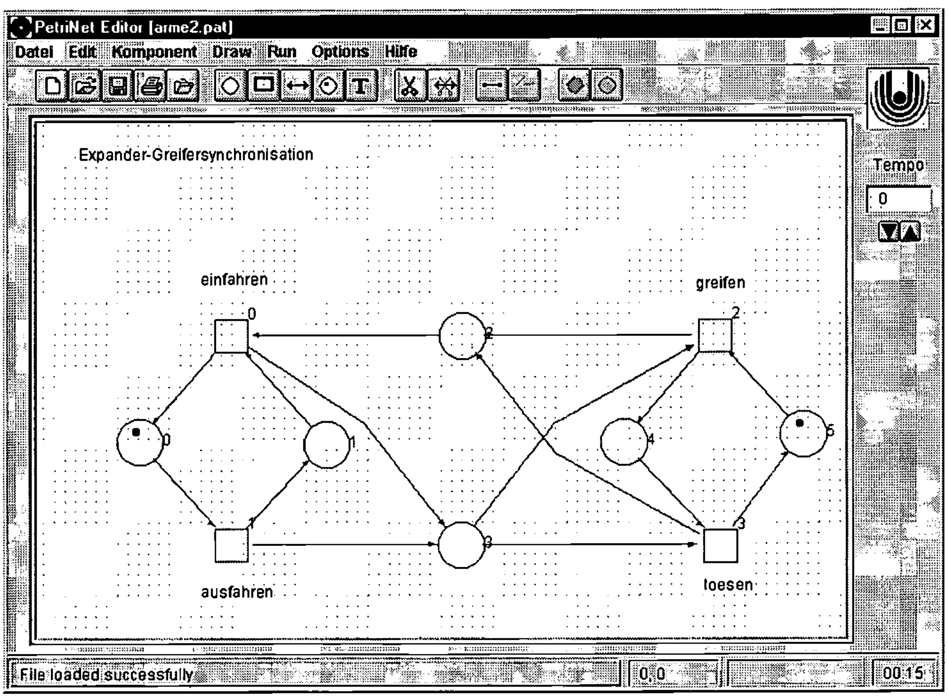

Figure 3: Screenshot of the Petri Net Editor

Evaluation

It is important that applications such as the FCell3D are evaluated externally. In our case, the most important evaluation criteria are compliance with general software-ergonomic standards such as user friendliness, robustness and a clear organization of the user interfaces.

The system was initially evaluated by system departmental staff not involved in the development of FCell3D. A crucial second step is user evaluation by the students.

BEST COPY AVAILABLE

In order to obtain sufficient feedback, we set assignments which require different versions of the virtual production cell. These are offered on the WorldWideWeb or copied onto CD-ROM. Furthermore, we organize annual study days on "Software Engineering of Distributed Systems". As part of this program, the students work with FCell3D in order to find mistakes in prepared control programs and to demonstrate their own control programs.

In summary, the feedback which we received through email and study days can be rated as positive. Most students reported that they had a lot of fun while working with the FCell3D system. We also received some constructive criticism for improving certain aspects of the virtual production cell such as adding sound effects. Altogether, the students who worked with FCell3D agreed that the production cell visualization was helpful for understanding problems occuring in the design of distributed control systems.

Conclusion and Outlook

Engineers traditionally entrusted with the development of software based control systems often have inadequate software training concerning the problems of safety-critical distributed control applications. At our department, we have developed a software engineering course specifically tailored to this student group. In this distance learning course, a simple production cell is used as a running case study. In order to visualize the behaviour of processes, a 3D representation of the production cell has been developed. Because this visualization should not only clarify control functions and safety requirements but should also be used as a base for the students' exercises, a three-part architecture was chosen. This consists of the 3D presentation tier, the functional user interfaces and the control level. On account of the required platform independence and Internet capability, we decided on Java and VRML as implementation languages for the visualization of the production cell. The main criteria underlying our design decisions and some of our experiences with the implementation have been described above.

In connection with this case study, we have also developed a Petri Net (see Reisig 1985) tool in Java. The aim of this tool is to enable students to study the analysis and mathematical exact modeling of concurrent processes. Processes can be input in textual form or with the help of a graphical Petri Net editor. They can then be analyzed using standard methods such as reachability analysis. The Petri Net tool will be interfaced with the visualization level of the virtual production cell. More precisely, firing of transitions in the Petri Net will be synchronized with the corresponding operations of the control tier of the visualization system. Thus, the execution of Petri Nets written by the students will be accompanied by a corresponding 3D animation. Through the visual feedback and the stimulation for experimentation, we expect to achieve a high learning effect.

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B.J. Krämer has adapted the production cell case study for his course on software engineering for distributed systems. He is also the initiator of the visualization tool and has provided constructive criticism for this paper. Further the authors would like to thank J. Völker for her support.

HIPPODAMUS: A WWW Based Expanded Learning Environment

Georgios Kouroupetroglou, Constantinos Viglas, Alejandro Pino
koupe@di.uoa.gr, cviglas@di.uoa.gr, grad0152@di.uoa.gr
National and Kapodistrian University of Athens, Department of Informatics,
Laboratory of Speech Communication, GR-15342, Athens, Greece

Despina Deligiorgi and Ioannis Kalogiros
despo@cc.uoa.gr, jkalog@dap.uoa.gr
National and Kapodistrian University of Athens, Department of Physics,
Laboratory of Environmental Physics, GR-15342, Athens, Greece

Abstract: This paper discusses the theoretical model, the design, and the implementation of a learning web entitled HIPPODAMUS, namely a cluster of interactive networks of persons and technological networks which harmonically collaborate with the aim to perform effective learning. The technological networks include the equipment for supporting the studies of the students (e.g. specific measuring instruments or networks of sensors) as well as the technology for supporting the learning process (such as computer systems and networks and especially the Internet). HIPPODAMUS constitutes an expanded learning environment that incorporates extensive use of the Internet and its services, effectively promoting the active participation of all the partners involved in the educational process, namely of students, teachers, academic / research community and the administration of the education. This web is based upon the use of information and communication systems built for the World Wide Web, and it constitutes the application of an experimental educational framework on subjects such as Informatics, Technology and Environmental Education. HIPPODAMUS ties with the current trends and requirements, concerning the joined preparation of high-school students towards the Information Society, the Learning Society and the Environment-aware Society.

Introduction

During the last years, the educational community has faced the boom in computer science and communication networks with special emphasis on the Internet. This has led to significant evolvement in software dedicated to educational process support systems (Edwing et al. 1999). At the same time, a considerably easier access to information sources is available (Gilliver et al. 1998). The design of a modern educational system is based on appropriate support systems for both the teacher and the student, which facilitate the access to information (Astreitner et al. 1998), such as databases, electronic dictionaries and online educational aids (Kraus 1995) (Metaxaki et al. 1999). In this context, the basic constituents of an efficient learning system for science education are:

- Accessibility to sources of raw and processed scientific information.
- Use of unified and interconnected educational content and open architecture for the presentation and analysis of scientific phenomena as well as their computation and assessment.
- Development of innovative learning techniques, computational methods and supplementary educational content as well as their integration in the unified and interconnected educational infrastructure.

Furthermore, we are interested in the general aims of an efficient educational system, such as:

- Redefinition of the teacher's role, with their participation in the design and practice of innovative educational methods.
- Update of school knowledge and didactic content.
- Improvement of the educational results.
- Setting higher standards in didactics on scientific and technical matters.
- Student's social sensitization through the introduction of novel pedagogic practices, the application of interdisciplinary scientific methods and the use of new technologies in education.
- Broadening of school's social role and involvement in local society's activities.
- Environmental sensitization.

Theoretical Model

The contemporary trends for an effective educational system demand the development of new educational methods, where the *student becomes active participant and creator*, and the development of an efficient communication way between the different and heterogeneous groups that participate in these new learning processes.

Based on the above principles, in this paper we present the design and implementation of an innovative educational approach, which is reliant on the *Learning Web* model (Kouroupetroglou et al. 1996), namely a cluster of interactive networks of persons which harmonically collaborate through appropriate technological networks, with the aim to perform effective learning.

We define the *learning environment* as a system that involves:

- The students that, with the help from their teachers, study the real world in terms of local and global problems, through appropriate learning activities.
- The technological equipment for the supporting the educational studies (e.g. specific measurement instruments).
- The technological equipment which supports the learning process (e.g. computer systems and networks, the Internet).

A learning environment should be able to collaborate with other learning environments in national and international level. In that case we refer to *interactive* learning environments.

The *expanded* learning environment involves not only the users (students – teachers) but also the persons who maintain, support and improve the system, either scientifically or technologically. Therefore it is a cluster of networks of persons and technological networks.

The structure of the Learning Web model (i.e. the expanded learning environment defined above) must be open and must support the integration – incorporation of heterogeneous subsystems. The Internet can be the basic communication medium between the *interactive* learning environments as well as the basic source of educational content.

Design

The application of the Learning Web model we have developed in the domain of the *environmental education* was named HIPPODAMUS [1]. The experimental application is based on the construction of a network of automatic weather stations for the measurement of atmospheric parameters at the school location, and the creation of a centralized database related to these measurements. Using World Wide Web communication means, we developed a methodology for the acquisition, retrieval and didactic presentation of the raw data and metadata so that the student understands the natural meaning, interaction and influence of atmospheric measurements.

The general objectives of HIPPODAMUS learning environment are:

- Development of new teaching and learning capabilities through:
  - ✓ Search for knowledge in multiple sources (with emphasis to electronic sources).
  - ✓ Active student participation in learning process.
  - ✓ Active student participation in real measurements analysis.
  - ✓ Students cooperation in the class and between different schools.
  - ✓ Electronic communication between students from different schools, but also between students and scientists and experts.
  - ✓ New methods of educational content distribution to the teachers.
  - ✓ Increased (electronic) communication between teachers and scientists or experts either in the field of education or administration and design.
  - ✓ Creation of an electronic forum for the teachers to cooperate and exchange experiences and educational content.
- Systematic introduction in the curriculum of secondary schools of a course involving Informatics, Technology and Environmental Education with an interdisciplinary approach.
- Obtainment of real experience on informatics and Internet's applications and services.
- Interconnection of scientific and local society with the educational process, and reinforcements of the school's bonds with the local society.

According to HIPPODAMUS system's design, the participants (students, teachers and scientists/experts) accomplish the following activities:

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[1] HIPPODAMUS *Pronunciation:* [hipod'*umus*] 5th cent. B.C., Greek architect, b. Miletus. He was the first to plan cities according to geometric layouts. For Pericles he remodeled Piraeus (the port of Athens). He also planned (408) the city of Rhodes and went with the Athenian colonists to replan (c.440) the new city of Thurii in Italy. Other cities of the ancient world followed his methods.

Students: take measurements of atmospheric parameters at their school's area using the automatic weather stations and share these data with other students and scientists via the Internet. Through specific learning activities they study the weather, and try to explain the phenomena that they observe in the atmosphere. They relate their observations with local environmental problems and compare them with the data at other locations. The continuous and broad measurements give the opportunity to the student to comprehend useful terms such as the mean value, the standard deviation, the correlation, etc. Students communicate through the Internet with scientists to learn about weather, environmental and atmospheric matters, and they use the capabilities of computer systems and the Internet for a variety of different applications. Finally, they participate in the evaluation of the system.

Teachers: guide students to acquire measurements and to use the computer systems and the Internet. They help students to understand the meaning of the measurements and explain the importance of data visualization. They also communicate through the Internet with scientists and colleagues to discuss atmospheric and weather matters. Finally, they use the capabilities of the technical equipment for a variety of different applications and they participate in the evaluation of the program.

Scientists: and *experts* develop the educational content for teachers and students as well as the software for visualization and analysis of the data for the students. They develop and maintain WWW pages for the project, train the teachers and support teachers and students through e-mail, chat sessions, web-conferences, etc. They finally participate in the evaluation of the program.

Scientists: Educators of Design and Administration participate in the design of the educational process, and carry the responsibility of selecting which schools will participate in the program. They facilitate the realization of the program and have constant communication with scientist and experts. They also participate in the evaluation of the program.

Implementation

The Learning Web of HIPPODAMUS is based on schools interconnection through the Internet, the systematic conducting of atmospheric measurements with a weather station and the exploitation of these measurements in learning processes. For its implementation, the *necessary equipment*, the *appropriate software* and *educational content*, the *teachers training*, the *experimental application in the classroom*, the *technical and scientific support* of the schools and the *evaluation* of the educational system, have all been researched, designed and developed.

The computer and communication system of HIPPODAMUS (Fig. 1) virtually serves three target groups: *students*, *teachers* and *scientists*. It provides the following services:

- Input and storage in a central database of the measurements that schools collect from automatic weather stations.
- Access and distribution of the data in order to analyze and compare.
- Data and metadata visualization.
- Student communication with other schools and experts.
- Educational content distribution.
- Discussion and opinion exchange between teachers.
- Presentation of the program on the World Wide Web.
- Technical support on computer, technology and environmental matters.

In HIPPODAMUS framework, acquisitions of various measurements of atmospheric parameters take place. We want to store these data keeping information about their time and location. Furthermore these measurements have to be exploited for the creation of graphical representations, which will be available on the World Wide Web. The Web will also be the interface for the access to the data and the requests for data visualization. These characteristics lead to the construction of a Database, which meets the specifications (Date 1996), and of a corresponding Database Management System with Web publishing and access capabilities.

The system was designed in such a way that it wasn't necessary to store any graphics in the database. All the data visualization is dynamic and created in real time. The Database is located at the Application Server, where all applications developed for HIPPODAMUS run. There is also a different machine, which is a Web Server, in constant and high-speed network communication with the Application Server. The cooperation of these two servers makes possible both updating and querying the Database.

The parameters that the weather station measures include mean hourly values of temperature, humidity, atmospheric pressure, rain, wind speed and wind direction. Student's presence is not required during the weather station's measurements, but they make observations on clouds (cloud type and coverage). The parameters above are fundamental for the weather prognosis and climate determination and give important information about the atmosphere.

HIPPODAMUS include a series of manuals and educational content that has been developed during the implementation of the program (Hippodamus 1999). These provide to the participants the means to understand the operation of the system and perform the learning activities. They are all available online through the WWW. Learning activities include Database updating. Students perform the update in two ways, so that they can gain broader experience in computer systems and communications.

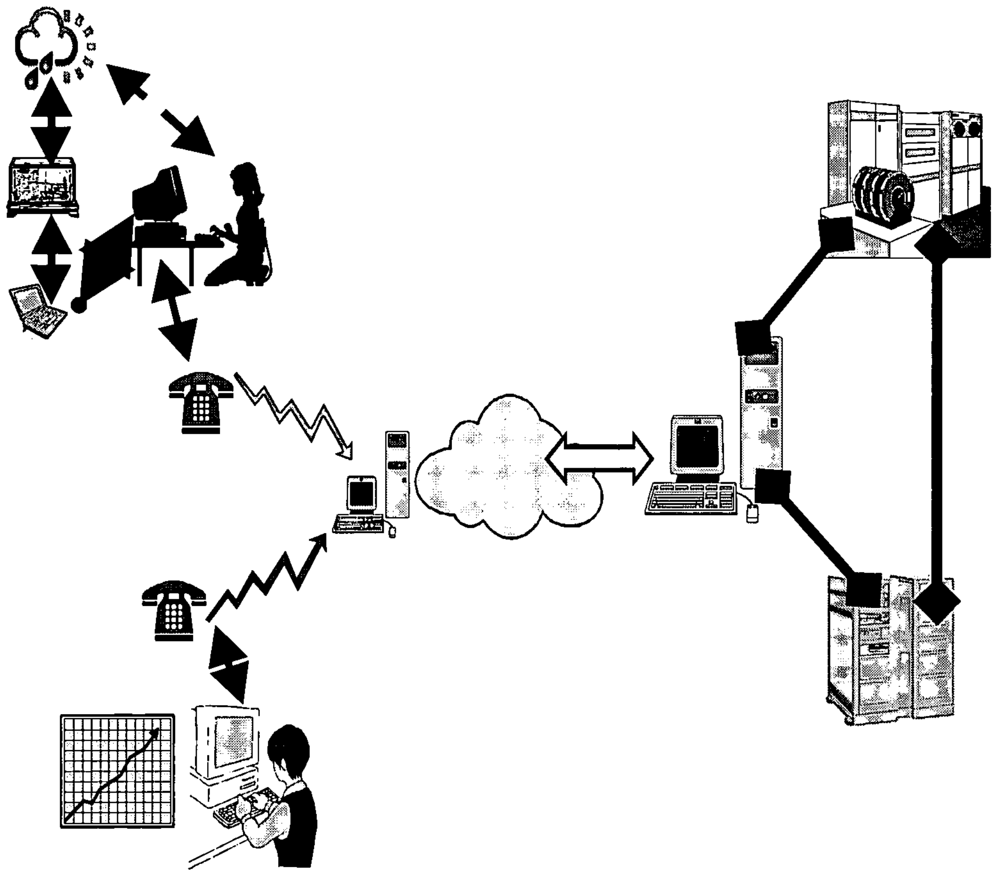

Figure 1. The computer and communication system of HIPPODAMUS

First, all measurements acquired from the Automatic Weather Station are downloaded locally on the student's computer (which is connected to the Weather Station through the serial port). Using the Weather Station's software, students can view, analyze and make chart of their own downloaded data. They are also able to export all or part of their data in an ASCII file, which they send to the Application Server using a simple FTP application. This application has also been developed especially for the needs of HIPPODAMUS. From this point the Application Server takes over and updates automatically the Database with the new data.

Second, as far as the cloud data are concerned, the update process is manual. Using a special Web page, students insert dates and values (cloud types and sky coverage percentages) of observations in a form and submit it to the Web Server. The Web Server updates the Database with these values and dates and responds with an acknowledgment. Both ways of Database Update are Password protected.

Learning activities focus on exploitation of the measurements contained in the central database. We give emphasis on creating and studying time series in order to draw out useful conclusions that help in theory comprehension. We use charts of the measured parameters, which, without implicating obscure mathematics equations, they explicitly show the qualitative behavior of the atmospheric parameters. These charts are available on the Internet, dynamically generated online and in real time by a Dynamic Web Application (Fournier 1999) that run on the Web Server using Active Server Pages (ASP) technology (Johnson et al. 1997).

The WWW pages of HIPPODAMUS are virtually the user interface for accessing the database system. Users submit a wide variety of queries in appropriate forms on the Web and receive charts as answers. Students are using their Internet browser to retrieve the charts, which help them to analyze their data, combine them or compare them with other schools data. The server is able to create in real time charts combining data from multiple schools, multiple parameters, simple or multiple time series, histograms and correlation diagrams, depending on the specific queries that it receives (see Table 1). These charts are published on the WWW, in HTML pages, which are constructed automatically at that time, and received by the user who submitted the query. A variety of prepared learning activities, require students to acquire these charts from the Internet and study them extracting useful conclusions.

Data Visualization		
Time Series (Charts)	One Station Data	Hour Variations
		Day Variations
		Month Variations
		"Average Day" Variations
	Multiple Stations Data	Hour Variations
		Day Variations
		Month Variations
Correlation Diagrams	One Station Data	
	Multiple Stations Data	
Histograms	Percentage Distributions	
Tables	Data Tables for any data, any stations	
	Degree Days	

Table 1. Chart and diagram creating capabilities of the HIPPODAMUS' visualization engine

The Visualization Engine requires the user's (student's) active participation, and is described in more detail:
Using the Internet browser interface, the user makes a query to the Database in order to acquire and visualize specific data according to the selections he made. In most cases he has to choose specific dates or periods, stations, and weather parameters in an HTML form. This query is submitted to the Web Server by clicking a button on the query HTML page. As soon as the query is received, the Web Server processes it, formats it and submits it to the Application Server. There, a Microsoft Office Application receives the query, retrieves the data from a Microsoft Access Database and returns them to Excel for further process. In Microsoft Excel all necessary calculations take place, and a chart is created. This chart is published in a new HTML page with other information needed for the answer to be complete. The HTML page is then returned to the Web Server and presented as a respond in the user's Internet browser. At this point, users can save their results in their local hard disk or print them. All this process never lasts more than a three or four seconds.
For the implementation of HIPPODAMUS we used the following tools: Microsoft Visual Basic 6.0, Microsoft Office 97 VBA, Microsoft Access 97, Microsoft Excel 97, Windows NT Server 4.0 (SP 5), Internet Information Server 2.0, Active Server Pages, Webclasses. The servers are PCs with Pentium III 450 MHz, 256 MB RAM, and 13 GB Hard Disks.
HIPPODAMUS system keeps up with the current trends and needs for the preparation of students for the Information Society, the Learning Society, and the Environmentally Sensitive Society, in local and global level.
The HIPPODAMUS project's experimental operation and evaluation is already in progress with the participation of a number of Greek Secondary Schools spread out over the country. The home page URL of the project is www.di.uoa.gr/ippodamos and the e-mail address ippodamos@di.uoa.gr

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Teaching Functional Programming for High School Students

Tami Lapidot, Dalit Levy, Tamar Paz
"Migvan" - Research and Development in Computer-Science Education
Department of Education in Science and Technology
Technion - Israel Institute of Technology, Haifa 32000
Israel
lapidot@tx.technion.ac.il

Abstract: Functional programming includes complex concepts and advanced ideas such as building abstractions with functions, compound data and list processing. As part of a new computer science curriculum for high school students in Israel, we developed a functional programming course, using DrScheme environment [1], based on recent research in science education that emphasizes the constructivist nature of learning. This paper deals with some preliminary findings from our field research and discusses some of the successes and difficulties of the high school students who took part in the course.

Introduction

Functional Programming (FP) is one of the main computing paradigms presented to computer science students. It includes complex concepts and advanced ideas such as building abstractions with functions, compound data and list processing. Teaching these FP issues to high school students gave us an opportunity to rethink our beliefs about computer science education, functional programming courses, and their implementations in schools.

As part of a new computer science curriculum for high schools in Israel, we chose to develop a functional programming course. Inspired by excellent sources (for example, Abelson, Sussman & Sussman 1985; Eisenberg & Abelson 1988; Felleisen et al. 1998; Ferguson et al. 1995; Friedman & Felleisen 1996; Harvey & Wright 1993) we looked for our unique recipe that will meet the following requirements:

- The Israeli CS curriculum is based on Algorithmics via Pascal;
- Functional programming is learnt after the first module (in grade 10) and in parallel to the second module (in grade 11), both in Pascal;
- This FP module is one of the electives of the "second paradigm" module, intended to introduce a second programming paradigm that is "conceptually different from the procedural approach adopted in the first two modules" (Gal-Ezer, Beeri, Harel & Yehudai 1995);
- Most CS high classes in Israel are heterogeneous with diverse background and students ability;
- The course had to be designed for 90 hours with three weekly lessons of one hour.

Considering the above requirements we were faced with the challenge to bring constructivist ideas into our functional programming course. In this paper, we will give an outline of the course and discuss some preliminary conclusions from our field research.

The functional programming course

Guided by our holistic approach to course development we try to influence the classroom culture as well as develop written materials for the students and the teachers. Within the culture we wish to foster, we try to "create a supportive climate in the classroom, in which students feel safe to explore, make guesses, and learn from their errors" (Leron 1994).

[1] DrScheme was developed by the PLT group at Rice University, Houston, Texas. Further information is available at http://www.cs.rice.edu/CS/PLT/

Our drive to create a constructivist learning environment was influenced by recent research in mathematics and science education (Von Glasersfeld 1995; Smith, diSessa & Roschelle 1993; Ball 1993; Cobb, Yackel & Wood 1992; Pirie & Kieren 1992; Cobb & Steffe 1983). This view guided our decision to introduce most concepts through concrete learning activities, both in the computer laboratory and in regular class settings. These activities combine individual investigations, small-group interactions and whole class discussions.

The course is organized around three periods. In the first period, the students are introduced to the paradigm, the language, and the environment. The second stage is devoted to recursion, while dealing with core concepts like list processing, data abstraction, and higher order functions. The last major part of the course is designed as an integrative phase in which the students work on individual (or group) programming projects. This period serves as a ladder in the spiral structure of knowledge constructing. The students have to review previous concepts, reflect upon their understandings, and face issues such as complexity and abstraction. Let us bring some examples for each period.

First Period: Introduction to Functional Programming

During the first stage of the course, the students learn about the main features of the language and environment. The learning process usually begins with individual laboratory tasks and succeeds by whole class discussions, based on the belief that "we construct our understandings through our experiences" (Confrey 1995). For example, in the laboratory, the students are presented with erroneous expressions, such as in Table 1. They are asked to classify the expressions according to their error types. Later, in class, the teacher can use this experience in order to foster a discussion on the evaluation model.

Expression	Source of error
(+ 3 (rest '(1 2)))	Problematic since (+ 3 (2)) is erroneous
(* 2 five)	Five is undefined (has no value)
((first '(+ - *)) 2 'word)	Unable to evaluate (+ 2 'word)

Table 1 - erroneous expressions

The topics in this period were chosen by their potential contribution to the understanding of the functional paradigm. For example, ordinary assignment was excluded from the first period and from the entire course in order to confront students with a conceptually different approach than the one adopted in Pascal. Obviously, they were equipped with parameters and hence the emphasis turned from imperative global assignments towards the functional flow of control and scoping issues.

At the end of the first period, the students should be familiar with the basic functions and data types (numbers, atoms and lists). They can write simple functions, pass parameters and test data.

Second Period: Recursion

The second period is devoted to recursion and lasts nearly one third of the course. This curricular decision was based on the central role of recursion in computer science in general and in the functional programming paradigm in particular. The construction of a good understanding of recursion is also important for those students who are going to learn software design, where recursion is used extensively and which is the next module in the computer science curriculum. In contrary to the 'laboratory first' principle of the first period, here we reversed the order and the students start with several class activities, aimed to enhance recursive thinking (see also Levy's paper in this proceedings). In one of these activities, the students are presented with recursive descriptions of several objects and try to describe (literally or by drawing) these objects. Figure 1 gives two examples of such tasks. As a supplementary class activity, the students are given objects such as the hourglass in Figure 2 and are asked to give them a recursive definition in their own language.

Task 1:
A tower of level N is build of a rectangle with a smaller tower of level N-1 on top of it. The basic tower in level 1 looks like a rectangle.
Draw a *tower* of level *three.*

Task 2:
A legal word in the 'cat' language starts with C, ends with T, and has a shorter legal word in between. The shortest legal word is CAT.
Give two examples of *legal words* in the 'cat' language.

Figure 1 – From the recursive description to an object

Give a recursive description to the next hourglass.
Hint: try to draw hourglasses of other levels (level 4, level 1 etc.).

```
5 5 5 5 5
 4 4 4 4
  3 3 3
   2 2
    1
   2 2
  3 3 3
 4 4 4 4
5 5 5 5 5
```

Figure 2 – From the object to a recursive description

During the class activities, the students get familiar with concepts like recursive definition, recursive call, and stopping rule. They return to the laboratory and to programming tasks only after a considerable period of experiences with recursive phenomena and recursive definitions. The object in Figure 2 can serve as a good starting point for the recursive programming phase, when the students try to translate their suggested recursive description into a programming language.

However, recursion is not the only issue here. At the same time, students get a chance to learn about list processing, data abstraction, and higher order functions. We allow them to spend enough time with these concepts as a preparation for the third part of the course, where they will have to develop their own programming projects.

Third Period: Projects

In the third and last part of the course, the students integrate their knowledge and understandings while working on a programming project either individually or in collaboration with other students. They can choose their project topic from a variety of options, such as games with a winning heuristics or strategy (tic-tac-toe for

example), or natural language recognition (in the spirit of 'ELIZA'). In order to help them with their decision and developing process, they are presented with examples of full typical projects.

At the end of the third period, students submit their projects according to customary standards. They have to defend their projects in front of an outside examiner and their final matriculation grade in the course is determined by an average of this project and of the sum of all their previous work.

In order to give the reader a feeling of the learning process during the third period, we wish to mention one example. Two boys wanted to build a simulation of a football game as it might have been broadcast in a radio. They decided to allow the user to build his group of players and game tactics. At the same time, the computer, playing as the opponent coach, chose its group and tactics. During the simulation, several game situations are described and the user is allowed to make changes in his group or tactics. The game ends after 90 minutes and the winner team is the one with the maximum number of goals. Although these boys loved football before, working on this project enabled them to become experts in the game. They analyzed the Israeli football league, talked to football coaches, and listened to numerous radio broadcasts. At the same time, they learned a great deal about design and management of a big project, list processing, how to represent and process compound data with abstract data structures, and heuristics modeling. Their learning during the third period of the course was both meaningful and enjoyable.

Preliminary conclusions

After three years of field research in heterogeneous high school classes that learnt the FP course, we can draw some preliminary conclusions. The curricular decisions proved to be effective. Although recursion and list processing are considered difficult to learn (Wu, Dale & Bethel 1998; Roberts 1986 and many others), most students achieved a fair understanding of these subjects as was shown in their programming projects. The strong emphasis on the active nature of students' participation in the learning process enabled students to rethink their conceptions and reconstruct their understandings. These reconstruction processes were evident mainly throughout the third period of the course, while the students were designing and implementing their programming projects.

Thanks to its simplicity, functional programming is often recommended as an appropriate paradigm to start computer science learning. Although we share this belief, our findings show that this simplicity can turn out to be complex for some students who have difficulties to overcome the paradigm changes. Let us examine the next case, taken from the first month of the FP course in 11th grade. The students were presented with the following simple task: Write a function that inputs a list of numbers and returns the sum of its first two numbers. During the laboratory work, the teacher observed two problematic solutions. Alex typed the next expression on his computer: (+ (first (L)) (second (L))). Benny tried another expression: (+ (first (L)) (first (L))) . Obviously, these solutions were wrong and the students spent a long time trying to understand why and how it should be corrected. When asked to explain their solutions, Alex explained, "I have to tell the computer that L is a list and lists have to come in parenthesis". Benny explained "after we used first, the list gets shorter so the second item is

As researchers, we can learn a great deal from these students. We believe that Alex, being in the middle of a conceptual conflict between the functional and the imperative paradigms, was trying to reconstruct Pascal's rules concerning variable declaration in this FP environment. As for Benny, we can assume that he had difficulties with the functional evaluation process and that he was probably also influenced by the imperative paradigm (for more details on this class episodes, see Lapidot, Levy & Paz 1999).

Further research is needed in order to locate the cognitive factors related to such difficulties. Such research can be done by carefully observing and interpreting learning and teaching situations as these naturally happen in the real classroom. The latter refers not just to the research on learning and teaching functional programming but also to the educational research of computer science in general.

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A New Efficient Retrieval Interface for Primary School Students

Chien-I Lee
Graduate Institute for Computers and Education
National Tainan Teachers College, Tainan, Taiwan, R.O.C.
E-mail leeci@ipx.ntntc.edu.tw

Hsin-Hung Chen
Graduate Institute for Computers and Education
National Tainan Teachers College, Tainan, Taiwan, R.O.C.
E-mail chensh@ks.edu.tw

Abstract: Through the Internet, users can conveniently get their desired information. However, in general, it is not quite easy for the users get what they just want though the Internet by using some keywords to do the conventional full-text searching. Most notably, such a searching process will be a heavy load for primary school students who are not able to choose the proper keywords because they are not familiar with the knowledge and semantic words about their desired topic. Therefore, in this paper, we will propose a new retrieval interface for primary school students, called leading-question retrieval interface, which applies a series of questions to inquire and analyze the answers from the users to understand their queried intentions. Such an inquiring process is embodied with the spirit of Construction and can omit the difficult task to choose proper keywords.

Introduction

Background Information for This Study

In recent years, as the fast process of computer and network technologies, computers connected in the Internet will soon become the indispensable electrical appliances of our daily life. Via the Internet, many schools, research institutes, academic associations, museums and the various research centers are making much efforts to provide many valuable and useful information on the World Wide Web (WWW), which currently become a highly interactive and distributed distance education environment for personal learning activities. Through the browser, users can conveniently get their desired data on the WWW. However, with the rapid increase of the amount of data on the WWW, it becomes a urgent challenge for all the Internet learning resource centers to support an efficient information retrieval interface to help users to easily and quickly get their really desired data from the resource centers. Most of them apply the conventional full-text retrieval with keyword-based techniques, which require users to provide some keywords and combine them to form a Boolean expression for information retrieval. However, it is much difficult for most users, especially for primary school students, to choose some proper keywords and construct them with Boolean expressions. Such a task is indeed a heavy burdens for primary school students whose knowledge concept and semantic configuration is still infantile (Zorn, Emanoil, Maarshall, & Panek, 1996; Soloway & Wallace, 1997).

By browsing and searching the useful data on WWW, primary school students can independently act on their own learning activities, but the students have no enough controls over them to manage their own learning activities (Dick, 1991). Consequently, it is very important to properly guide the students in the complicated linked structures of homepages to avoid going astray, and at the same time, also maintain the free-learning activities of students. Therefore, in this paper, we propose a new efficient retrieval interface by using a leading-question strategy to guide the students to the correct searching direction.

Related Researches and Motivations

Related Works in Designing a Retrieval Interface

Bruner (J. Bruner, 1961) advocates that learners should explore knowledge on their own initiative, and discover the structure of every kind of knowledge. The Learning theory of Constructivism supports that knowledge is consisted on the initiative of those individuals with ability of recognition. Thus, we have to offer a really and interactively learning environment. While the learners are exploring new knowledge, they can also adjust their cognitive structure. Furthermore, the role of a teacher should exchange from a knowledge transmitter into a learning promoter (Bagley & Hunter, 1992).

The leading-question teaching is a learning activity in which teachers ask students one question after one, and through those relative questions-asking teachers guide their students from the surface of the question into the deeper point, and let students figure out new knowledge and some universal principles in their own experiences. This method coheres with the basic spirit of the Learning theory in Constructivism. Actually, the theory of Constructivism emphasizes on learning methods those guide students to find by themselves (Guided Discovery Approach) (Yackel, Cobb, Wood & Merkle, 1990).

Moreover, in the conventional full-text searching interface, users have to submit a set of alphabetic strings as keywords, which may be combined with Boolean operators, to form a Boolean expression (Wilkinson & Fuller, 1996). However, it is so difficult for most users to construct such a Boolean expression without being well trained. Ideally, a good information retrieval interface should not only return what the users really want but also help users to easily develop their searching process (Becker & Dwyer, 1994; Hedberg & Harper, 1996; Stoney & Wild, 1998).

Therefore, in this paper, we will apply the leading-question manner to the user interface for information retrieval in order to not only make the users kept with the basic spirit of Constructivism but also help the users to easily get their really desired data.

Hypothesis of This Study

In this paper, we will propose a new retrieval interface called leading-question retrieval interface to help users to construct their real retrieval processes and implement an Internet learning database system with referential connections. Then, we will discuss the four hypotheses as below by taking vertebrates as subject in the following study. Because the vertebrates, such as like cats, dogs, birds, and fishes, are usually seen in the daily life of primary school students. They can arouse students' interests in understanding what they are by searching their related information in the Internet.

1. The primary school students who use the leading-question retrieval interface to retrieve information on line will have better computer attitude than those who use the full-text retrieval interface.
2. The retrieval precision of the retrieved data for the primary school students who use the leading-question retrieval interface will be better than the one for those who use the full-text retrieval interface.
3. The retrieval recall of the retrieved data for the primary school students who use the leading-question retrieval interface will be better than the one for those who use the full-text retrieval interface.

Method for the Study

In this study, we will implement an Internet learning resource with subject of vertebrates in a web server and propose some database techniques to create a retrieval interface with leading-question method to help pupils to get their desired data. There are 4 issues in our method, which are investigative design, investigative object, investigative implement, and experiential procedure.

Investigative Design

We apply the nonequivalent-control group design of quasi-experimental research, dividing randomly those who are going to receive the experiment into two groups to process the information retrieval activity according to the independent variable. To avoid the original computer attitudes of those who receive the experiment to interrupt the dependent variables, we take the results of the pretest of their original computer attitudes as the covariates, applying the method of statistical control to exclude their influences.

Independent Variable

Retrieval interface: We implement two the retrieval interfaces, respectively, which are "the leading-question retrieval interface" and "full-text retrieval interface".

Dependent Variable

1. Computer attitude: The score of the ones who receive the posttest of computer attitude test.
2. Retrieval precision: The retrieval precision means the proportion of correct results, replied by the retrieval system. The method of measure: the retrieval precision = (the amount of correct results in the search) / (the amount of total results in the search).
3. Retrieval recall: The retrieval recall means the proportion of the amount of the correct results in the amount of entire correct results that assume the users retrieval intention, replied by the retrieval system. The method of measure: the retrieval recall = the amount of correct result / the amount of the entire correct result.

Investigative Objects

We regard the six grade students of the primary school as samples for this study. To avoid students' culture background to effect the results of the study, we sample the students from four schools where geographical distance and learning environment are far away from each other, and have many differences. Totally we choose 160 pupils as our experimental sample.

Investigative Implements

Database System

We takes vertebrates as the investigating subject, using relational database (Microsoft SQL Server) and Web server (Microsoft Windows NT Server & Microsoft IIS) to build an Internet learning database system. The following is the general introduction of its major contents and functions:

1. The retrieval system offers both the "leading-question" retrieval interface and the "full-text" retrieval interface.
2. Users can use the leading-question retrieval interface to input their retrieval intentions while answering the questions on the referential interface; they do not have to key any keyword by themselves.
   For each answer of the questions, there will be one or some attributes which are determined. The basic principle of the leading-question retrieval interface is using a set of questions to ask users their answers in order to collect users' retrieval intentions. After knowing users' intentions, the system will check and automatically construct the retrieval condition with the collected attributes related to the answers.
3. The retrieval system offer many sets of leading questions designed by some professionals, users can choose one set of the leading questions by themselves.
4. There could exist a conflict during the question-answer process, where a conflict denotes that two values of answers made by the users are opposite. For example, there are two questionnaires (i, j) $(i < j$, that is, the order of the presentation of questionnaire j are after that of questionnaire i). Suppose in the group of questionnaire i, users select the answer with value "having hair on skin" which is a characteristic only belonging to mammal. Then in the group of questionnaire j, they select the answer with value "having a pair of wing" which is a characteristic only belonging to birds. Obviously, there is a conflict between these two values of answers because there do not exist an animal which is a mammal and is also a bird, such that no retrieved results will be returned. The reason why a conflict occurs is that the users may have wrong judgement on the observation or wrong recognition about the vertebrates. To avoid this conflict to occur, our retrieval system can automatically eliminate such a situation by disabling the conflicting values in the following process of answering, to help users not to make the mistake above.
5. While users are selecting the answers of vertebrate characteristics, this retrieval system will also present the vertebrate category that conforms to the users' demand, and achieve the effect on "learning by doing". For instance, when users select the answer "Having feather covering on the body", then, the system will present the category—Aves-- that conforms to the answer at the same time.

6. After users answer the whole set of questions, or stop answering, the system will start checking according to users' answers, and present a list of retrieved results.

The measure of Computer Attitude

We apply the measure of computer attitude, designed by W. Lin (1994). This measure can be divided into three minor measures: the confidence toward computer, the application of computer in education, and the utilization of computer. There are 24 questions in the whole measure which includes 14 positive questions and 10 negative ones. The interior the interior accordance Cronbach's á coefficient is .81.

The Procedure of Carrying Out the Experiment

The study was done during June in 1999 and the procedure is:

1. Dividing those students whom receives the experiment into 2 groups with random drawing.
2. Letting those students receive the pretest of the measure of computer attitude.
3. Training those students how to use the Internet about 10 minutes, and then starting the information retrieval activity on line about 40 minutes. During the retrieval process, the system will record the retrieval results and calculate the retrieval precision and retrieval recall.
4. Letting those students receive the posttest of the measure of computer attitude.

Results of the Study

The Statistic of Valid Sample

During the process of retrieval activity, we find that some students are not familiar with the control of computer. To avoid affecting the statistic results by those students, we will regard them as invalid samples. After excluding those invalid samples, we have 145 valid samples left. During the pretest and posttest of the measure of computer attitude, some of those students have the tendency of choosing the same scale, or not answering the question completely during the test, they will be also regarded as invalid samples. And excluding those invalid ones, we still have 112 valid samples of the assumptive test of computer attitude presentation.

The Assumptive Test of Computer Attitude Presentation

We take the pretest results of the measure of computer attitude as the covariate. And, we take groups as independent variable, where Groups A uses the leading-question retrieval interface and Groups B uses the full-text retrieval interface, taking the posttest results of the measure of computer attitude as dependent variable. And, we are going to process one way analysis of covariance of independent samples to test investigative Assumption 1 (i.e., the computer attitude of the primary school students who use leading-question retrieval interface to retrieval information will be better than the one of those who use full-text retrieval interface.). Before doing the analysis of covariance, ANCOVA, we have to process the test of homogeneity of within-class regression coefficient (F=1.853, p>.05), not meeting obvious class, conforming to the basic assumption of ANCOVA, then we can go on the step of ANCOVA. From Table 1, we know that the group that use the leading-question retrieval interface has better presentation at the posttest of the measure of computer attitude than the group that use the full-text retrieval interface.

Resource of Change	*SS*	*df*	*MS*	*F*
Retrieval Interface	1462.444	1	1462.444	39.84*
Error	4001.2	109	36.708	

Table 1: Summery of ANCOVA of the Posttest of the Measure of Computer Attitude (*p<.05)

The Assumption Test of the Retrieval Precision

We take the average number of the retrieval precision of Group A that uses the leading-question retrieval interface and the average number of the retrieval precision of Group B that uses the full-text retrieval interface to perform the *t*-test of independent sample in order to test the investigative Assumption 2 (i.e., the retrieval precision of the primary school pupils who use the leading-question retrieval interface to process the information retrieval is better than the one of those who use the full-text retrieval interface.).

From the Table 2, we can find that the retrieval precision of the leading-question retrieval interface is better than that of full-text retrieval interface when the retrieval targets are hard for students to guess their names, such as Formosan Whistling Thrush and Crab-eating Mongoose. However, we get opposite results while the retrieval target is familiar to the students, such as, Asiatic Elephant. The reason is that the students can easily guess some letters or words, which will be a part of the names of the retrieval targets, and submit them to the full-text retrieval interface. Thus, when the retrieval targets are familiar to the users, the retrieval precision of the leading-question retrieval interface is not obviously superior.

The Assumption Test of the Retrieval Recall

We perform the *t*-test of independent sample with the average number of the retrieval recall of Group A and the average number of the retrieval recall of Group B to test the investigative Assumption 3 (i.e., the retrieval recall of the primary school pupils who use the leading-question retrieval interface to process the information retrieval is better than the one of those who use the full-text retrieval interface.).

From the Table 2, due to similar reasons for the retrieval precision, the retrieval recall of the leading-question retrieval interface is better than that of the full-text retrieval interface, especially for those unfamiliar vertebrates. Moreover, since for each target vertebrate, there is only one correct animal in our database, the reciprocal of the retrieval recall can be used to denote the number of searching operation needed to get the correct result as stated before. Therefore, by using the full-text retrieval interface, the number of searching operation needed to get the correct result are usually increased due to wrong-typing of the target animal's name by students. Such a case also becomes a factor in decreasing the retrieval recall by using the full-text retrieval interface, but can be absolutely avoided by using the leading-question retrieval interface.

Retrieval target	Retrieval interface	*t*-test of Retrieval Precision				*t*-test of Retrieval Recall			
		N	Mean	SD	*t*	N	Mean	SD	*t*
Duck-billed Platypus	Leading-question	62	.1383	.2048	.048	62	.6022	.3740	.054
	Full-text	61	.1361	.2826		61	.5982	.4266	
Formosan Blue Magpie	Leading-question	63	.0141	.0441	-.0168	63	.5685	.3828	3.096**
	Full-text	59	.0216	.0327		59	.3522	.3883	
Koala	Leading-question	55	.0288	.0690	-1.185	55	.4270	.4048	-.374
	Full-text	54	.0462	.0836		54	.4559	.4019	
Formosan Whistling Thrush	Leading-question	55	.0315	.0470	4.673**	55	.6447	.3962	7.978**
	Full-text	57	.0018	.0027		57	.1585	.2214	
Red-eared Guenon	Leading-question	54	.1022	.1698	-.318	54	.5427	.4018	1.002
	Full-text	53	.1124	.1616		53	.4613	.4380	
Crab-eating Mongoose	Leading-question	54	.0680	.0706	3.528**	54	.6713	.3860	5.477**
	Full-text	61	.0299	.0386		61	.3053	.3228	
Asiatic Elephant	Leading-question	60	.0137	.0139	-2.364*	60	.5317	.3659	-.164
	Full-text	55	.0880	.2328		55	.5436	.4133	
Black-faced Spoonbill	Leading-question	57	.0264	.0139	-.244	57	.8172	.3256	2.440**
	Full-text	58	.0276	.0335		58	.6499	.4060	
Average of all above	Leading-question	71	.0603	.0745	.526	71	.6196	.2395	5.225**
	Full-text	74	.0544	.0589		74	.4059	.2530	

Table 2: Summery of *t*-test of Retrieval Precision and Retrieval Recall (*$p<.05$, **$p<.01$)

Conclusion

From this study, we find that the computer attitude of primary school students who use the leading-question retrieval interface is obviously better than that of students who use the full-text retrieval interface. The reason could be that most experimental samples, using the full-text retrieval interface, feel puzzled while keying in the retrieval keywords, especially while facing those retrieval targets whose names are unknown or hard to guess. They could also feel frustrated when the system returns the useless results by submitting the wrong keywords again and again. This situation will also affect the positive computer attitude indirectly.

In general, the retrieval precision of leading-question retrieval interface for the primary school students' is obviously better than that of full-text retrieval interface. But it is not always true. The reason is that for some familiar vertebrates, the students have already known the names or easily guess the partial names of the vertebrates. Moreover, on the other hand, for some vertebrates, which outside characteristics are not special or apparent, it is difficult for students to distinguish the differences among these vertebrates such that they would make a wrong choice during the question-asking process. To sum up, the retrieval precision will be promoted by using the leading-question retrieval interface to retrieval the targets that users are not familiar with.

In addition, the retrieval recall of the primary school students who use the leading-question retrieval interface to retrieval information is better than that of those who use the full-text retrieval interface. The reason is that for the unfamiliar retrieval targets, users who use full-text retrieval interface have to guess blindly several times before getting the correct results. They could be frustrated by the wrong keyword they choose and that results in a decrease in the retrieval recall.

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Classification and Discussion of Recursive Phenomena By Computer Science Teachers

Dalit Levy
Department of Education in Science and Technology
Technion - Israel Institute of Technology, Haifa 32000
Israel
dality@tx.technion.ac.il

Abstract: Recursion is a significant concept, appearing in almost every introductory course in computer science (CS). CS educators and educational researchers often refer to difficulties in learning and teaching recursion. However, the research literature barely addresses the unique ways in which students and teachers relate to this interdisciplinary concept and their particular language concerning recursive phenomena. This paper reports on a study in which groups of mathematics and computer science teachers collaboratively classified and discussed several recursive phenomena. The discourse was recorded and analyzed, and a grounded categorical system was formed and examined. Preliminary results indicate some basic aspects of recursion in the discourse, although these teachers apparently talk a slightly different language from that of expert computer scientists. Some 'potentially rich' discourse episodes were evident as well, representing conflicts among alternative conceptions. Such episodes can serve as a springboard for further understanding of recursive phenomena.

Introduction

Recursion is a core concept in computer science, and many agree about its being powerful and significant, yet difficult to learn and understand. Books and papers concern this multi-facetted nature of recursion (Wu, Dale & Bethel 1998; Bhuiyan, Greer & McCalla 1994; Roberts 1986), explain the origins for the difficulties (Troy & Earli 1992; Leron 1988), and suggest methods for teaching recursion (Anderson, Pirolli & Farrel 1988; Harvey 1985; and other sources). The literature, however, has not emphasized the learners' voice or the learning and teaching processes as they show up in a natural setting.

Looking through constructivist lens, one can think of the process of learning recursion as an individual gradual process of meaning construction (Connell 1998; von Glasersfeld 1995). Social-constructivists would also talk about communal processes of meaning construction (Steffe & Gale 1995). In both cases, cognitive acts such as naming, comparing, generalizing, arguing and discussing can be thought of as elements in the overall knowledge construction process. In order to promote such a constructivist learning process of recursion, a classification and discussing learning activity (CDA) has been developed. CDA is designed to expose teachers and students to a variety of recursive phenomena and to encourage the use of classification, generalization and discussion in order to construct and refine the concept of recursion. The research presented in this paper analyzes mathematics and computer science teachers' discourse of recursive phenomena while engaged in a recursion CDA.

The Classification and Discussing Activity

A constructivist belief is that "knowledge is necessarily a product of our own cognitive acts" and that "we construct our understandings through our experiences" (Confrey 1995). A general educational goal that could follow such a belief is to create a learning environment that encourages the development of intuition, reflection, conceptions and ideas. More specifically, the recursion CDA is planned to encourage the use of classification, generalization and reflective discussions in order to construct and refine the concept of recursion. The CDA is suitable for computer science students in various levels of learning, as well as for teachers who try to reconstruct recursion as an interdisciplinary and abstract idea.

The activity begins by presenting different examples of recursive phenomena taken from various sources: pictures, music, literature, newspapers, mathematics and programming. Recursion is widely viewed in this activity as an interdisciplinary concept, rooted in everyday life and experience, and not merely as a programming tool or a CS exclusive idea. The participants classify these instances according to some criteria of their own choosing. There is no 'right' classification, and the participants work in groups and offer several different criteria.

After the initial classification, each group shares its way of categorizing with the rest. The teacher encourages a comparative and reflective discussion and, finally summarizes and offers generalizations and formal terminology for the constructs already mentioned. This discussion exposes the participants to new concepts and to different ideas offered by other groups. This, in turn, encourages the reconsideration of their previous perspective. Throughout the process, the teacher acts as a mediator between the formal meaning and the individual meanings of the participants. The teacher's role is to navigate the discussion toward creating a 'taken-as-shared' meaning for recursion in the class (Cobb, Yackel & Wood 1992).

The Study

The research goal was to document and analyze the discourse of recursive phenomena while participating in a CDA, as a way to look at recursion through the participants' eyes. Such documentation was done in several learning settings. Here I deal with one setting, in which the observed class was composed of five small groups of pre-service and in-service mathematics and computer science teachers. These teachers participated in an academic course as part of their studies (toward a B.Sc. or Ms. degree) in a top Israeli university. The CDA served in this course as an introduction to recursion, although some teachers had already met this topic in other programming or mathematics courses. They were not expert programmers, though, and were not very familiar with the complex nature of recursion. Throughout the activity, the author served as a participant observer and took field notes, while a peer researcher documented the activity with a video camera. The videotapes were then fully transcribed and served as the source for a qualitative inductive analysis. According to this method of analysis, "As you read through your data, certain words, phrases, patterns of behavior, subjects' ways of thinking, and events repeat and stand out... These words and phrases are coding categories" (Bogdan & Biklen 1998 p. 171).

In the first phase of analysis, four different dimensions were recognized in the discourse: (a) levels of consent; (b) levels of abstraction; (c) working strategies; and (d) the content - properties or aspects of recursion each episode demonstrates. Finally, the content dimension was investigated, by writing all the properties of recursion found in each discourse episode (see Table 1) and by gathering and classifying these properties into a primary categorical system.

Episode	Properties of recursion
"This example repeats itself (points to a certain item). It repeats itself like a fractal, these examples repeat themselves. And this. OK? Examples that repeat themselves. 3, 5, 12, 13 (these are numbers of items on the page). You can 11 somehow...though it is not exactly, it is just two (she probably means just two directions). They are fractals... fractal forms."	*Repeats itself* *Fractal*
"and then there are sequential things. Just a minute. There are sequential things. Which is this one (points to one item). Is this sequential? (asks another students) and is this sequential? (points to another item)"	*Sequential*

Table 1: Example of Episode Coding

Results

I would like to begin this section with one finding concerning what was missing in the teachers discourse, namely the property of self-reference. Look, for example, at what Vicki says in the next discourse episode. Vicki is an experienced mathematics teacher in high school: "This is a circle (pointing to one of the items in the page)... a little bit problematic. Like... it's something that is defined by itself, defines itself. But all of them define

The above episode presents the aspect of self-definition, in the words of the participants, or the issue of self-reference if we use a more formal language. Self-reference is in the essence of recursion, or in Harvey & Wright's words: "Recursion is the idea of self-reference applied to computer programs" (Harvey & Wright 1993 p. 168). This idea can be theoretically seen in many items of the classification task, but only one episode of all 100 could be categorized as mentioning it. The absence of the property of self-reference is a remarkable finding. Moreover, the gap between the participants' language and the language of experts was present even though the participants were not novices. Look for example at the next conventional definition of recursion: "Recursion is a technique in which a function or a procedure calls itself, and a recursive algorithm is one in which a process refers itself" (Garland 1987 p. 321). The discourse documented in this case did not contain even one of the terms used by the above definition. A possible explanation is the non-programming context in which the recursion CDA took place.

Let me proceed with the a short discussion of what was present in the discourse, as was found by searching for properties, aspects, associations and metaphors concerning the concept of recursion. At first, the analysis led to the construction of twelve major content categories, named according to the authentic phrases used by the observed participants: The categories are (1) Formula; (2) Definition; (3) Stopping; (4) Resemblance; (5) Containing; (6) Direction; (7) Cyclic; (8) Repetition; (9) Sequence; (10) Symmetry; (11) Metaphors; and (12) Other (see Levy 1999 for the full description).

The categories above are one kind of findings: they represent the use of a wide variety of properties, many of them should indeed be essential parts of a recursion concept map, although the participants' terms are often less formal/scientific and further exemplify the gap discussed above. Another finding is the participants' wide range use of analogies and metaphors. This stands out in a sharp contrast to the argument Pirolli and Anderson (1985) made concerning the lack of everyday analogies in explaining difficulties in conceptualizing recursion. Those who took part in the analyzed recursion CDA were imaginative and associative, and their favorite areas of images were animals (rabbits, chicken, crab...), plants (trees, roots, flowers) and transportation. These associations and metaphors can also be helpful in interpreting the participants' concept image (Vinner 1991), as can the special hand movements and 'musical' phrases that were documented by the video camera. For example, in the case of the next episode, we can interpret the 'music' as a certain kind of repetition (the eighth category): "Look, here, (points to the 1st level of fractal in one of the items) so you get pam-pam-pam (waits) tam-tam-tam, bam-bam-bam now this? (Points to the 2nd level) look: you get tam-tam-tam, tam-tam-tam (lower the voice)... and this, it's like the...like the rabbits of fibonacci. Exactly like the rabbits" (the rabbits appear in another item on the page) (Group 1, episode 40).

On later phase of the analysis, I searched for connections among the properties of recursion discovered in the discourse. The origin for this search lies in the assumption that combinations of properties best describe abstract concepts such as recursion. For that reason, the categorical system was not formed as an exclusive one, so that each episode could be coded as belonging to many categories or, in other words, as combining many properties.

Here I relate to two main kinds of findings. First, most episodes (75 out of 100) combined more than one property. Among the rest 'one-property' episodes were two remarkable episodes that gave an intuitive explanation of recursion, as shown in episode 16 discussed above or the following: "What's the idea? The idea is that from one thing you can get to the second thing" (Group 1, episode 20). Both episodes were observed in the same group, and both express a fairly high level of abstraction. The abstract nature could be the reason for skipping other properties.

The second sort of findings concerns episodes at the other end of the combination continuum. Fifteen episodes were coded as referring to more than three categories. In other words, they express combinations of more than three different properties. An interesting finding was that these "potentially rich episodes" tended to represent arguments among participants or conflicts among alternative conceptions. The phrase 'potentially rich' is meant to describe the opportunity for further learning hidden in such discourse episodes. For example, in one

episode (Episode 37, Group 1) Vicki used the cyclic terms to describe a certain item, while Hanna used sequential movements to describe the same item. The conflict between these two points of view was not solved in this episode, nor was it bridged later in the discourse. However, in this conflict lies a potential opportunity for reconstructing the concept of recursion and for further learning, because what those students were not aware of was that, indeed, recursion can be cyclic *and* sequential at the same time. Such awareness could probably not be spontaneously achieved. The harmonization of conflicting points of view depends on teacher interventions (Mariotti & Fischbein 1997) or, more generally, on mediation (Feuerstein, Rand, Hoffman & Miller 1980).

Conclusions

In analyzing the discourse of those who participated in a recursion classification and discussion activity, one can locate some conceptual processes as they evolve in the natural setting. The main terms and phrases apparent in the discourse were found to construct a fairly account for recursion, albeit a spontaneous one. Teachers can use these terms and language in mediating toward further learning and conceptualization, in order to close the gap and get closer to the theoretical formal language.

The preliminary categorical system needs to be refined with data from other types of learners, keeping in mind especially the non-content aspects of the discourse not addressed here at all. The latent potential in certain 'potentially rich' discourse episodes was evident on the content level as representing conflicts among alternative conceptions. But, at the same time, it hints at an arguing type of discourse episodes. In such episodes, learners make their arguments and try to be persuasive in order to reach an agreed classification. Analyzing the discourse, looking at what can be called the "level of consent" aspect, one can find links among argumentation, critical thinking, and conceptualization. This kind of analysis is planned for the future.

A present implication for teaching could be that the recursion CDA has a good chance of supporting participants' construction processes by enabling them to engage actively and reflectively in this classification task, either on the group discourse level or on the whole class discourse level. This implication may well be extended to other concepts via a similar group activity. When teachers are involved, such activity can help both in exposing their current understandings of recursion and in promoting their individual and professional growth.

In summary, the learning activity served as an interesting site for participants' conceptions, as well as an excellent opportunity for educational researchers to recognize and understand these conceptions. Following our experience with the recursion CDA, we developed and tried some other CDA's (such as abstract data types CDA) that have showed a similar potential. The categorical system developed by this research can be used in the discipline of computer science education, and the framework for this research could also be used by other science educators, in applying social-constructivist theories of learning, teaching and research.

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An Integrated Common Theme-Based Web Site for Teaching Science and Technology in Australian Primary Schools

Min-Jin Lin
Elementary Science Education Graduate Institute
National Hualien Teachers College
Taiwan, R.O.C.
minjinlin@hotmail.com

Abstract: The paper describes an integrated common theme-based web site that supports the teaching of Science and Technology in Australian primary schools. There are ten components in the web site. The "Background Information" component strengthens teachers' background scientific knowledge and skills. The "Content Strands", "Learning Outcomes", "Program Overviews", and "Links to other key learning areas" components assist Australian primary school teachers implementing the theme-based programs for teaching Science & Technology. Moreover, the "Internet Lesson Plans" and "Teaching Resources" components help teachers to reflect on their designs of the program. The "Fun Web Sites for Kids" motivates students to learn by exploring fun sites that are specially designed for children. The "Ask Expert a Question" and "News Discussion Group" components help teachers to solve problems in subject domain or teaching. This web site reveals the common theme-based characteristics of Australian primary curriculum, and it contributes to improve Australian primary school science teaching.

Introduction

The Australian primary science curriculum emphasizes the process of investigation, the process of designing and making, and the use of technology. It also has a theme-based learning characteristics that integrates Science with Technology and other key learning areas such as English, Mathematics, Creative & Performing Arts, Human Society & Environment, and Personal Development/Health/Physical Education. Instead of learning fragmented knowledge and facts about Science & Technology, the use of common themes provides a framework for students to understand and apply what they learn in an integrated way from different perspective of six key learning areas.

Most Australian primary school teachers teach almost every subject in a class. They have a great opportunity and freedom to be creative and to fulfil their ideal of teaching. However, it is also a great challenge to design well-integrated Science & Technology units. Many teachers did not have enough scientific background knowledge and skills, especially in the areas of Chemistry and Physics. Hence, they are more comfortable to teach familiar animals and plants than machine and electricity (Fleer & Hardy, 1996). Moreover, many teachers think that Language and Mathematics are more important than Science & Technology, so the latter may be neglected to some degree in Australian primary schools (Lin, 1999).

In New South Wales (NSW), the Board of Studies provides a Science and Technology Syllabus and Supportive Documents for K-6 curriculum (Board of Studies, 1993). The Syllabus provides guidelines in terms of learning outcomes, content strand, learning processes, link with other key learning areas, assessment and evaluation. Yet, a survey showed that the contents of the primary Science & Technology Syllabus were too vague and insufficient for teachers to design the science & technology programs (Board of Studies, 1996). The Supportive Documents provide some sample units of work with good examples to demonstrate how learning outcomes can be addressed through various activities, but only limited Supportive Documents are available. Furthermore, there is usually very little collaboration among primary school teachers in the design of science & technology program overviews (Board of Studies, 1996). Therefore, even an experienced primary school teacher may find that it is difficult to implement a theme-based science unit, not to mention the inexperienced new teachers.

The components of the theme-based learning web site

The author had constructed an integrated common theme-based web site in 1998 for Australian primary school teachers to use as a quick reference or a good starting point in teaching Science & Technology units. Each unit of work has a theme that not only integrates Science with Technology and other key learning areas but also emphasizes the process of investigation, process of designing & making, and the use of technology in Australian primary curriculum. The themes chosen to construct the science units in this web site are "sounds great", "stuck on you ", "out in space", and "our environment".

There are ten components in each unit. The components "Content Strands" and "Learning Outcomes" give a straightforward guideline in deciding the contents and outcomes of the science unit. The component "Background Information" strengthens teachers' background scientific knowledge of a particular theme. The component "Internet Lesson Plans" provides many lesson plans on Internet related to the selected theme, so teachers may reflect on their own design of programs. The component "Teaching Resources" provides information regarding to teaching kits, reference books, transparency, CD-ROM, computer software, and organizations or institutions to arrange for excursion. The component "Fun Web Sites for Kids" is a collection of web sites designed particularly for primary school students to explore and to have fun. The components "Ask Expert a Question" and "News Discussion Group" help teachers to ask questions and solve their problems by emailing science experts and discussing with other science teachers. The other two components will be explained in greater details in the following sections.

Details of the "Program Overviews" Component for Science & Technology

The component "Program Overviews" includes eight tasks related to the theme. Each task contains the following elements: Keyword of Concepts, Knowledge and Understanding, Teaching and Learning Activities, Teaching & Learning Strategies, Teaching and Experimental Resources, and Assessment Strategies. The context is carefully chosen with a consideration of students' background knowledge and the connection to local community and environment. A studènt-center approach is taken in the following teaching & learning activities of the eight tasks in the "Program Overviews" component under the theme "our environment".

1. Students watch the videotape "Greenhouse Effect", and then group discussion about their responsibilities to the environment. Then, they watch the videotape of "Recycling Paper" and draw a flowchart about the procedure of paper recycling.
2. Students read the consumer information and identify the materials of packaged products used at home. Then, they investigate what types of packaging are environment friendly.
3. Each group of students chooses an environment unfriendly packaged product and redesigns it to be more environment friendly. Then, they present the results to the class.
4. Students watch the videotape "Electricity Power" and group discussion about energy options, safety, efficiency, and environmental consequences of home appliances. Then, a database was constructed.
5. Students design and conduct a survey to find out how people conserve energy at home. Then, they research an "energy efficient way of living" and record their findings as a slide show on the computer and present it to the class.
6. Students observe nearby homes and school buildings to identify how they are serviced. They investigate what are the building materials of the local built environment. Then, students design a family home with consideration for the environment.
7. Students watch the videotape "Disappearing Water", and group discussion about the water cycle. Then, they investigate how Sydney Water is supplied using a brochure and conduct a survey to find out how people conserve water at home. Next, students use school maps to identify water supply, carrier and storm water facility in school buildings. Finally, students search the web sites for "Sydney Water pollution in 1998" and record their findings as a slide show to present it to the class.
8. Students conduct a self-assessment by using a Q&A worksheet and self-assess the strength and weakness of their designs in this unit and suggest the possible improvement.

Details of the "Link to other Key Learning Areas" Component

Creative & Performing Arts

1. Students use the recycled papers to design crafts, containers or artworks.

2. Students design an environment friendly family house, then draw and color it.
3. Students draw, color and label the diagram of water supply, storage and storm water in a school building.
4. Students sing a song about the beautiful environment in the Earth.
5. Students draw pictures to show the pollution caused by the packaged products in the local environment.
6. Students design and make an advertisement to call for the action to protect the local environment.

English

1. Students write a story about an environmental disaster.
2. Students write a poem to describe the beauty of the Earth and show their appreciation about it.
3. Students pretend that they are news reporters and write a report about the greenhouse effect in Australia and other countries.

Mathematics

1. Students investigate how many trees can be saved if Australians recycle 20% of paper per year.
2. Students investigate the influence of the greenhouse effect if 10000 more cars are manufactured each year in Australia.
3. Students investigate how much money can be saved a year if they use more energy efficient appliances or try different energy options at home. For example, compare the cost of using electricity or gas or solar energy to cook or to heat hot water.
4. Students investigate how much money can be saved a year if their family save 10 liters of water every day.

Human Society and Environment

1. Students investigate what happen to the society if there is no electricity or gas.
2. Students investigate the services (e.g. water, electricity, garbage collection, roads, etc) supplied in the local community (such as shopping centers, libraries, schools, banks, churches, hospitals, ...etc). They also investigate how space is managed, what materials are used, what regulations are applied, and what facilities are available. They suggest reasons for the selection of the building materials. Also, they identify how the local, state or federal government controls these services.
3. Students investigate how indigenous Australians live in harmony with nature before White Settlement without the usage of electricity and gas.
4. Students imagine that they are in an island where modern appliances are not available and there is no electricity or gas supply, how will they live?

Personal Development, Health and Physical Education

1. Students investigate how to use electricity or gas and other energy sources safely.
2. Students investigate what actions to take to reduce the greenhouse effect.
3. Students role-play as home appliance dealers or shop owners. What should they recommend to the customers?
4. Students write to their local council to find out what it does and how it handles environmental issues and laws that regulate the recycling, building permits, and tree preservation.
5. Students design an outdoor activity to clean the beach or the local community.

Conclusions

The construction of this theme-based web site is aimed to support Australian primary school teachers in implementing the theme-based programs for teaching Science & Technology. It also shows how to link to other key learning areas under a chosen theme. Moreover, teachers can reflect on the improvement of their own design of the lesson plans and program overviews. It is also beneficial for them to solve problems and to strengthen their scientific background knowledge and skills. Nonetheless, many supports are given to help teachers find teaching resources and to motivate their students to learn.

Due to the rapid advance of the information technology, the web-based learning will gradually become a common practice for both teachers and students given the network hardware and software are properly

provided in schools. Although the full-scale implementation of web-based learning is still in the early stages, the importance of web learning has been well recognized. The construction of this integrated theme-based web site helps to accelerate web learning for Australian primary school teachers. In fact, it is not only good for Australian primary school teachers in teaching Science & Technology, it is also useful and informative to all academic community members who care about the improvement of science education via the application of the information technology.

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Representation of Problem-Solving Procedures in MathCAL

Janet Mei-Chuen Lin*, Jie-Yong Juang**, and Ponson Sun*

*Department of Information and Computer Education
National Taiwan Normal University
Taipei, Taiwan
mjlin@ice.ntnu.edu.tw

**Department of Computer Science and Information Engineering
National Taiwan University
Taipei, Taiwan
juang@csie.ntu.edu.tw

Abstract: MathCAL is a network-based learning system for users to practice mathematical problem solving. Math knowledge is pre-analyzed to derive a set of *macro functions* for use in solving problems in a specific domain. Each macro function typically represents a math concept or rule which may be used to transform a math problem from a state into the next. Learners select problems to work on from the problem bank and proceed with problem solving step by step. The kernel of the system uses Petri nets to dynamically record a learner's problem-solving activities. The Petri-net representation allows the system to determine appropriateness of a user's application of a function at a certain step. It also enables the system to understand a user's thinking process when it is requested to offer guidance. MathCAL also supports synchronous and asynchronous network functions which may be used to establish a collaborative problem-solving environment. In addition, MathCAL allows users to add new problems and/or new solution paths to its databases.

1. Introduction

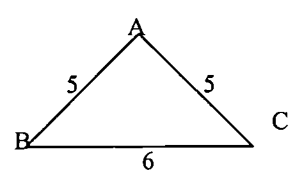
MathCAL is a prototype system for users to practice mathematical problem solving in an exploratory style (Lin, Juang and Sun, 1999). In mathematical problem solving, we usually approach a problem by first analyzing the problem statement to extract given conditions. These given conditions will then be used to derive other known conditions. The process continues until the requested results are finally obtained. At each step, the problem solver has to determine what mathematical concept or rule to apply based on all the known conditions available at that time. We use the following example to illustrate such a process.

The Problem Statement:

In an isosceles triangle $\triangle ABC$, if $\overline{AB}=\overline{AC}=5$, and $\overline{BC}=6$, what are the values of the six trigonometric functions of $\angle B$?

Given Conditions:

1. $\triangle ABC$ is an isosceles triangle.
2. $\overline{AB} = 5$
3. $\overline{AC} = 5$
4. $\overline{BC} = 6$



The Problem-Solving Steps:

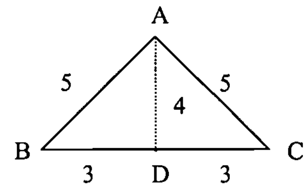
- Step 1:

  [Objective] In order to find the values of trigonometric functions of $\angle B$, we need to form a right triangle which includes $\angle B$ *as one of its acute angles.*

  [Concepts] Draw a perpendicular line from vertex A to base $\overline{BC}$.

  [Added Conditions] $\overline{AD}$ is the height of $\triangle ABC$.

- Step 2:
  [Objective] Find the measure of $\overline{BD}$.
  [Concepts] The height of an isosceles triangle bisects its base.
  [Added Conditions] $\overline{BD} = 1/2 \times \overline{BC} = 3$.
- Step 3:
  [Objective] Find the measure of $\overline{AD}$.
  [Concepts] The Pythagorean theorem.
  [Added Conditions] $\overline{AD} = 4$.



- Step 4:
  [Objective] Compute the values of trigonometric functions of $\angle B$,
  [Concepts] Trigonometric functions of an angle.
  [Added Conditions] $\sin B = \frac{4}{5}$, $\cos B = \frac{3}{5}$, $\tan B = \frac{4}{3}$, $\cot B = \frac{3}{4}$, $\sec B = \frac{5}{3}$, $\csc B = \frac{5}{4}$.

To capture the essential elements of a problem-solving process as analyzed above, MathCAL's main screen (Figure 1) includes display areas for the problem statement and the currently known facts. It also provides two pull-down menus: one menu contains concepts and rules to choose from; the other menu allows users to enter given conditions about a point, a line segment, a triangle, etc. The various buttons on the screen are for users to solicit guidance from either the system itself or other MathCAL users on-line.

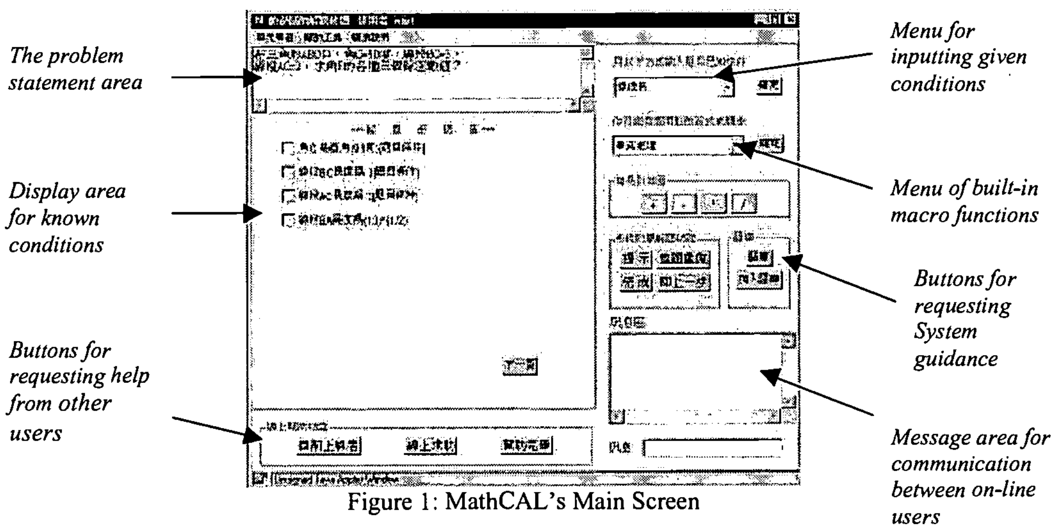


Figure 1: MathCAL's Main Screen

A user first logs on to the web server hosting MathCAL with a JAVA-enabled WWW browser to have the system set up a practicing environment as shown above. The user then begins an interactive session with MathCAL by selecting a problem to work on. To enter the given facts about a problem, the user selects a particular item from the menu at the upper right hand corner, and the system will prompt him for more information. For example, he may choose the 'triangle' entry to tell the system what the name of the triangle is, whether it is a right triangle, etc., or he may select the 'line segment' entry to enter its measure, the names of its two end points, etc. At each problem-solving step, the user ticks the boxes next to certain given conditions and selects a concept or rule to apply from the menu of built-in macro functions. MathCAL will first examine if the conditions ticked are sufficient for applying the function. If so, it executes the function and appends the newly generated results to the known conditions. The procedure ends when the required results finally become know facts.

When a user encounters difficulties during problem solving, he may press the 'UNDO' button to back up any number of steps and try to use alternative functions, or he may click the 'START OVER' button to redo the whole problem from the very beginning. If he needs system's guidance, he may press the 'HINT' button or the 'MORE HINTS' button to have the system display messages about what he may want to do at that point. Besides asking for system's help, a user may also activate some useful network functions supported by MathCAL. The current version of MathCAL implements both the *chat* function for

synchronous communication among on-line users and the *e-mail* function for asynchronous communication.

2. The Characteristics of MathCAL

MathCal's learning environment is characterized by the following features:

(a) *Mechanism for Recording Problem-Solving Steps*

The usefulness of a computerized exercising system would be quite limited if it can only check correctness of the final result of a solution. A feedback message such as '

is useless for most learners. The system should be able to know more about *how* the learner solves a problem in order to offer helpful guidance. Whether it is built-in guidance provided by the system or human guidance from other users, it is essential that the helper know what the learner has done up to that point. In other words, the system has to employ some mechanism to keep track of a user's solution path. Such a mechanism needs to take the following four important factors into account:

- It must be able to capture the dynamic nature of problem solving.
- The solution path should be stored using as little memory space as possible.
- It must be properly structured to facilitate the system's diagnosis of the user's problem-solving difficulties.
- As far as network communication speed is concerned, it must reduce the packet size to be transmitted over the network.

With the above four factors in mind, we employed Petri nets as our record-keeping scheme. In Section 3 we describe in detail how math knowledge has been segmented into suitable chunks in order to apply the Petri net theory. We also illustrate how Petri nets are constructed dynamically and how they are represented internally.

(b) *Extendibility of the Problem Bank*:

With a computerized exercising system, users will get bored easily if the problems to choose from are always those same few problems. In order to attract users' interest in using a system, the problem bank must be able to *grow* with time. Furthermore, it should not rely solely on the system engineer to update the problem bank. Instead, *users* themselves should be allowed and encouraged to contribute new problems to the system so the problems will have variety. MathCAL implements a problem editor for users to enter new problems. In addition to providing the editing window for keying in problem statements, the system will prompt users to enter other properties about the new problems, including their problem types, their difficulty levels, etc. Moreover, MathCAL requires that the contributor also provide at least one solution path for the new problem before it gets admitted to the problem bank. MathCAL needs such information for the purpose of offering system guidance as described before. Fortunately, with MathCAL's special design, what a contributor needs to do is simply to solve the problem once using the interface shown in Figure 1, and the system will generate and store the solution path automatically. MathCAL's problem editor even allows the user to add textual explanations about each problem-solving step for the new problems. Those explanations will be used by the system to provide hints to other problem solvers.

(c) *Network-based Assistance from Other System Users*:

When we attempt to help someone who gets stuck in a problem-solving process, we usually start by asking the person to describe what he has done thus far so we can guide him from that point on. The situation is the same with a computerized exercising environment. Exchange of textual messages over computer networks can be accomplished easily through mechanisms such as *chat* and *e-mail*. However, it would be more convenient if the helper can actually 'see' what the learner has done step-by-step. It would be even better if the helper can teach the learner how to solve the problem step-by-step. MathCAL achieves such effects by synchronizing the screen displays between the learner and the helper when the learner asks for help and the helper is willing to offer help. Such synchronization allows the helper to see each step performed by the learner simultaneously, or the other way around. Our Petri net representation scheme results in very efficient transmission of the problem-solving procedure between the learner side and the helper side. Instead of transmitting the actual screens in any file format, what MathCAL does is by transmitting some problem-solving data and then using those data to reconstruct the screen image at the receiver's side. With the availability of these communication

functions, the system actually becomes an outside-classroom tutoring environment when the helper is a teacher, or a collaborative learning environment when the helpers are peer learners.

3. The Petri Net Representation

The simple Petri net view of a system concentrates on three primitive concepts: events, conditions, and tokens (Peterson, 1981). Conditions are modeled by places in a Petri net; events are modeled by transitions. The holding of a condition is represented by a token in the place corresponding to the condition. With MathCAL, the occurrence of an event is the firing of a macro function at a problem-solving step, and a condition is a piece of or a set of known data for firing a macro function. In a Petri net the occurrence of the event may cause other conditions, postconditions, to become true. With MathCAL, the postconditions are the newly generated data after a macro function has been applied at a certain step. A Petri net is constructed dynamically as a user proceeds with each problem-solving step.

Figure 2 is a Petri net graph which shows the procedure of solving the problem shown in Section 1. It consists of six transitions and nine places. It is worth noting that if a problem may be solved in more than one way, different users may fire different transitions or same transitions but in different sequences. The Petri nets constructed will then be different.

Based on a matrix view of Petri nets, a Petri net graph such as the one shown in Figure 2 can be efficiently represented internally as two matrices $\mathbf{D}^+$ and $\mathbf{D}^-$. $\mathbf{D}^-$ defines the inputs to the transitions and $\mathbf{D}^+$ defines the outputs. Table 1 shows the two matrices for the Petri net of Figure 2. Since the correct solution path(s) can be stored in our database as matrices too, diagnosis of a learner's difficulty spots becomes a matter of comparing matrices. What complicates the matter is that a math problem usually can be solved in more than one way, and all the different solutions for a problem are recorded in MathCAL's database. As such, MathCAL needs to identify which one of the solutions the learner is most likely using before it does the matching and offers proper guidance accordingly.

Table 1. Internal representation of a Petri net graph (Matrices $\mathbf{D}^-$ and $\mathbf{D}^+$.)

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	
t_1	1	3	0	0	0	0	0	0	0	
t_2	0	1	1	0	0	0	0	0	1	
t_3	1	3	0	0	0	0	0	0	0	$\mathbf{D}^-$
t_4	0	2	0	0	1	1	0	0	0	
t_5	0	3	0	0	0	1	0	0	0	
t_6	0	0	0	2	0	0	0	0	0	
	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	
t_1	0	0	1	0	0	0	0	0	0	
t_2	0	2	0	0	1	1	0	0	0	
t_3	0	0	0	0	0	0	0	1	0	$\mathbf{D}^+$
t_4	0	1	0	0	0	0	0	0	0	
t_5	0	0	0	0	0	0	6	0	0	
t_6	0	0	0	0	0	0	0	0	1	

To identify the set of macro functions to be provided by the system, it is necessary to analyze the typical problem types in a certain domain to know what concepts or rules will be used toward solving problems in that domain. Since this is highly content-dependent, we currently focus on the topic of trigonometry only. Table 2 shows what the six transitions used in Figure stand for. The number of transitions implemented by MathCAL's kernel necessarily determines its power, i.e., how many different problem types it can handle.

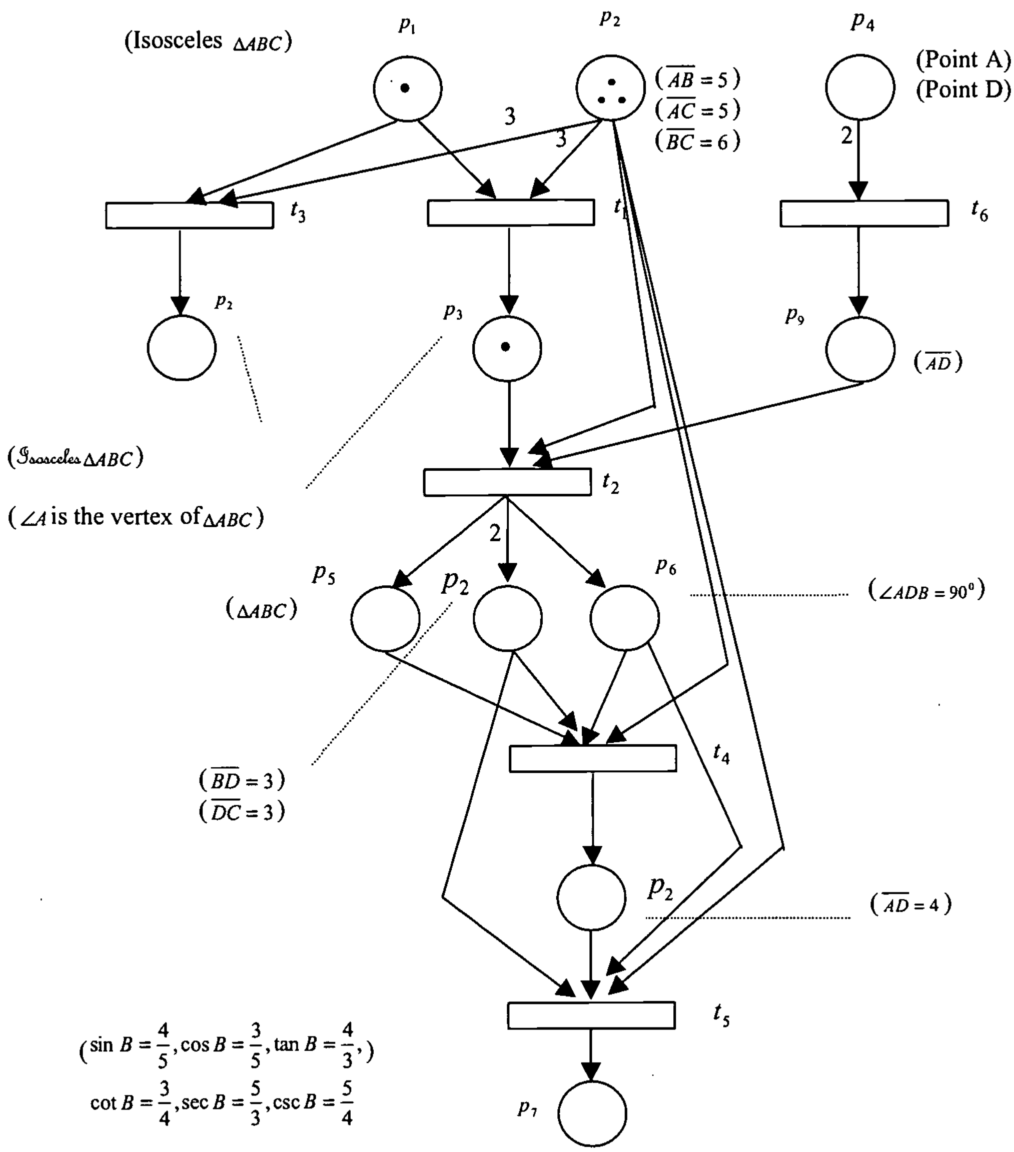


Figure 2: A Problem-Solving Procedure Represented as a Petri Net

Table 2. The transitions and their meanings

Transitions	*Meaning*
t_1	Given the measures of the three sides, find the top vertex of an isosceles triangle.
t_2	The perpendicular line from the top vertex of an isosceles triangle bisects its base.
t_3	The Pythagorean Theorem: Determine if a triangle is a right triangle.
t_4	The Pythagorean Theorem: Find the measure of the third side of a right triangle.
t_5	Determine the values of trigonometric functions.
t_6	Draw a perpendicular line from the top of a triangle to its base

Each transition identified determines the conditions which must be satisfied for firing that transition. For example, in order to fire t_1, we need to provide the lengths of three line segments representing the three sides of a triangle. As mentioned previously, conditions are modeled by places, we thus have place p_2, as included in Table 3. Table 3 also shows the meaning of other places used in Figure 2. When new transitions are added to the system's kernel, it may also require some new places to be added as well.

Table 3. Places and their meanings

Places	*Meaning*
p_1	An isosceles triangle
p_2	The length of a line segment
p_3	The vertex of an isosceles triangle
p_4	The name of a point
p_5	A triangle
p_6	A right angle
p_7	Values of trigonometric functions
p_8	An isosceles triangle which does not contain a right angle
p_9	The height of an isosceles triangle

4. Conclusions

In this paper we described the implementation details of MathCAL, a network-based learning system for users to practice mathematical problem solving. MathCAL is capable of guiding a learner through the problem-solving process. It also can set up a communication channel between two system users so they may help each other. We have been able to implement these functions effectively and efficiently due to careful analysis of domain knowledge and the use of Petri nets to economically record learners' problem-solving procedures. Our current efforts with the development of MathCAL are directed towards enhancing its capability to handle more problem types. This means more transitions and places need to be added to the system matrix maintained by the kernel. Any reader interested in trying the prototype of MathCAL is encouraged to contact the authors via e-mail. Currently we only have a Chinese version for MathCAL, but we will try to implement an English version for it when the Chinese version reaches a mature state.

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PCLogo and Mathematical Thinking Processes

Leping Liu, Ph.D.
Assistant Professor of Instructional Technology
Department of Reading, Special Education, and Instructional Technology
Towson University, U.S.A.
Email: **lliu@towson.edu**

Abstract: While Piaget's theory of cognitive development stages and van Hiele's theory of geometrical thinking levels emphasize the "state" of children's thinking, and describe the characteristics and applications of thinking at each particular stage or level, this paper demonstrates the thinking "processes" that advance thinking from one level to another higher level, with a C-A-C (concrete-abstract-concrete) learning model. Specifically, the C-A-C model using *PCLogo* assumes that repeated practice on concrete procedures of solving geometry tasks can lead a child's thinking to a higher level of abstract thinking. However, how much practice can be considered "enough"? This paper investigates how many tasks, or what difficulty-level of the tasks would be necessary for a child to advance his/her thinking from concrete level to abstract level and solve the abstract geometry problems. Current data and results in this is on-going study indicate that different "amount" of practice makes significant difference in children's geometry concept learning.

Literature Review

Mathematical Thinking and Technology

As stated in the Principles and Standards for School Mathematics 2000 (NCTM, 1999), one of the goals of mathematics teaching is enhancing mathematics thinking skills. The increased emphasis on teaching mathematical thinking has resulted in the development of new and innovative instructional technologies, especially programming tools and mathematics software, that are available for mathematics education (Davis & Hersh, 1981; Abramovich & Nabors, 1997; Vacc & Bright, 1999). A number of studies have investigated the use of instructional technology to improve students' mathematical thinking skills. Most of these studies have focused on one of three areas: (a) programming and cognitive styles and development (Clements & Gullo, 1984; Swan, 1993; Oakley & McDougall, 1997), (b) technologies and thinking levels (Olson, Kieren & Ludwig, 1987; Clements & Meredith, 1993; Liu & Cummings, 1997), and (c) the effective use of mathematical software packages to enhance mathematical reasoning (Abramovich & Nabors, 1997; Wright, 1997; Pokay & Tayeh, 1997). Findings of these studies suggest that programming experience, especially when enriched with appropriate activities and discussions, can help children become cognizant of their mathematical/geometric intuitions and thus move to higher levels of mathematical/geometric thinking. Furthermore, these findings suggest that use of well-designed mathematical software programs that incorporate effective procedures for teaching problem-solving can help children develop the abstract reasoning skills required for high levels of mathematical thinking.

Levels and Processes of Mathematical Thinking

Traditional theories of cognitive development suggest that learning occurs only when teaching is appropriate to the level of children's thinking (Piaget, 1936; van Hiele, 1986). van Hiele's geometric thinking hierarchy explains how children's learning and thinking about geometry changes as they advance through three levels (van Hiele, 1997, 1999; Fuys, Geddes, & Tischler, 1988): (1) Visual level, (2) Descriptive/analytic level, and (3) Abstract/relational level. The van Hiele model describes children's thinking about geometry at three levels and specified how they apply their thinking to tasks at each level, it does not describe how thinking progresses from one level to the next. The process of advancing through the levels does not appear to be automatic, however, in that children's thinking skills do not spontaneously jump from one level to the next (Liu, 1999). It is important, therefore, to understand how a child's thinking progresses from one level to the next and what thinking processes must be in place before the transition can occur. By understanding these processes, teachers can design effective teaching/learning strategies to stimulate the transition.

In contrast to these descriptions of thinking levels or states, Liu and Cummings (1997) have described two thinking processes that advance movement through van Hiele's three levels and that are essential for geometry learning: (1) Concrete-abstract process, and (2) Abstract-concrete process. The concrete-abstract (CA) process accounts for movement through the three levels of the van Hiele hierarchy. The CA process begins with children's initial sensation of concrete objects and experiences in the physical world (Liu & Cummings, 1997). Once these physical stimuli have been detected by the sensory system, their particular qualities and characteristics are identified and interpreted through perception. This process ends as the individual formulates concepts, ideas, or laws about what was sensed and perceived, extracting an abstract concept of the concrete experience. The CA process also can be conceived of as a process of inductive thinking—reasoning from particular facts (e.g., geometric shapes, and measurements) to a general conclusion about concepts, ideas, or laws (e.g., geometric concepts or rules). In geometric learning, the CA process leads thinking through the van Heile hierarchy, and stimulates transitions between each of the three levels.

Once children go through the concrete-abstract thinking process, their thinking about geometry progresses to the third level of van Hiele's hierarchy, the abstract/relational level. However, in contrast to van Hiele's scheme, the abstract/relational level is not the highest level at which children can think about geometry. Once they reach this level, children are ready to move to an even higher level of thinking, that of abstract-concrete (AC) thinking, which allows them to apply their newly-learned concepts (Liu & Cummings, 1997).

PCLogo and CA Thinking Process

The programming language, Logo, was advocated as a useful tool to enhance mathematical thinking (Papert, 1980;Clemments & Meredit, 1993; Liu & Cummings, 1997). It was created to let people of all ages use the computer in a more natural way (Harvard, 1994). Like many computer languages, Logo provides users with the capability to create attractive graphic images, perform calculations, maintain and update data, and even create sounds and play music. In a Logo environment, even children can perform these tasks and have fun at the same time. There is one important difference between Logo and other languages, however, in that Logo was uniquely developed as a conceptual framework for understanding children's construction of knowledge about mathematics and problem solving (Papert, 1980; Clemments & Meredity, 1993; Liu & Cummings, 1997). Accordingly, Logo has been used in a large number of studies designed to investigate its effectiveness as a concrete context for facilitating children's abstract reasoning about geometric problems (Geddes, 1992; Weave, 1991). Logo encourages children to learn through exploration and discovery. Through these processes, children soon learn that there are several solutions to any task. Thus, as children experiment and look for different solutions to a task, they use different thinking skills and construct knowledge in different ways. Therefore, by examining Logo commands or procedures developed by the child, we gain insight into that child's thinking and learning processes.

The CA process assumes that a child needs to practice the concrete procedures of solving geometry tasks with PCLogo repeatedly, and after enough concrete practice, his/her thinking will reach the higher level of thinking-abstract thinking. However, when the mathematics teacher designs the learning procedures, he/she needs to determine how much practice is "enough" for a child to accomplish the Concrete-Abstract thinking process.

Purposes and Research Questions

The purpose of current study was to investigate what would be the appropriate "amount" of practice on children's geometry concept learning. That is, to determine how many tasks or what difficulty-level of the tasks is necessary for a child to advance his/her thinking from concrete level to abstract level. The research questions examined in this study were:

1. Are there any differences among children's test scores of geometry concept learning with different amount of concrete tasks (from one task to five tasks)?
2. Are there any differences between boys and girls' test scores of geometry concept learning with different amount of concrete tasks (from one task to five tasks)?

It was hypothesized that children need to practice more than two tasks to achieve expected test results.

Methods
Subject

Subjects in this study were 10 girls and 10 boys aged from 8 to 9. They were convenient subjects in an after-school program. They came from three public schools. Their learning achievements on Reading and Math were around average level in their classes.

Learning Tasks and Measurements

Five learning tasks were designed to use PCLogo programming to learn the concept of geometric shape—square. Each task started from writing the Logo programming code that will produce a square shape. The code for the five tasks were:

1. repeat 4[forward 100 right 90]
2. repeat 4[forward 150 right 90]
3. repeat 4[forward 150 left 90]
4. repeat 4[back 200 right 90]
5. repeat 4[back 200 left 90]

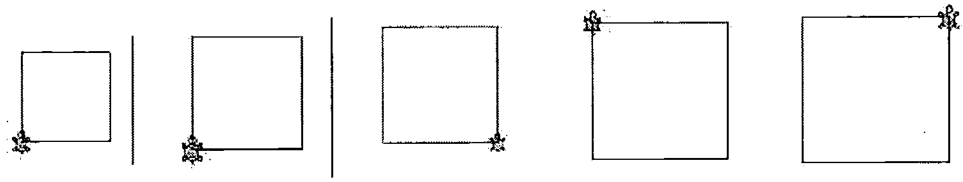


Figure 1. Square Shapes Produced Using PCLogo

The five codes will produce five shapes as in Figure 1, corresponding with tasks 1 to 5. The five tasks were at the same difficulty-level. The criteria used to measure the outcomes of each task included: (1) Use the given PCLogo codes to construct the square shapes, (2) Describe the characteristics of the basic components of the square shape (e.g., sides, angles, ...), and (3)Summarize the definition of geometric shape—square. The answers were scored from 1 to 10 (2 points for criteria 1, 4 points for criteria 2, and 4 points for criteria 3). Scores 9 to 10 indicate that students can perform abstract thinking skills to summarize the abstract concepts.

Design and Data Analysis

In this study, all children were first taught to use PCLogo. When they understood the procedures of Logo and feel comfortable about the code and graphing, they were asked to work on the five tasks. After each task, they were given the test to summarize the definition of the shape; then continue to work on the next task. When they completed the five tasks, each of them had completed five tests. Their scores of the five tests were recorded. In this way, each student's learning was repeated measured: the five scores represented the progress of learning and the effects of the amount of the tasks. For example, the score of task 3 indicates the learning effects after the practice of three tasks. Therefore, repeated measure was considered the appropriate method of data analysis (see Tables 1 & 2)

Table 1. Repeated Measures (Total)

	Task 1	Task 2	Task 3	Task 4	Task 5
Subjects					

Table 2. Repeated Measures (Gender Groups)

	Task 1	Task 2	Task 3	Task 4	Task 5
Boys					
Girls					

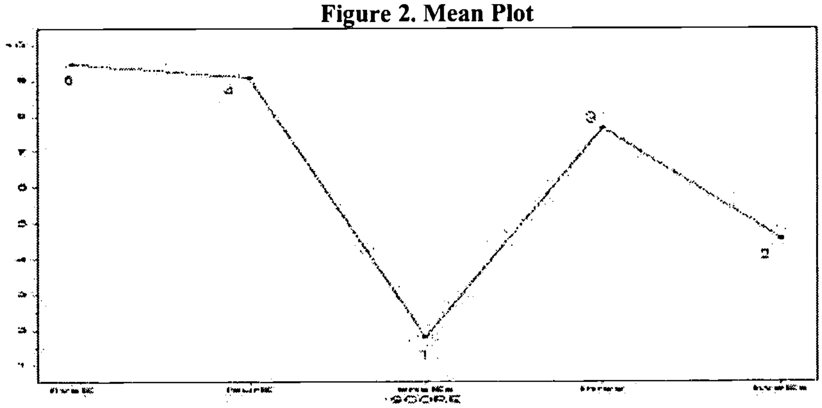
SAS system was used for the data analysis, and assumptions for repeated measures were checked. The data set did not violate the assumptions of equal variance, normality, and extreme ourliers. Therefore, we consider that the statistics results of the repeated measures explain the situation of the data well.

Results

Two data analyses were performed: (1) single-group (total subjects) repeated measurement, and (2) two-group (boys and girls) repeated measurement.

The results of the data analysis from the single-group measurement show that significant differences were found among the test scores of the five tasks (see Figure 2):

Figure 2. Mean Plot



The results and the mean plot show that Test scores after five tasks are the highest and lowest after one tasks. The differences are significant ($p < 0.01$) between the test scores after task 1 and task 2 ($t= -13.97$), task 3 and task 2 ($t =15.65$), task 4 and task 3 ($t = 7.22$). The difference between test scores after task 4 and task 5 is not significant ($t = 1.93$, $p <0.06$). The mean test score after three tasks is 7.66 out of 19, 9.09 after four tasks, and 9.47 after five tasks, indicating that students need to repeat at least three concrete tasks to achieve the expected learning effects.

The results of data analysis from the two-group measurement show significant difference among the five tests' mean scores ($F = 531.96$, $p < 0.0001$), but not significant between boys and girls ($F= 2.19$, $p <$ o.1564). Also, the interaction is not significant, as in Table 3.

Table 3. Test of Fixed Effects (Two Groups)

Source	NDF	DDF	Type I F	Pr > F
Gender	1	18	2.19	0.1564
Tasks	4	77	531.96	0.0001
Task * Gender	4	77	0.50	0.7355

The mean scores of the two groups in each task are in Table 4.

Table 4. Group Mean Scores

	Task 1	Task 2	Task 3	Task 4	Task 5
Boys	1.60	4.50	7.40	8.80	9.40
Girls	2.00	4.65	7.91	9.36	9.54

Although there is no significant difference between the two groups, in this table, all five test-scores of girl-group are higher than that of boy-group. This might suggest some potential differences of the learning between boys and girls. This study will continue collecting data from more subjects. Further data analysis with a larger sample may confirm whether there is difference between boys and girls.

Figure 3. Interaction Mean Plot (Graduate Groups)

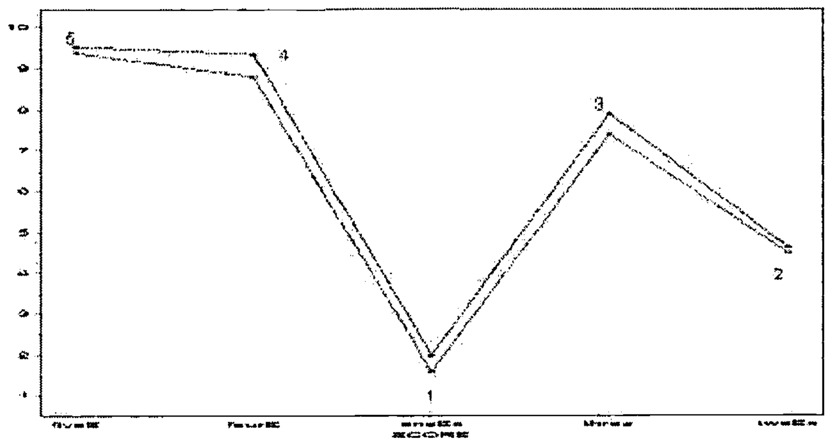


Figure 3 also shows the same pattern of the results as in Figure 2.

Conclusions and Discussions

Based on the results presented in the previous section, some conclusions may be drawn. First, More practice will produce higher learning achievement. That is, more concrete examples will help students progress their mathematical thinking from concrete level to a higher abstract level. Second, for average students, when we design the course materials to use PCLogo in geometric concept learning, four repeated concrete tasks that reflect different perspectives of the concept may be considered the appropriate amount of practice to advance students mathematical thinking to a higher level.

The findings suggest that there is no significant difference between the results after four tasks and that after five tasks. Does this mean that we do not need more than four concrete tasks? Further study may include the test of the performance after six or seven concrete tasks to determine whether a larger amount of practice is necessary, or whether using tasks with increasing difficulty level would reduce the amount of necessary tasks.

The results that there is no significant difference between boys and girls in performing the CA thinking skills, if further studies produce the same results, make it easier for us to design course materials—we may use same instructional strategies for boys and girls.

This preliminary study exhibits some interesting guidelines for the next phase of the on-going study. In the further processes of this study, the types of learning tasks may vary by the difficulty-levels. Students from higher or lower achievement levels may be examined. The fact that four tasks was the appropriate amount for advancing thinking skills with PCLogo in geometric concept learning suggest some guidelines for technology-based course design, for instance, multimedia courseware design in other learning areas. It may help us decide the times of practice on certain topics. Also, further studies will examine students' learning in the next thinking process—Abstract-Concrete thinking.

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Math in a Web Environment

Marcelo Llarull, llarullm@wpunj.edu
Educational Technology, New Jersey City University, USA
Department of Mathematics, William Paterson University, USA

Abstract: This paper addresses two issues, one is writing mathematical expressions on the web and the other is creating interactive math websites to teach and learn mathematics. In both cases, helper applications play a crucial role to successfully achieve both.

Introduction

When I was approached to develop the online course *Technology in the Math Curriculum*, I was expecting that the most challenging task was going to be to introduce the different and current technologies in the mathematical context from a curriculum ranging from K-12 to college level. Soon after I began, I learned that an equally challenging part of developing this course was to find the appropriate technology that I needed to use to be able to deliver the course over the Internet.

I did not want the course to be a collection of images and instructions on how to use the technologies, which could be better accomplished with a textbook. Rather, I was interested in adding interactive components to create engaging pages (Roempler 1999) where students could experiment and test the different technologies and explore the math concepts.

There is an extensive source of technologies that can be introduced in the math curriculum, but not all of them allow interactive web components

Mathematical Expressions on the Web

Creating web pages with mathematical expressions in them is still an awkward assignment. There are two ways in which this can be accomplished. The most common and quickest approach is to use images (GIF or JPG formats) to represent formulas. Using the equation editor, most popular word processors will automatically generate the images when a file is saved in HTML format. The number of images generated in this way can be overwhelming even for simple math expressions. Another disadvantage is that the mathematical expressions created in this way cannot be edited.

An alternative to using images is to use $\mathrm{T_EX}$ (or $\mathrm{LAT_EX}$), the most widespread program to typeset mathematical expression in research math papers. $\mathrm{T_EX}$ is a computer program created by professor Donald Knuth (Knuth 1984 & Lamport 1985) capable of typesetting any mathematical expression regardless of its complexity. Files in this format have the extension .tex. Using files in $\mathrm{T_EX}$ format gives three more options for displaying math on the web. Two of them require the use of plug-ins or helper applications: IBM techexplorer Hypermedia Browser or Adobe® Acrobat® Reader. The third option requires a converter to HTML.

Using the IBM plug-in techexplorer (http://www-4.ibm.com/software/network/techexplorer/), files typeset using $\mathrm{T_EX}$ (or $\mathrm{LAT_EX}$) can be interpreted by browser. The mathematical expressions can be as sophisticated as $\mathrm{T_EX}$ would allow and they can be edited in $\mathrm{T_EX}$.

Another option is to save the original $\mathrm{T_EX}$ file as a PDF (Portable Document Format) and then use the Adobe® Acrobat® Reader to view the file.

The third option is to convert the T_EX file into an HTML file. There are several converters, for example T_tH (**T_EX** to **HTML**) (http://silas.psfc.mit.edu/tth/). A converter will generate the necessary HTML codes to display the mathematical expressions as close as it is possible. I prefer this method since it does not slow down the loading of the web page and does not need special plug-ins. It also has the advantage that the mathematical expressions can be edited in any HTML editor and no images are used. But there are some limitations to the degree of sophistication of the mathematical expressions and often the display is not as perfect as we would want it to be.

The future of writing math for the web relies on MathML™ (**Math**ematical **M**arkup **L**anguage) (W3C 1999), which is an XML (e**X**tensible **M**arkup **L**anguage) (W3C 1998) application for describing mathematical notation and capturing both its structure and content. The purpose of MathML™ is to make possible mathematics to be processed on the web, just as HTML does with text. Future versions of the browsers will incorporate these viewing and processing capabilities and web page editors will have a built-in "equation editor". Currently, techexplorer can interpret the MathML codes.

Interactive Math Web Sites

When I was planning the course I wanted to include as many types of technologies as possible. Restricted by the finite length of one semester, I decided to include at least the most popular ones and then assign students with the task of reporting on at least two of their favorite technologies. One of the goals of the class was to compile an inventory of math technologies and to implement the ones I selected into the curriculum in which the participants were involved. The technologies considered in detail were graphing calculators, CBL, spreadsheets, Internet: PBL, Geometer's Sketchpad, Logo and Computer Algebra Systems: Mathematica™, MathView™ & Maple™. As a conclusion, there was a comparison of technologies and a discussion of future directions.

After selecting the different technologies, I was faced with the problem of how to demonstrate their use over the web in an engaging and, when possible, in an interactive manner. I had to develop different types of web presentations and activities depending on the technology to be presented and the technology that I had available to make the presentation interesting enough to motivate further activities and explorations.

Presenting interactive mathematical topics on the web is possible but not easy since it requires a certain level of technological expertise on a variety of programs in order to create an appealing site. The tools I could count on were GIF animations, Java applets and plug-ins.

I particularly used two technologies (which were part of the topics in the course) to built interactive pages. I used MicroWorlds™ (http://www.lcsi.ca) to create interactive logo boards and MathView™ for all the other topics. Both of them require the use of a browser plug-in.

MicroWorlds™ makes possible the creation of sites with multimedia features, including text, sound, video, graphics and animations, to develop different types of presentations and activities, including mathematical games.
Viewers need to install the plug-in WebPlayer (http://www.microworlds.com/webplayer/).

LiveMath Maker 3.0 (formerly know as Theorist, MathView™ and MathPlus) (http://www.livemath.com/main/) is a computer algebra system with a browser plug-in LiveMath Plug-in (www.livemath.com/) (formerly known as MathView Internet). The plug-in not only allows the viewer to see the notebooks created with the program, but also allows the viewer to interact with the web page. This is a great tool to explain and explore mathematical concepts.
Producing an interactive web site requires using LiveMath Maker to create a notebook designed to investigate the specific math topic in question. The notebook is then imbedded into the web page using a very simple HTML code. The object embedded in the web page acts as blackboard, calculator and sketching pad where students can input their own equations, functions and graphs.

Plug-ins such as LiveMath have a remarkable impact on the teaching and learning of mathematics. They can also be used to establish support web sites in order to complement different courses at all levels. Currently I am working on an online version of Multivariate Calculus and LiveMath plays an essential role due to its versatility and friendliness.

Other interactive objects are specific Java applets custom designed for the mathematical topics in question. This requires appropriate knowledge of Java.

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Student-Instructor E-mail Exchange in Active-Learning Biology 100

Gili Marbach-Ad and Phillip G. Sokolove
Department of Biological Sciences
University of Maryland Baltimore County
United States
Admarbac@umbc.edu sokolove@umbc.edu

Abstract: Student-instructor communication was examined in a large, introductory biology class for majors (enrollment ~250). Students were encouraged to send questions, comments and suggestions to the instructor using e-mail. All messages were collected after the semester and classified as either content-related or procedural. Content-related messages typically contained questions, comments or suggestions about a topic that had been discussed the same day in class. Procedural messages included questions or requests concerning homework exercises and exams, reports about student absence from class, or requests to switch classes or sections. Messages from females and males reflected class gender distribution, but Asian and African Americans were more likely than Caucasians (relative to their class distribution) to send content-related messages. Most students whose messages were classified as content-related had earned final grades of A or B.

Introduction

For over a decade, educators have drawn attention to the importance of students' questions and discussions in the teaching/learning process (Commeyras 1995, Dillon 1988 & Good et al. 1987). However, even when teachers encourage questions, students – particularly students in large classes – are reluctant to raise their hand to ask a question or to volunteer a comment. Consequently, in-class participation soon becomes limited to only a few individuals (Hedges and Mania-Farnell 1999).

One of us (Sokolove) teaches a large, introductory biology course for majors that enrolls about 250 students. In order to encourage students to participate in class and to promote student-instructor and student-student interactions, Sokolove started in 1995 to teach this course as an "active learning" class that employed student-centered, constructivist-based and interactive instructional approaches such as small-group cooperative learning (see Sokolove 1998). One innovative example of his effort to build an interactive atmosphere in the classroom involved student name badges. Students were provided with pin-on name badges at the beginning of the semester and were required to wear them to every class session. Name badges enabled the instructor to become familiar with students' names (he could recall about half of them by the end of the semester), and allowed students (who were mainly freshmen) to get to know each other.

In this active learning environment, frequent in-class questioning was encouraged. However, many students remained reluctant to participate in class because they were unsure of themselves, because of their temperament, because of their relative inexperience (first-semester freshmen), or because they were afraid of their peers' reactions. One student in the class wrote: "When students ask overcomplicated or technical questions, peers 'eat them alive.'"

In order to promote students' questions we concluded we would have to provide a "private channel" that would produce for students a secure and unthreatening environment for student-instructor communication. Strauss and Fulwiler (1987, 1989) have advocated in-class writing as a means of communication between students and faculty. They suggested to students in a large chemistry class that they write notes to the instructor about problems they encountered in interpretation of text or lecture material. A simple question box at the back of the large lecture room encouraged many students to put their concerns and confusions on paper (Strauss and Fulwiler 1987).

Similarly, in our large, active-learning biology class all students were asked at the beginning of the semester to bring a laboratory notebook to each class session. The advantage of lab notebooks is that students can write a question or comment to the instructor and still retain a copy for themselves of what

they wrote. Like Strauss and Fulwiler we encouraged students to write notes during class and leave them at the end of class in a special box at the front of the lecture hall.

Another way to promote student communication with the instructor is through computer telecommunication. Schoenfeld (1993) described the use of an electronic forum to lend an anonymous voice to every student, and Collins (1995) used an electronic bulletin board in his college biology class. Zack (1995) reported that electronic messaging improved the quality of instruction, and Coombs (1992) used electronic mail and computer conferencing systems in his American history telecourse.

We, too, have employed electronic bulletin boards and newsgroups, but the majority of students in the class seem to view such forums in much the same way as the large lecture hall: they are too public, too "exposed" and (potentially) too embarrassing. Therefore, we decided to use unstructured e-mail to keep communication both simple and private. E-mail is also convenient for students to use. Every student that matriculates at UMBC gets a personal e-mail address, and many public computers (about 850) are available around the campus in various locations, such as the library, the engineering/computer sciences building and all of the residence halls. In addition, there are approximately 1,500 computers in resident hall rooms connected to the Internet. A significant number of students at this largely commuter campus also have access to e-mail on home computers.

Student-Instructor Communication

This study was conducted in the active learning introductory biology class offered in Fall 1998. The instructor (Sokolove) encouraged students to send him e-mail about anything they were interested in (questions, comments, suggestions, complaints etc.). At the end of the semester we examined all archived e-mail that had been received, along with all of the replies that the instructor sent back to the students.

Over the course of the semester 54 students in the class sent 150 e-mail messages. Students' messages were mainly of two types: questions or comments about class content (63 e-mail messages from 26 students) or procedural messages (87 e-mail messages from 38 students).

Content-related Messages

Content-related messages contained mainly questions about a topic that had been discussed that day in class. The number of content-related e-mail messages increased toward the middle of the semester and decreased toward the end (Fig. 1, months 1-4; month 5 is after the end of the semester).

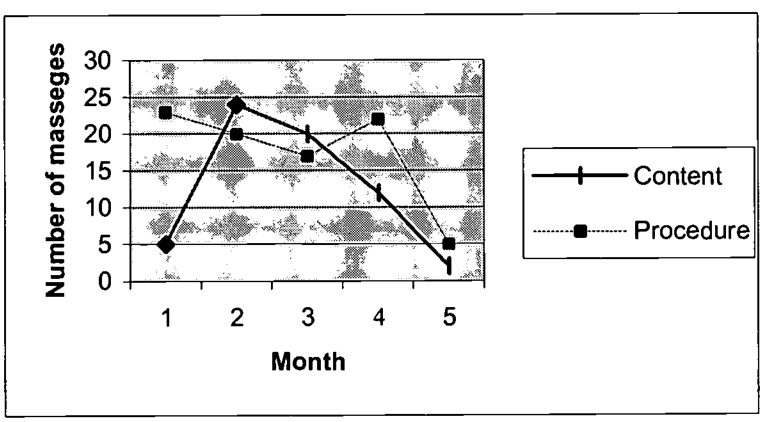

Figure 1: Distribution of E-mail Messages During the Semester

It is difficult to identify the reason for the peak in messages that occurred in month 2. It might have been due to the fact that near the middle of the semester the topics being covered were genetics and

evolution. Both topics contain difficult concepts for many students. Indeed, about half of all content-related messages (32) dealt specifically with these topics (Fig. 2). For example, one student asked: "If a [female] horse and a [male] donkey mate, a mule [is produced. But] the mule is not able to reproduce . . .. Is the mule considered to be a member of a species"?

Fewer content-related messages (11) dealt with cell energetics, which was taught earlier in the semester. One student asked regarding cell energy: "I understand how ATP is made. I even know what it is used for. What I would like to know is how ATP is used to carry out the necessary functions [of a cell]"? Other messages (13) dealt with body systems – "What does the appendix actually do in animals that actually use it"? – While some messages (2) dealt with the first topic taught in the semester, "What is life"? "When the virus connects to a host cell, doesn't it symbiotically become 'alive'"?

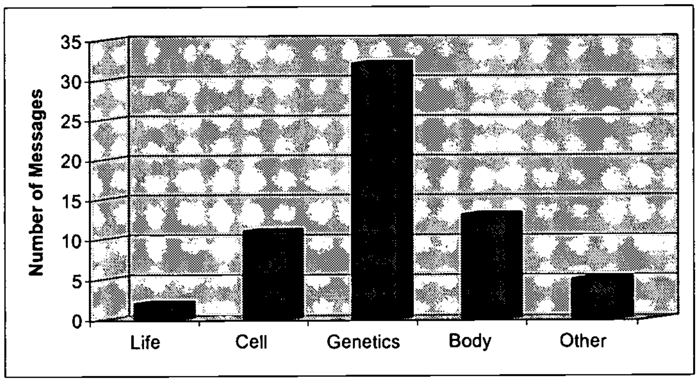

Figure 2: Messages Classified by Content

An immediate benefit derived from content-related messages is that some will expose student misunderstandings, which reflect a common misconception that can then be addressed in class. For example, when students learned about the circulatory system, one asked, "In what form is 'heat' carried by blood cells? Is there a 'molecule' that the heat is packaged into before it is carried to the surface of the skin and then released"? Another student wrote during the unit on genetics, "Can environmentally produced deformities become inherited deformities"? In both cases the instructor addressed these topics during the next class session.

Some content-related messages were thoughtful and insightful: "Darwin's theory of evolution suggests that the environment keeps the number of reproducing individuals in check so that there is no overpopulation of a single species. Does this statement apply to the human population, too? [Or] are we an exception to this rule"? Others raised philosophical issues: "I was wondering, an offspring gets his traits from his parents. So what if his two parents were murderers or big criminals, and they always thought of doing harm to others. Is it true that their child would also be like them? And if that is true, don't you think it's unfair for them, as they will probably go to prison or get executed"?

Students often write about events that they see or hear about or experience personally outside of the class that connect in some way to an in-class topic: "...This got me to thinking about a summer science camp I went to the summer after my freshman year in high school. It was a gene cloning camp where we took bacteria that was sensitive to both kanamycin and ampicillin and made it resistant to both by using two other strains of bacteria, one resistant to the kanamycin and the other resistant to the ampicillin. ...I saved my notes from that [summer,] and I can bring them with me to class if you would like."

The instructor was generally able to reply to students' e-mail messages within one or two days. Different answers were provided depending on the type of question a student asked. In many cases the instructor provided a short answer and referred the student to other sources of information (textbook, journal articles or other instructors in the department). In some cases the instructor recommended that the student work with his/her cooperative group to find an answer. One student wrote to the instructor after receiving such a recommendation, "Thanks for the advice about forming a 'Chemiosmosis' group. I arranged a meeting with my [cooperative] group and we all went over the concept. I now understand it much better . . .."

In a number of cases the instructor replied with a longer response (such replies could exceed 500-1000 words), and in other cases he challenged the student to research the topic and bring the information gathered back to the class. For example, the instructor wrote to one student who had asked about enzyme pills, "How about finding out for us how those enzyme pills work"? Two days later the student sent him the following message: "After an extensive Internet search, I ended up with a phone number for the makers of the Lactaid pill. They told me that the active ingredient in the pills is actually the lactase enzyme itself. How they get the enzyme into the pill is unclear to me. However they said they would send me a packet on lactose intolerance along with a free sample of the product. I believe this is a credible source of information because the producers of Lactaid are also the producers of several other drugs such as Tylenol and Nasalcrom (a nasal spray for allergy symptoms)."

Procedural Messages

Over half of the procedural e-mail messages (57%) included questions on take-home assignments (how to cite references, how many pages to write, and where to find information sources) and questions about exams or exam scores; 10% reported that the student would be absent from class; 8% requested a change in discussion section or lecture class; 11% (received mainly towards the end of the semester) were about how the student felt in this innovative class (some of these even thanked the instructor). A few students complained about their teammates or about their graduate TA. The frequency of procedural messages was roughly constant over the course of the semester (Fig. 1). About 20 messages were received each month.

Type of Students Who Were Likely to Communicate

Table 1 compares the demographic distribution of students who sent content-related e-mail messages, and the demographic distribution of the entire class. Roughly 60% of the students who sent content-related e-mail messages were majoring in biology or in biochemistry even-though only about a third of the students in the class were majoring in these areas; while the other 40% who sent such messages were majoring in other areas or were undecided.

Demographic Distribution	Percent of Students sending Content-related Messages N = 26	Percent of Students in Class N = 249
Primary Major		
Biology or Biochemistry	58	32
Other and undecided	42	68
Gender		
Female	69	60
Male	31	40
Ethnicity		
Caucasian	46	60
Asian	35	25
African-American	19	14
Other	2	1
Final grade in class		
A	58	21
B	23	31
C	15	33
D	0	10
F	4	5

Table 1: Demographic Distribution of Students who Sent Content-Related Messages Relative to their Distribution in the Class

Two-thirds of the students who sent content-related messages were female, which roughly reflected the percentage of females in the class. In contrast, the percentage of African-American students (19%) and Asian students (35%) who sent messages was greater than their total percentage in the class (14% and 25% respectively), while among Caucasians the relationship was reversed (48% vs. 60%). This was interesting in light of the fact that in another study (unpublished), we found African-American students to be more likely than Caucasians or other ethnic groups to study with others for exams. Treisman (1992) suggests that African-American students who are accepted to good universities are highly motivated and prepared to comply with an instructor's suggestions in order to succeed. In the active learning class, the instructor urged students to communicate with him and to study with others in order to get better scores.

We also found a strong correlation between the number of students who sent content-related messages and final grades: 58% of the students who sent content-related messages earned As, while only 21% of the entire class earned an A as their final grade. The use of e-mail to communicate with an instructor outside of normal class time has been previously linked to improved academic performance (Slovacek & Doyle-Nichols 1991). However, the fact that students with higher grades were more likely to send content-related messages than those with lower grades might indicate either that student-instructor communication enhanced student achievement, or simply that good students have a tendency to send more e-mail messages to the instructor. Our data do not allow us to distinguish between these alternatives.

Conclusions

Our observations and informal student feedback suggest that e-mail messages provide an important asynchronous modality for student-instructor communication in large classes particularly for students who can not wait around after class, or who are hesitant (or unable) to find time to schedule an office appointment in order to meet privately with the instructor. Students have noted that around-the-clock availability of the system allows them to ask questions and receive answers at any time of day or night. From the instructor's point of view, the system encourages more frequent student-instructor interaction, and allows students to "find" him without having to track him down or to schedule a face-to-face meeting. He, in turn, can answer students' questions and respond to their requests in his free time.

We believe the e-mail mode of communication serves to support and enhance an active learning environment. It allows instructors to offer more personalized attention to students in meeting their specific learning needs, and it provide an opportunity for students to ask for special help or for additional information about class lectures and out-of-class assignments. The act of writing is also a good way to clarify ideas and understanding. E-mail encourages students to express themselves through the written word in order to communicate (Laurillard 1999). The use of e-mail allows both students and instructors to compose messages in advance, thus producing clearer, better-prepared questions and answers.

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Is There Appropriate Science and Mathematics Software for Young Children?

Dr. Robin McGrew-Zoubi, Dept. of Curriculum and Instruction,
Sam Houston State University, USA
edu_rmz@shsu.edu

Dr. Joan Livingston Prouty, Dept. of Language, Literacy and Special Populations,
Sam Houston State University, USA
edu_jlp@shsu.edu

Dr. Kim Arp, Department of Curriculum and Instruction,
Sam Houston State University, USA
edu_kca@shsu.edu

Abstract

This paper describes a study of mathematics and science software marketed for preschool children. Preservice teachers observed young children at work, reviewed the literature available about computers and young children, and interviewed early childhood, technology, mathematics, and science specialists. Teachers, childcare providers, and parents shared their beliefs about the value of computers for young children. Analysis of specific software packages and their alignment with developmental benchmarks, still in progress, will be presented.

Introduction

For a technology project in an elementary teacher education program at a mid-size university in the southwest, preservice teachers investigated young children (three years old through Kindergarten age) and their use of the computer. During two semesters preservice teachers observed approximately 150 hours of young children's computer behaviors. The research questions follow:

Questions

The teacher researchers asked three questions for this project:

1. What are the benchmarks of early childhood development according to teachers, childcare providers, parents, and experts in early childhood education?
2. Does computer software offer young children developmentally appropriate mathematics or science learning experiences?

3. What behaviors can be documented as young children interact with the computer? Are gender-based stereotypes related to science and math evident at this age?

Methodology/Investigation

Interviews with certified and non-certified teachers and specialists in math, science, and early childhood, as well as interviews with parents, offered a large body of anecdotal information. Areas of inquiry included developmental benchmarks in young children, developmentally appropriate activities, gender preferences for varied types of computer experiences, time at the computer, and opinions and views about the math and science software marketed for use with young children. In addition, preservice teacher researchers conducted a review of the literature on young children and computer usage and reviewed the NAEYC position statement entitled, *Technology and Young Children--Ages Three through Eight.* They also gathered over 150 hours of observational data of young children at the computer in a variety of educational settings, public and private.

Analyzing the anecdotal data from observations and interviews, as well as data from the literature review, preservice teachers constructed a rubric that included the constructs found in their collected data. The rubric to evaluate software includes identification of developmentally appropriate activities and abilities, appropriate math or science opportunities present, and the type of software i.e., creation, simulation, situation exploration, reference exploration, tutorial, drill and practice, game, electronic book. Time at the computer and language interactions at the computer were reviewed through interview. The interviews were examined and summarized, noting similarities and discrepancies with the literature review.

Findings

Benchmarks for Early Childhood Development

Agreement among the respondents and the literature emphasized children's need for physical movement in daily activities. Respondents and the literature information emphasized that in physical actions, young children move through age appropriate skill development of fine motor, gross motor, social, and language abilities (Haugland 1996). Also, the development of self-identity and self-esteem at this young age were deemed important.

The characteristics by age in the development of young children have been well documented and discussed in the literature. Table 1 on the following page illustrates some of the most common descriptors by age (NAEYC 1996).

The literature review and the specialists have similar views about the benefits of monitored computer use for young children—30-60 minutes. The common view in the literature (NAEYC 1996), however, suggests a much shorter time frame for daily computer use by a young child—20 minutes.

Software and Developmentally Appropriate Interactions

Computer use in early childhood settings is both innovative and controversial. The two

most common concerns are that computers are not developmentally appropriate for young children and that children working alone at a computer can become isolated and fail to develop social skills. At the same time there is agreement in the literature and among interviewees that computers offer important growth experiences for young children.

> Dr. S, a technology specialist, states that "*computers develop hand-eye coordination, abstract and cognitive thinking, problem solving, and exposure to vast information.*"
>
> According to daycare provider, Ms. L, "*Very young children have shown comfort and confidence using software. No longer do we need to ask whether the use of technology is developmentally appropriate.*"
>
> "*Computers should not take the place of experience, adult supervision is required, children should balance computer use with activities that use their five senses*, Dr. W, early childhood specialist and Ms. L, mother of young child and leader of Mother's Day Out program

Physical, Social, Emotional, and Cognitive Development In Children Ages 3-5

	Physical Development	**Social Development**	**Emotional Development**	**Cognitive Development**
3 years	Runs well, marches, stands on one foot, feeds self, puts on shoes and socks, unbuttons and buttons, pours from a pitcher	Enjoys being with others, takes turns, knows if they are a boy or girl, likes to help in small ways	Likes to conform, has an easy going attitude, are more secure, has greater sense of identify, begins to be adventuresome, enjoys listening to music	Can say short sentences, great growth in communication, tells simple stories, wants to understands their environment, wants to answer questions, can count to 10, holds simple concepts, speech is usually grammatically correct
4 years	Skips on one foot, cuts with scissors, can dress self, but not well, can throw a ball over handed	Engages in cooperative play, enjoys other children's company, plays loosely organized group games, is versatile	Seems to be sure of self, may be defiant, needs controlled freedom, seems to be testing self out.	Uses complete sentences, asks endless questions, learns to generalize, highly imaginative, dramatic, can draw recognizable simple objects knows hi/her age, able to define common

				object in term of use and knows common opposites
5 years	Hop and skip, dress without help, skate, print simple letters, tie shoes, girls small muscle development is about one year ahead of boys	Has specialized friends, highly organized, enjoys simple table games requiring turns and observing rules, feels pride in clothes and accomplishment	Self-assures, well-adjusted, home-centered, likes to associate with their mother, enjoys responsibility, and likes to follow the rules.	Knows around 2072 words, can tell long tales, carries out directions well, asks the meaning of words and are beginning to know the difference between fact and fiction, repeats sentences, can use description spontaneously, and can follow three commands given without interruption

Table 1: Descriptions of characteristics of physical, social, emotional, and cognitive development of children ages 3-5 years

Cognitive Development and Science Processes and Mathematics Concept Development For Children Ages 3-5

	Cognitive Development	Science Processes	Mathematics Concepts
3 years	Can say short sentences, great growth in communication, tells simple stories, wants to understands their environment, wants to answer questions, can count to 10, holds simple concepts, speech is usually grammatically correct	Uses hand-lenses and measuring cups to make simple investigations. Uses a simple scale to compare weights of objects and observe which objects are heavier/ lighter. Identifies patterns through observations (i.e. day vs. night).	Makes simple comparisons between measuring cups. Uses a simple scale to compare weights of objects and observe which objects are heavier/ lighter.
	Cognitive Development	**Science Processes**	**Mathematics Concepts**
4 years	Uses complete sentences, asks endless questions, learns to generalize, highly imaginative, dramatic, can draw recognizable simple objects knows hi/her age, able to define common	Asks questions about organisms, objects, and events. Explore simple pat-terns with shapes and colors and predict what comes next.	Asks questions about objects. Explore simple pat-terns with shapes and colors and predict what comes next.

	object in term of use and knows common opposites	Observe changes in weather and seasons. Identify parts that, when separated from the whole, may result in the part or the whole not working, such as cars without wheels and plants without roots.	Differentiate between hotter and colder. Identify halves of objects or shapes. Sort shapes into like groups.
5 years	Knows around 2072 words, can tell long tales, carries out directions well, asks the meaning of words and are beginning to know the difference between fact and fiction, repeats sentences, can use description spontaneously, and can follow three commands given without interruption	Discuss how a simple scale shows that one object is heavier than another. Identify basic needs of living organisms. Use language such as more than, same as, and less than to describe objects. Identify characteristics of living and nonliving things.	Compare and order two or three objects according to weight (lightest to heaviest), length (longest to shortest), capacity (what holds the most), or temperature (hotter or colder). Use language such as more than, same as, and less than to describe objects. Compare shapes based on certain attributes and describe how groups are formed. Counting by ones to 100. Develop one-to-one correspondence.

Table 2: Descriptions of characteristics of cognitive development, science processes, and mathematics concepts of children ages 3-5 years

Behaviors of Children Working with Computers

Observations of young children at the computer show a wide variety of interactions. In many situations, children worked together amiably. They often worked at the computer in harmonious partnerships. At other times, observations showed conflict between partners, mostly stemming from the mouse. In one observation, a five-year-old girl sat quietly in tolerance of the short-term partnership formed for a computer task until completion and then both boy and girl quickly dispersed to their gender groups. In boy/girl partnerships, observers noted cordial and conflicting partnerships. In some situations, the girl would defer to the boy's leadership throughout the computer activity.

Development of Science and Mathematics Concepts

Using software that is in line with the developmental abilities of 3-5 year olds, children can be actively engaged in activities that develop underlying science processes and mathematical concepts. The concepts for both science and mathematics content areas are similar for this age group. The goals are to help children to

- make observations
- record observations
- distinguish between objects based on attributes
- classify objects
- sort objects, and
- develop problem solving strategies.

Software appropriate for children at this age must include talking instructions/directions – not have text that the user has to read to work the program. Animation enticing to children and easily identifiable icons that allow the children to self-direct the activity are also necessary parts of the software.

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Learn Anytime Anywhere Physics (LAAP): Guided Inquiry Web-Based Laboratory Learning

Gerald W. Meisner, Physics Dept., UNCGreensboro, Greensboro, NC, USA; jm@curie.uncg.edu
Harol Hoffman, Physics Dept., UNCGreensboro, Greensboro, NC, USA; hh@curie.uncg.edu
Mike Turner, Guilford County Schools, Greensboro, NC, USA; mturner@curie.uncg.edu
WebslingerZ, Inc., Carrboro, NC, USA; mstrickl@webslingerZ.com
Wolfgang Christian, Physics Dept. Davidson College, USA; wochristian@davidson.edu

Abstract. The Extended Physics Community Consortium will author Learn Anytime Anywhere Physics (LAAP). LAAP will provide both synchronous and asynchronous learning experiences for undergraduate students, high school physics students with various needs as well as preservice and inservice teachers.

We will use Java technology to develop and build an online physics laboratory learning environment comprised of typical introductory, algebra-based physics modules, in an innovative pedagogically sound format:

- virtual lab equipment applets (Laaplets)
- virtual lab setup device applets (Laaplets)
- associated curriculum modules in which students perform experiments in the virtual lab
- student assessment components
- peer interactions and peer mentoring

By means of interactivity between client machine and servers, student input will be stored in server side databases. This will permit just in time analysis (JITA) for immediate feedback.

Introduction

Television in the 1970's, microcomputers in the 1980's and centralized video conferencing in the 1990's were touted as being able to revolutionize education. However, extensive use of these technologies has resulted in little gain. Over the past several years there has been a growing use of the World Wide Web (**WWW**) in education. Cables have been connected to schools with fast data transmission rates and browsers have been loaded. Nevertheless, an examination of the educational use of the Web thus far has yielded few encouraging statistics. Indeed, it is fair to say that the Web has had minimal impact on learning during its first five years of existence[1]. This is the conclusion in spite of the fact that hardware is in the school place, educational software of various quality abounds, and tens of thousands of workshops for teachers have been held throughout the country – by school system personnel, universities, commercial vendors and others. Where lies the problem?

Searching for a common thread we see that current Web use, video conferencing, early use of microcomputers and television operate essentially within a pedagogy framework based on passive acceptance of information. This pedagogy, well known to students who have attended hundreds of hours of lectures, permits many students to listen to the transmission of information without becoming engaged in the learning process, no matter how articulate or famous the lecturer may be.[2]

For the past 20 years, Physics Education Research (PER) has shown that students must actively confront and articulate their misconceptions of physical phenomena, must develop representations of various models of the physical world – kinesthetic, diagrammatic, graphical and mathematical – and must continually test their models by comparing predictions and experimental results.[3] Only then will significant changes in student understanding of

[1] John F. Wallin, *Distance Learning and the World Wide Web*, Computers in Physics, **12**, 4, 322-327, 1998.
[2] D. Bligh, *What's the Use of Lectures* (ADB, Devon, England, 1978.
[3] Lillian C. McDermott, "Research in Physics Education", APS News7, 1, January, 1998. Priscilla W. W. Laws, Millikan Lecture 1996: *Promoting Active Learning Based on Physics Education Research in Introductory Physics*

physics[4] take place. We may refer to this approach as one of Interactive Engagement or Guided Inquiry, with the latter subsuming the former but also adding a guiding intelligent mentor or agent.

None of the technologies described above has had a large-scale educational impact. As we enter the 21st Century, will the educational use of the Web lead to broken promises as well? Evidently the answer may be 'yes' if the Web remains a mere repository of information and authors use the medium as an electronic substitute for the lecture method of instruction. On the other hand, if the Web is used as a guided, interactive learning environment rather than one used to solely transmit information, then revolutionary changes in learning can occur, particularly in the area where the **WWW** excels – asynchronous learning. This is the essence of *Learning Anytime, Anywhere Physics: A Web-Based, Guided Inquiry Laboratory Learning Environment.*

Use of the Web in Education

In his autobiography, Robert Millikan described how ineffective he thought large lecture classes were, and proceeded to integrate laboratory and quiz work into his classes. This pioneering work languished for nearly 70 years until Lillian McDermott's *Physics by Inquiry* [5] and Priscilla Laws' *Workshop Physics* [6] approaches began to revolutionize the way in which introductory physics could be taught in post secondary (and secondary) settings. With support from NSF, PI Meisner adapted Workshop Physics material in 1992 at his institution to a variety of settings, including an introductory course for premed majors and education graduate students and summer workshops for inservice teachers. Titus and Christian have worked in the field of PER for a number of years and Strickland in recent years. Meisner has offered an online course for three years, Strickland and Christian have authored numerous Java applets; Strickland is cofounder of webslingerZ, a web development company, and Christian is author of Physlets[7], Java applets designed for student problem solving activities. Titus is co-author of WebAssign. PI Hoffman has managed several large projects, including the NSF-funded statewide TechTools project which in 1995 developed one of the first science resource web sites in the nation and provided technology leadership to science teachers statewide in NC. The development team for this proposal is well qualified to carry out the tasks set out in this proposal and toward that end has formed an affiliation called the Extended Physics Community Consortium. The Consortium team has the background in content, PER, pedagogy, online course authoring and programming skills and complex project management which, when combined with recent software developments, will enable the project team to produce a Web-based, laboratory learning environment wherein the student is guided in inquiry and assessed in performance by an Guide Agent (see below).

The Web is becoming a major player in Computer Based Teaching or Computer Based Training (CBT). The interchangeability of the translation of this acronym suggests the current problem: CBT has been most successful when used to train a cadre in a particular skill, rather than to engage the student in critical and analytic thinking. In a recent review article, Wallin[8] classifies current Web use in Physics: (1) faculty home page (2) class administrative information such as syllabus, homework assignments, and occasionally more ambitious interactive Java applets[9] and (3) Web sites which serve as electronic textbooks. By and large, none of these uses has affected the way classes are taught. Faculty who lectured are still lecturing, referring students to the web site for class assignments, problems and solutions, rather than directing students to notebooks or to a study room. The additional reliance on electronically stored information may have the unintended effect of diminishing the importance of peer study groups for 'traditional' students who attend classes *in situ* at a university. A similar situation exists in the **DL** community.

Courses, Am. J. Phys. **65**, 1, 14-21, January, 1997. These approaches are extensions of the Learning Cycle developed by Robert Karplus and others as part of SCIS in the 1960s.

[4] Richard R. Hake, *Interactive-engagement vs. Traditional Methods: A Six-thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses*, Am. J. Phys. **66**, 1, 64-74, 1998. Edward F. Redish and Richard N. Steinberg, *Teaching Physics: Figuring Out What Works* , Phys. Today **52**, 1, 24-30, 1999.

[5] L.C.McDermott and the Physics Education Group at the University of Washington, *Physics by Inquiry Vol. I and II* (John Wiley & Sons, New York, NY 1996).

[6] P. Laws, *Workshop Physics Activity Guide* (John Wiley & Sons, New York, NY 1997).

[7] W. Christian, ibid.

[8] J. Wallin, Ibid.

[9] W. Christian, *Developing Web-Based Curricula Using Java Physlets* , Comput. Phys. **12**, 3, 227-232, 1998.

Material traditionally in hard copy format now exists in electronic form, with little shift in the teaching and learning paradigm.

The convergence of recent hardware and software developments with pedagogical developments based on careful PER results will enable those with strong backgrounds in content, pedagogy and web technologies to revolutionize **DL** via the **WWW**. Fast and reasonably priced microcomputers are becoming nearly as ubiquitous as television sets. The emergence of Java as a stable, compiled, object-oriented programming language enables authors to write platform-independent programs on the Web server, compiled into Java byte code, and executed on the (Web) browser's machine. The execution of these small applications or applets on the student's machine results in displays that can quickly change and in user inputs that can be quickly transmitted to the server and thence connected to robust relational databases. Depending on the design details of the educational software, this student-generated database contains the information necessary to assess the student's progress and to formulate a student profile necessary to guide the student through the Web learning environment. This guidance takes the form of a simulated mentor, which we refer to as a Guide Agent.

There is work being done in the physics community to incorporate curriculum and the Web. Ten percent of the papers presented at recent annual meetings of the American Association of Physics Teachers include Web material as a central part of the paper. Some describe courses on line with links to graphics and to other related web sites, others describe physics problems in animated or video format and student assessment based on these and similar problems[10], and others describe use of the web to assist in class management techniques.[11] None of these approaches embrace the pedagogy enunciated by Millikan and more recently by McDermott, Laws and others. Nor does the approach of commercial products such as Interactive Physics. Our LAAP approach develops a learning environment which enables students to investigate phenomena through inquiry guided by feedback generated by an analysis of a database of student on-screen responses, much as they would do in a workshop physics environment. Students can explore, confront conceptual difficulties and paradoxes, observe, reformulate concepts, develop a theoretical framework, make and check predictions, and analyze results with tools very similar to those used in 'real' laboratory settings across the country. Formative student assessment will be done with Physlets and similar Java applets, video-based problems, and textual responses as well as with multiple-choice problems. Student progress through the virtual physics laboratory (VPL) investigations is monitored and stored in relational databases, becomes part of the student portfolio and forms a basis for student evaluation. The end product of this program will be an algebra-based, introductory college-level physics course, with eight hours of undergraduate credit available from the participating institutions, and transferable under existing agreements among colleges and universities across the country. Work will begin in parallel to produce a calculus-based course.

WWW and Economy of Scale

By means of interactivity between client machine and servers, student input will be stored in server side databases. This will permit just in time analysis (JITA) for immediate feedback and guidance as well as for the construction of a student profile to be used for both the creation of a guide agent for assisting student inquiry and as information from which the evaluation of student performance in the course can be made. Responses to questions based on Java based laboratory activities or Laaplets, multiple choice quizzes, questions based on conceptual evaluation questions or physlets and multiple choice exams will be available for assessing the student knowledge. Additional feedback is possible and will be encouraged. Students will be urged to use a chat room, listserve, bulletin and white boards. The Extended Physics Community that created LAAP will maintain these, along with server-side databases. LAAP assessment will be self-contained, but will also permit the option of additional assessment by an instructor at any participating university, college, community college or high school (AP courses).

The extensive Java-and database-driven interactivity enables us to create a web-based DL model with nearly zero to low marginal cost. Karelis has shown[12] that in order to produce cost effective DL instruction, as compared to traditional classroom techniques, the problem of scale barrier must be solved. Scale barrier is defined as the upper

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[10] Titus, A., Martin, L., & Beichner, R. (March/April, 1998). Web-based Testing in Physics Education: Methods and Opportunities, Comp in Phys, March/April, 1998..

[11] G.M. Novak, E.T.Patterson, A. Gavrin and W. Christian, *Just in Time Teaching: Blending Active Learning with Web Technology*, (Prentice Hall, Upper Saddle River, New Jersey, 1998).

[12] C. Karelis, *Education Technology and Cost Control: Four Models* , Syllabus, Feb., (20-28),(1999).

limit of the number of students enrolled in a course, for whatever institutional and/or practical reasons. In cost analysis of traditional vs. other means of instruction, the presence of a barrier has had the effect of preventing the 'break-even' point of non-traditional instruction from being reached. The 'break-even' point is the enrollment number above which the non-traditional instruction becomes cost effective. This is indicated on the graph below, taken and modified from Karelis.

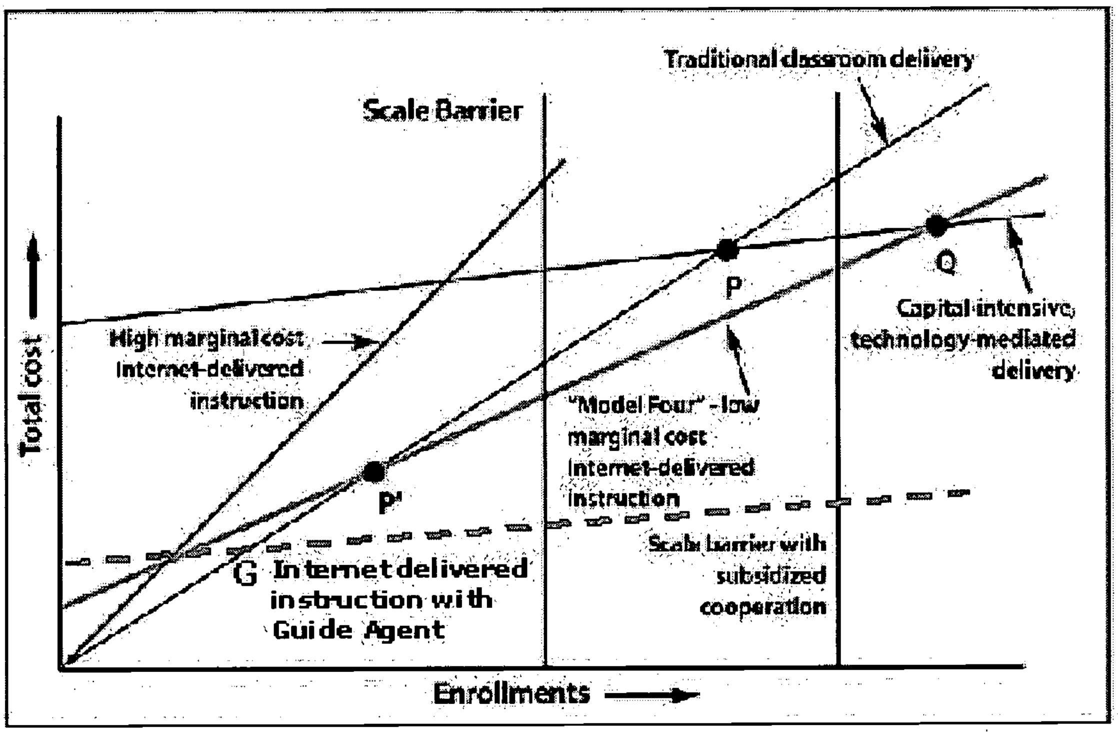

Figure 1; Online Cost Effectiveness – Modified Karelis Graph

The LAAP project is represented on the Karelis graph by a dotted line that intersects the 'traditional delivery' line at point G. There is little marginal cost for a totally self-contained, Java-based interactive course with database created Guide Agent. If students instead arrange to interact with an instructor at a local institution, the dotted line shifts toward the Karelis "Model Four" line, with low marginal cost and a point of intersection P'. Both our LAAP model and the Karelis Four model reach the breakeven point of enrollment considerably to the left of the Barrier enrollment number. Both are economically feasible and sustainable.

Implementation of the LAAP model can produce a line on the Karelis graph with nearly zero slope as the Guide Agent becomes more effective. During the first two years of the LAAP project, the Guide Agent responses in modules will be continually tested with students from UNCGreensboro, NC A&T and Davidson. During years three and four, this web-delivered general physics course will be offered concurrently with a similar course using the same pedagogy. Students taking both delivery modes will be interviewed and classes videotaped for detailed comparison. Such comparison will lead to 'in-flight' corrections. This cyclical approach will result in a deliverable first semester course in year three of the LAAP program, and in a deliverable second semester course during year four.

Technology Description

As outlined above, we are developing software for the ***Learn Anytime Anywhere Physics*** program, including

Software Type	Intended Use
Java Applets	"Virtual Laboratory" student front end
Java Servlets	Web site administration and front end
Java Applications	Translation of TeX source into HTML and general document management functions
Database/Artificial Intelligence	Information entered by the student will all be recorded in a database for later assessment.

Virtual lab equipment applets (Laaplets) [e.g., motion detectors, force probes, pressure probes, quick-response temperature probes, accelerometers, and timers with direct read-out] can be physically moved and applied by the user in experimental settings.

Virtual lab setup device applets (Laaplets [e.g., air tracks, inertial balances, spring loaded dynamics cart on a precision track, curved track fixed to a support, dart gun and ring stand, ball and ramp, model cars] have parameters which can be modified, altered, and controlled by the user in an experimental setting.

LAAP is tied to existing physics curriculum materials from the best pedagogy programs that have emerged from current research in physics education and as such will: provide a distance learning experience in the sciences for those unable to obtain such experiences in traditional college laboratory settings.

By means of interactivity between client machine and servers, student input will be stored in server side databases. This will permit just in time analysis (JITA) for immediate feedback and guidance as well as for the construction of a student profile to be used for both the creation of a guide agent for assisting student inquiry and as information from which the evaluation of student performance in the course can be made. Standard assessment instruments will be used to compare LAAP students with traditional in situ students.

A prototype will be shown.

IN-SERVICE PROGRAMS: DOES THEIR EFFECTIVENESS LAST?

Michelle Merriweather
Department of Mathematics
West Chester University
United States
mmerriweather@wcupa.edu

Abstract: This paper discusses the findings of a study conducted on two types of in-service programs. The program, Virginia Network for Technology (VANT) consisted of an overview course and an intensive course. The study examined the differences in both the attitudes toward and actual use of calculators between the participants who participated in the overview course, intensive course, and those who did not complete either course. The results indicate a trend that after attending VANT, teachers incorporate technology into the classroom and continue to use it in the years following VANT. In addition, the teachers who participated in VANT have a more positive attitude toward calculator use in the mathematics classroom than when they first completed VANT. However, there was not a significant difference in attitude between those who completed the overview course, intensive course, and those who did not complete either course.

Introduction

The use of calculators has become increasingly popular in mathematics courses in high school. This is in part due to the National Council of Teachers of Mathematics (NCTM) recommendation that appropriate calculators be available to students at all times (NCTM, 1989). There are numerous studies that support the use of calculators in mathematics, stating that they improve students' attitudes towards mathematics and allow students to do more conjecturing and generalizing (Hembree & Dessart, 1986; Bitter & Hatfield, 1993; Army, 1991). Furthermore, calculator use has been shown to increase the understanding of algebraic and graphical concepts and to allow students to see the connections between different areas of mathematics (Alexander, 1993; Rich, 1990; Tolias, 1993). Despite the overwhelming evidence of the benefits of calculator use, graphing calculators are either not being used or not being implemented effectively into the classroom (Huang & Waxman, 1996; Lehman, 1994; Ognibene & Sheele, 1990). Therefore, training should be given to teachers so they can implement technology in their classroom.

Studies have shown that in-service or training programs can have a positive impact on teachers if they are given proper support. That is, teachers participating in such programs tend to modify their teaching methods to incorporate the new information (Clarke, 1994; Watterson, 1994; Langrall, 1993). These studies also report that in-service programs need to be practical, actively involve teachers, and provide ongoing teacher support in order for teachers to modify their teaching (Clarke, 1994; Peterson, 1995). Many researchers measure the effectiveness of their in-service by determining if teachers have incorporated the new information into their teaching immediately after the in-service program. However, the question remains, do teachers continue to use the methods that were introduced after the novelty of the new techniques wears off? This study attempted to answer this question.

Methodology

This study investigated the effects of the Virginia Network for Technology (VANT) in-service program. The VANT Outreach survey course was a one-credit college telecourse that met for five sessions, three hours per session, throughout the semester. The participants were middle and high school mathematics and science teachers. During these sessions, a one hour televised lesson on using the graphing calculator was presented. In addition, each site had two trained instructors who reviewed in depth the material covered in the televised segment.

The VANT Leadership intensive course was a three-credit college course that met for two weeks, eight hours per day. The majority of the participants in the VANT Leadership Institute first took the VANT Outreach

course. Each morning, instruction was given on how to use graphing calculators in the mathematics and science classrooms. Each afternoon, the participants were divided into smaller groups by the subjects they taught. Specialists gave more specific instruction in how to use graphing calculators in each subject area.

Specifically, this study examined the differences in both the attitudes toward and actual use of calculators between the participants in VANT Outreach, VANT Leadership Institute, and teachers who have not had either course in the Virginia Beach school district. In addition, this study investigated how graphing calculators are being used in high school mathematics.

Results

An attitude survey was administered after each VANT course and again in the fall of 1997. Differences in scores were obtained to determine if there has been an increase in calculator use. Differences in scores were also obtained to determine if teachers have a more positive attitude in the fall of 1997 than after they completed the VANT course. In addition, six teachers were observed for one week to determine how graphing calculators are used in secondary mathematics.

The first question investigated whether the participants who complete the VANT Leadership Institute and VANT Outreach courses use graphing calculators in their classrooms more frequently in the fall of 1997 than when they completed the course. Due to the small sample size, inferential statistical tests were not possible for this hypothesis. Therefore, descriptive statistics were used.

Nine of the 77 teachers who completed the survey in the fall of 1997 could be matched to their survey from their VANT course. Each of the nine teachers either continued or increased the level of calculator use in their classroom. This increase was not dependent on how long it has been since the VANT course was taken. In addition, two-thirds of the teachers reported that they use calculators on a daily or weekly basis, when appropriate.

The goal of the second hypothesis was to determine whether those who complete VANT Leadership Institute course have a more positive attitude toward calculator use than those who complete the VANT Outreach course or those teachers who have not taken either course. The Kruskal-Wallis test was performed to investigate this hypothesis. The Kruskal-Wallis test indicates that there is no significant difference ($\underline{p}$=0.260) in attitudes between the three groups of teachers. However, descriptive statistics show that the mean attitude score for VANT Leadership ($\bar{x} = 7.0435$) is greater than the mean attitude score for VANT Outreach ($\bar{x} = 6.4000$), which is greater than the mean attitude score for those who did not take either course ($\bar{x} = 5.9545$).

The third question addressed whether the participants who complete the VANT Leadership Institute and VANT Outreach courses have a more positive attitude in the fall of 1997 than when they completed the course. Twelve of the teachers who completed the survey in the fall of 1997 could be matched to their survey completed from the VANT course. Nine of the twelve teachers surveyed either continued or had a more positive attitude toward calculator use in the classroom. Although this data supports the hypothesis, there is not enough data to determine a pattern.

Actual calculator use in high school mathematics was observed for the fourth part of the study. I observed six high school mathematics teachers for one week and recorded the amount of calculator use. On average, the six teachers used graphing calculators more than one-quarter (27.9%) of their class time. About half of that time (42.7%) was used for activities in which the calculator was the focus of the lesson. An example of this type of activity is when the Algebra II teacher used the calculator to teach the students how to solve systems of quadratic equations. In addition, calculators were also used as an aid (39.8%). Graphing functions and checking algebraic work were examples of calculators used as an aid. A small percentage of the time (17.6%) was used for basic calculator use. This was used primarily in the Probability and Statistics class to calculate means, standard deviations, and z-scores.

The amount of calculator use was dependent on the subject and topic being taught. For example, in the Calculus class the students were learning integration techniques. Therefore, the use of graphing calculator was not appropriate.

Conclusions

There are several implications for teachers and administrators. In-service programs are an integral part of passing along new information to existing teachers. This study shows that in-service programs can make a difference. For the Virginia Beach School District, the VANT program has encouraged teachers to learn how to

appropriately use graphing calculators in their classrooms. This study indicates that after attending VANT, teachers incorporate technology into the classroom and continue to use it in the years following VANT. In addition, the teachers who participated in VANT have a more positive attitude toward calculator use in the mathematics classroom. Therefore, school administrators should invest time and money into this type of training for teachers.

Even if a teacher has not participated in VANT, they can gain benefits from VANT. Out of the six teachers observed, two had completed the VANT course. From discussions with these six teachers, the VANT program served as a starting point. VANT encouraged the teachers to train the other members of their departments. Therefore, it was not necessary for all the teachers in the department to complete VANT.

However, after discussions with teachers at several high schools, training of colleagues was not performed. Therefore, VANT Leadership needs to be re-evaluated to train teachers to try new techniques and be leaders in their schools. More specifically, issues such as forming a network among teachers and training teachers to conduct future in-service programs needs to be considered for future leadership institutes. This could be a contributing factor to the non-significant difference of attitudes of teachers who completed VANT Leadership, VANT Outreach, and those who did not complete either course.

The teachers who trained their colleagues formed their own networking system. They implemented new techniques in their classrooms and discussed their results with their colleagues. From this discussion they determined which methods work. If the methods did not work, they discussed possible modifications that could be made to their lessons. This type of dialogue is crucial for teachers to be able to implement new ideas into their lessons. Therefore, any in-service program should include a networking system for teachers to discuss the implementation process and reactions from students.

Another important aspect of implementing new techniques into the curriculum is support. The teachers indicated that support from the school and the central administration is very important. Support can come in several forms. First, administration needs to support their teachers by acquiring the necessary resources. Examples of these resources can be calculators, manipulatives, or training. Furthermore, administration needs to support their teachers by giving them time to modify their lessons and discuss their changes with their colleagues.

This study indicates that the majority teachers from Virginia Beach are using graphing calculators to some extent in their classrooms on a long-term basis. More research is needed to determine what characteristics encourage teachers to use calculators in their lessons. For example, is it the in-service program, a network for the teachers, support from the school district, or a combination of all of these?

In addition, more in-depth research needs to be conducted to determine how graphing calculators are used. This study started this process by observing six teachers for a week. This research needs to be continued on a larger scale; that is, more teachers need to be observed at varying times to get a more diversified sample. Furthermore, analysis of the types of lessons and calculator usage needs to be conducted to answer questions such as whether teachers are using calculators appropriately in their lessons.

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Discovering xyAlgebra: Intelligent Interactive Internet Instruction

John C. Miller
Algebra Courseware Project
The City College of CUNY
United States
jochmiller@aol.com

Abstract: Passive activities such as watching presentations, listening to explanations of general principles and watching experts solve sample problems are helpful, but peripheral, to the mathematical learning process. For students the indispensable step is solving problems for themselves. Yet most commercial mathematics software still concentrates on presentations and sample problems, while sending students off line to do practice problems on paper without interactive support. Answers are either multiple choice or limited to a single simplified final step. Early Internet courses are even less interactive. In contrast, students using xyAlgebra can enter each step of each problem solution. They enjoy intelligent support at every step as xyAlgebra's suggested solution strategy changes in response to their steps in simplifying expressions, solving equations and even in setting up and solving verbal problems. The next version of xyAlgebra will support instruction over the Internet, yet the entire package can be downloaded without cost at math0.sci.ccny.cuny.edu/xyalgebra.

Recent History

The primary instructional delivery system for basic algebra at The City College of New York since 1995 has been xyAlgebra, a complete course of instruction for computers running MS-DOS or Windows. Two hundred and twenty students are currently registered for the course. Experience with this instructional package has been very favorable. Since the introduction of xyAlgebra as the medium of instruction, students have required significantly less time to learn as much as students learned previously in traditional classrooms. As the Computer Learning Center staff has become more experienced and expert in using these materials, a significant improvement in student performance is being observed. The problem is human, not technological. Staff are learning to persuade students to spend the time required to excel rather than settling for the marginal passing grades to which many are accustomed and which most can obtain in less time using xyAlgebra than their predecessors could when taught in traditional classrooms.

The Problem

Solving problems is the primary way that students learn algebra, or any mathematics course. Explanations of general mathematical principles, explanations of general problem solving methods and demonstrations of solutions to problems all play a useful role. However, solving problems is the most important part of the learning process for every student. A dominant theme in the reform movements in mathematics instruction in recent years is the importance of involving students sooner and more actively in the learning process and especially in the problem solving process. One is therefore astonished at the design of most commercial algebra courseware. In case after case the commercial programs play movies, explain principles and demonstrate problem solutions. However, when they pose a problem for the student to solve, they send the student off-line to solve it on paper. They offer no assistance while the student works. They require the student to enter a completely simplified final step or to choose one from a multiple-choice list. Then they typically display a pre-stored solution bearing no necessary resemblance to the solution used by the

student and leave it to the student to locate and understand the reason for any errors. In effect, they turn a computer into a $2000 programmed workbook.

Courses being prepared and offered for instruction over the Internet are similarly limited, and some are far less interactive. Even the limited commercial programs already discussed at least have the advantage that they inform the student promptly if a final answer is correct. Some attempts to offer instruction over the Internet rely on e-mail interaction, thereby regressing from answer assessment in milliseconds to answer assessment in hours or days.

The Solution

In basic algebra classes at The City College, xyAlgebra allows and encourages each student to enter arbitrarily many steps of a proposed solution directly into the computer. It checks for correct syntax after each character is typed and instantly detects and describes any syntax error. When a step is complete, xyAlgebra determines whether it is equivalent to the previous step using a definition of equivalence appropriate to that type of problem. It immediately rejects any non-equivalent step, a key feature since student mastery of the basic operations depends so heavily on making mistakes and promptly learning not to make them again. It also accepts any equivalent step, even if a non-standard solution method is used. After any step xyAlgebra can suggest a next step, either by describing the type of step appropriate at that stage or by providing the actual step. It can do this even after an unanticipated or non-standard step or sequence of steps. Students are thereby encouraged to try shortcuts and alternate solution methods, confident that help will be forthcoming if needed. When a student enters an incorrect step and requires help to correct it, xyAlgebra temporarily redisplays the student's incorrect step and suggests a correct step immediately beneath it, so that the student can compare the two. This allows the student to discover the nature of the misconception leading to the incorrect step, and also to learn an appropriate method of solving that problem.

The problem-solving algorithm used to generate xyAlgebra's step-by-step solutions and explanations becomes "smarter" as a student progresses. A simplification that xyAlgebra would demonstrate in several steps at an early stage in the course is done later in a single step, when it occurs in the context of a more complicated problem. In every type of problem the algorithm modifies its problem solving strategy based on the student's partial solution. The correct steps as entered by the student up to that point determine xyAlgebra's suggested next step. In helping solve a verbal problem, for example, xyAlgebra selects the target relation(s) to use in generating the final equation(s) by beginning with the currently entered expressions and applying a "shortest route" strategy to determine the "best" subset of the many available relations. Each time a student enters another correct expression the program reevaluates the shortest route and changes its target relations and its strategy for obtaining equations accordingly. Most available programs offer only pre-stored solutions uninfluenced by the student's steps or the student's errors.

Numerous convenient shortcut commands are available in xyAlgebra to speed student progress. A student can request automatic retyping of any earlier step, including an erroneous step, whenever editing is quicker than retyping. A student can pop up a previously solved sample problem of the current type with a description of each step or a calculator to evaluate arithmetic or algebraic expressions. A student doing verbal problems can pop up a summary of the real world principles and relations needed to solve the current problem or a table of the relevant quantities as expressed or evaluated thus far.

The basic algebra component of xyAlgebra comprises 330 instructional items, each typically requiring five to twenty minutes of work, and each introducing a single new concept or a significant new complication in an earlier concept. This helps students build expertise incrementally, one concept atop another. By any count counting method, xyAlgebra significantly surpasses most commercial packages in the number and variety of carefully graduated problems that it poses to students on each topic, typically by a factor of three. Moreover, several of the commercial packages do not randomly vary the coefficients of the problems they do offer, so that a student who comes back for a second try on a given topic encounters the identical problem sequence a second time.

An Unexpected Benefit

An unanticipated benefit that has accrued from using xyAlgebra is the pedagogical experience that it has provided to some City College undergraduate math majors and Master's candidates who have served as tutors in the departmental learning center. These tutors now look over students' shoulders, making suggestions and responding to questions. No other instructional or tutorial experience offers the same combination of personal contact with students and opportunities to observe how they work and how they learn.

Use on the Internet

By the end of the year 2000, a version of xyAlgebra will be available which offers instruction in basic algebra over the Internet. The student will run the program locally and it will constantly access the instructor's database maintained on the instructor's web site. Discussion among students and instructors will be supported.

Available for Download Without Cost

The entire xyAlgebra package is available for downloading without cost over the Internet. The downloadable package includes a site license permitting unlimited copying for academic purposes. The site address is: http://math0.sci.ccny.cuny.edu/xyAlgebra.

Building and Using Simulation Based Environments for Learning about Complex Domains

Marcelo Milrad
The Institute for Media Technology
LIST Group & EIST program
Box 450, 551 16 Jönköping
SWEDEN
marcelo.milrad@tm.imt.se

J. Michael Spector
EIST program
University of Bergen
N-5020, Bergen
NORWAY
michael.spector@ifi.uib.no

Pål I. Davidsen
System Dynamics Program
University of Bergen
N-5020, Bergen
NORWAY
pal.davidsen@ifi.uib.no

Abstract: A variety of substantive issues confront education with respect to technology support for learning increasingly complex knowledge. How can learners acquire and maintain deep understanding about difficult-to-understand subjects? We argue that because students are learning for real life and preparing to solve real complex problems in the future, the complexity of the world should be taken into account much more and much earlier than usually happens. In this paper we describe and illustrate our approach to the design of interactive learning environments for complex domains and the role technology can play on these environments.

Introduction

Current and emerging technological advances in Information and Communication Technology (ICT) make it possible to develop interactive learning environments to support new ways of learning. Interactive learning environments (ILEs) are having an increasing role in teaching and learning and are likely to play an important role in the future (Wasson, 1997). In particular, those tools that encourage and enhance discovery, creativity, thinking and expression are very much-needed (Fischer, 1999; Shneiderman, 1999).

Simulations as learning environments have had a long history of use in education and training (Roberts et. al, 1994) and have been based on a variety of theoretical views of learning. Along with increasing computational power, software has increased in complexity so that object-oriented systems can now be used to simulate devices of great complexity. Simulation learning environments are going to have a profound impact in the way we learn and teach about complex problems, both in the social and in the natural sciences. The key feature of an educational simulation is that it makes use of a model to represent a process, event or phenomenon, which has some learning significance. The learner is able to interact with this representation and the simulation provides intrinsic feedback that the learner can interpret as the basis for further interaction. The existence of an underlying interactive model provides the opportunity for a learner to formulate and test a particular hypothesis about a complex system or even to restructure the system. The underlying model may be mathematical leading to the generation of numerical results, rule-based with the intention of providing feedback on subjective input, or even context-based in that the learner is placed in a context that simulates a real situation.

A variety of substantive issues confront education with respect to supporting students learn increasingly complex knowledge with technology. How can learners acquire and maintain deep understanding about difficult-to-understand subjects? We argue that because students are learning for real life and preparing to solve real complex problems in the future, the complexity of the world should be taken into account much more and much earlier than usually happens. In the following sections we describe and illustrate our approach to the design of interactive learning environments for complex domains.

Interactive Learning Environments and Learning Theories

Emerging trends in education are increasingly moving towards learner-centered approaches. In these, learning becomes an active process of discovery and participation based on self-motivation rather than on more passive acquaintance of facts and rules (Sfard, 1998). The role of the teacher is coming more to be seen as mentor or guide, facilitating and playing an essential role in this process. From this perspective, learning can be considered as a dynamic process in which the learner actively "constructs" new knowledge as he or she is engaged and immersed in a learning activity (Papert, 1993). The theory of constructivism is at the core of the movement to shift the center of instruction away from delivery in order to allow the learner to actively direct and choose a personal learning path.

Heath (1997) recognises a trend in instructional design towards replacing traditional behaviorist approaches with constructivist orientations emphasizing the use of emerging technologies. Problem-based learning (PBL), an instructional strategy which emphasizes problem-solving in situated contexts, exemplifies situated learning. By incorporating interaction with an environment, cognitive conflict and negotiation of shared understanding, PBL provides an ideal vehicle for modeling constructivist approaches (Savery and Duffy, 1995). PBL is a type of case-based learning which places emphasis on solving authentic problems in authentic contexts. PBL also stresses the introduction of concepts in the context of such authentic problems.

In our approach to the design of ILEs for complex domains we are exploring the design implications of learning theories such as constructivism and socioculturism (Nardi, 1996) that have heretofore received less attention than, say, behaviorism (upon which computer-assisted instruction (CAI) is built) and cognitive psychology (upon which intelligent tutoring systems are built). Constructivism and socioculturism perspectives are consistent with each other; they just emphasize different themes: the former speaks to the individual's cognition, while the latter speaks to the contributions of the surroundings to that cognition.

Complex Domains

Complex systems can be depicted as a collection of inter-related items (e.g., stocks and flows in system dynamics), characterized by internal feedback mechanisms, nonlinearities, delays, and uncertainties (Sterman, 1994). These systems typically exhibit dynamic behavior, especially in the sense that how they behave has an effect on the structure of the system, perhaps strengthening or changing the feedback mechanisms. This change in internal structure in turn has consequences for how the system will behave in the future (Davidsen, 1996). Such complexity is difficult to understand, especially for newcomers to a complex domain. Complex systems can be found in abundance at many different levels. Economics, ecology, epidemiology, project management, and training all typically involve complex, dynamic systems. People have difficulty in understanding and making good decisions about such systems (Dörner, 1996). There are clearly individual exceptions, persons who somehow acquire a deep understanding of such systems. Typically, such deep understanding, characterized by effective decision making across a wide variety of changing conditions, takes years to acquire, and appears not to be easily acquired in spite of concentrated education and training efforts (Dreyfus & Dreyfus, 1986). Why have we failed to improve our thinking skills in complex domains in spite of such persistent and serious efforts? In part, we have not fully understood relevant psychological and sociological factors. In part, we have not fully integrated relevant principles about human learning into design praxis.

We believe that instructional scientists have not fully understood the socially situated learning perspective and its implications for human learning in and about complex systems. There is a great deal of discussion about situated, problem-based, and collaborative learning, but we are missing critical pieces of a design framework. Put differently, we believe that we lack a well-articulated design framework with sufficient detail to take us from a socially-situated, problem-based, collaborative learning perspective to the design of a particular learning environment for a particular subject domain. The closest such approach we find is cognitive

apprenticeship (Collins, 1991). We regard our work as an extension to that approach.

Designing a Simulation Based Environment for Learning about Complexity

One of the purposes with this research is to develop an interactive learning environment to support young learners' understanding in the domains of environmental sciences and ecology. The basic assumption is that environmental issues will become increasingly significant and much more complex in the next century. In order to meet new challenges and sustain an inhabitable global environment, we need to dramatically improve education at all levels in the environmental sciences. Therefore, there is a need for new tools to support complex learning in this domain.

Our approach is based on analysis of previous research on designing ILEs for complex learning (Arias et al., 1997; Enkenberg, 1995; Eden et al., 1996; Forrester, 1994; Spector, & Davidsen, 1997) and differs from these in three major aspects:

- It assumes that the integration of constructionism and systems dynamics is a powerful combination for the design of a new kind of complex task environment for simulating and thinking about real-life phenomena.
- It focuses on the significance and attainability of authenticity in learning scenarios.
- It argues that the design of ILEs for lifelong learning cannot be investigated in isolation by looking just at one small part of it, such as K-12 education, University education, or designers.

We have implemented an environment for school children which involves a LEGO-logo simulation as well as a physical experimental environment and some data modeling using live sensors in the experimental environment so as to explore how children come to understand the complexities of plant growth. This technological environment provides an experimental arena for learning in and about complex systems. The learning environment has then a LEGO-logo component supporting experiential learning and an experimental setting with sensors linked to computer modeling and analysis tools to support inquiry-based learning. Furthermore, we are designing a system dynamics web-based simulation, which will support policy design and promote transfer of learning to other complex domains. These three components proceed from the more concrete (LEGO-logo) to the more abstract (system dynamics). They are all problem-based but address different aspects of problem solving activities and behavior, proceeding from problems directly associated with a concrete and specific environment, to problems associated with hypothesis formulation in a concrete setting, and then to problems associated with abstraction, generalization, and deep understanding of underlying structural causes for observed model and actual behavior.

In order to promote meaningful learning in this kind of environment, we believe learners may begin with concrete operations, physically manipulating objects in order to solve specific problems. As these operations are mastered, they can then progress to more abstract representations and solve increasingly complex problems. Our approach to characterize this view with regard to implications for learning and understanding the complexities of plant growth is explained as follows:

1. Start with concrete operations. Introduce a specific problem *(PBL)* in the context of manipulating physical

things. In this stage students are involved in constructing and programming a lego greenhouse to grow herbs.

2. The next stage towards formal operational understanding is to introduce the first level of abstraction, still within the context of solving specific kinds of problems. This shifts the problem-solving context into something more appropriately supported with a dynamic or interactive simulation so that alternative scenarios and hypotheses can be tried out. This kind of learning is more abstract and can be characterized as *inquiry-based learning* to indicate that it is a different form of problem-based learning than that associated with the first and more concrete stage. In this stage learners are involved in the construction of a small greenhouse with

sensors and computer software to analyze parameters, make projections, formulate hypothetical explanation for observed results.

3. A higher level of understanding occurs when a learner is able to explain why things happen the way they do in a complex system. The focus of this kind of learning is not only to be able to predict what would happen under different circumstances but to be able to explain exactly why they will happen that way *(policy-based learning)*. In this stage learners are involved in constructing a synthetic reality (a simulation model) and using it to experiment with a variety of decision-making rules and policies.

Just as there has been a progression from simple and concrete to more complex and abstract when going from stage 1 to stage 3, within stage 3 we can image a similar progression from simpler representations to more complex representations. We call both of these notions (from stage 1 to stage 3) *graduated complexity*.

This work has been developed in conjunction with the Kreate-IT (Creativity, Technology and IT at elementary schools) project carried out by the Institute for Media Technology. Since September 1997, we have been working in the Kreate-IT project together with several elementary schools in Sweden. Target population of the project are students of the ages of 12 to 13.

Concluding Remarks

Our primary goal in this project is not to help young learners accomplish some task faster or more effectively, but rather to engage them in new ways of thinking and learning about complex domains, in particular those concerning environmental sciences. Our aim with the design of this learning environment and all the learning activities related to it is to bridge the gap between understanding the structure and understanding the behavior of dynamic systems. We want to demonstrate how mathematical intuition can be built without making use of detached formalisms and how this fact can help kids to describe and analyze a far wider range of complex models, based upon an intuitive systems understanding.

Furthermore, we are exploring the use of system dynamics to develop an educationally meaningful way to exhibit the relationship between the structure and the behavior of dynamic systems. We are pursuing a parallel effort, using an elaboration of the underlying framework, for adults learning about environmental issues related to marine biology. The new piece of the learning environment, in addition to those presented before, it will be the design and implementation of a web based simulation using system dynamics to facilitate understanding of particularly difficult aspects of the system (second order delays, non-linearities in the system, etc.). More broadly, we hope that these studies will help us to develop a richer theoretical framework for understanding the role of this new kind of learning environments for learning about complex domains.

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Using Controls to Construct Dynamic Spreadsheets for Teaching Math and Physics: the Design of Interfaces and Worksheets.

Simon Mochon
Department of Mathematical Education
Center for Research and Advanced Studies
Mexico
smochona@mailer.main.conacyt.mx

Abstract: In this article we discuss the advantages of using controls in spreadsheets for educational purposes. The most evident is that graphs change in a dynamic way, which gives a powerful visual support to the understanding of the situation represented in the spreadsheet. We will show some spreadsheets with controls that were designed for an educational project in Mexico to teach math and physics with computers. The article also describes the structure given to the corresponding worksheets and the pedagogical model followed within the classroom to ensure an efficient use of the computational activities developed.

Introduction

Some educational software like "Stella", "MathWorlds", "Interactive Physics" or "Physics Explorer" have controls, like sliders or spinners, as their standard arsenal of tools. Spreadsheets however, up to recently, didn't have this valuable option. In this article we will show the educational advantages of having this type of controls in spreadsheets to change in an automatic way the values of some cells. These cells might represent parameters in a mathematical model or coefficients of a mathematical equation. When the controls are pressed to change their associated values, the graphs of the spreadsheet change in a continuous, dynamic way.
To illustrate the previous point, Figure 1 shows a spreadsheet of a mathematical model of the circulatory system which can predict for a wide variety of circumstances the arterial pressure as a function of time (it oscillates normally between 120 and 80 mm of Hg).

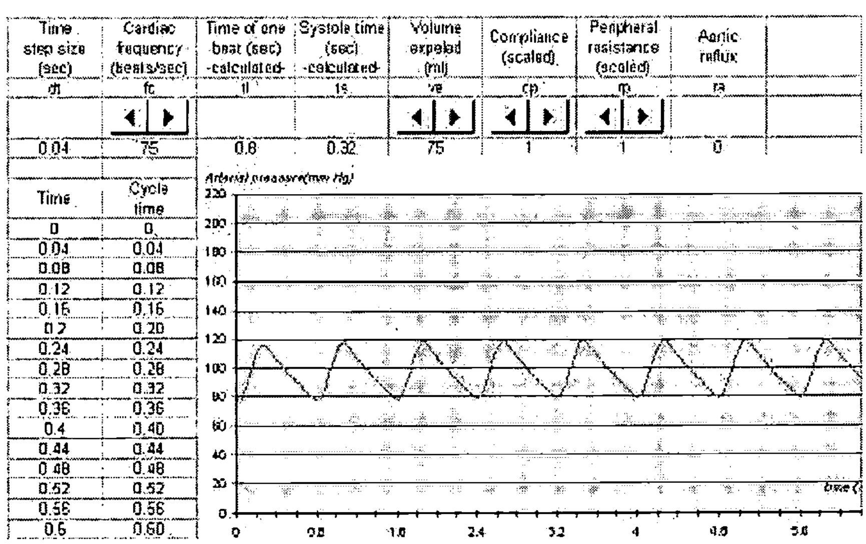

Figure 1: Math model of the circulatory system

With the four controls in the spreadsheet we can change many parameters of the model and observe their effect on the graph, in a continuous fashion. This is a very effective visual aid in understanding the behavior of the system.

The Ministry of Education of Mexico has being sponsoring, since 1997, a national program to teach mathematics and physics with technologies at the secondary level. In the first stage, relevant software was evaluated, both "tutorials" and "open" software. Although using open software implies more preparation work, its advantages outweigh this disadvantage.

The tools chosen for the math classroom are a combination of calculators (TI-92) and computer 'open' software: Spreadsheets (for all topics), "Stella" (Modeling package), "MathWorlds" (Mathematics of Change package) and "Cabri" (Dynamical Geometry package). Also, in the physics classroom there are a few tools used in the classroom like "Interactive Physics", NIH-Image, sensors and Spreadsheets (for all topics).

Parallel to this education project, there is an ongoing research project that has as its main purpose to investigate the impact of this technological implementation in students' learning, teaching practices and curricular transformation.

In this paper we will describe some of the spreadsheets with controls that were designed for this educational project. . We will show the advantages that controls like sliders in spreadsheets offer for a dynamic analysis of the changes of graphs involving parameters. At the conference we will also present a few interfaces with controls designed with Interactive Physics for a course at the secondary level (on mechanics).

The computer interfaces or the spreadsheets built, can be ineffective, if the students are left alone to "explore" them. Some guidance is needed to ensure the students discover important ideas. Thus, a worksheet for this is recommended. In this paper we will describe a structure for the worksheets that has proven to be very useful. In addition to these two components (computer interface + worksheet), we need a pedagogical model to follow inside the classroom. We will also discuss briefly this issue in this article.

The Spreadsheets Design

In this section we will show some of the spreadsheets with controls that were designed to use in the math and physics classrooms (in this paper we can only show a static version of the screens. In the oral presentation we will be able to demonstrate more fully the dynamic power of the use of controls in a spreadsheet for educational purposes).

Figure 2 shows a spreadsheet with the graph of a general quadratic function ($y = a x^2 + b x + c$), where three controls change the three coefficients:

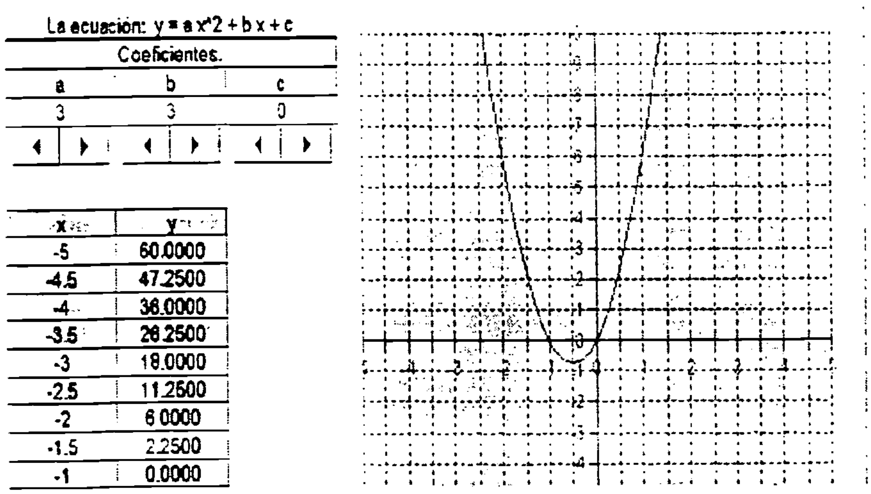

Figure 2: Spreadsheet with the quadratic function graphed

As the controls corresponding to the coefficients a, b or c are pressed, the graph will move accordingly to these changes, making evident the effect of each of the coefficients on the graph.

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Figure 3 shows a spreadsheet where a problem is represented graphically for the students to explore the situation and solve a few questions (Problem: Two retirement plans: 1. Get $1000 yearly after the age of 60. 2. Get $600 yearly for 5 years starting at 60 and then $1200 yearly after the age of 65. What plan is better? Why?) With the controls we can change any of the three quantities mentioned and the age where the new rate of the second plan goes into effect.

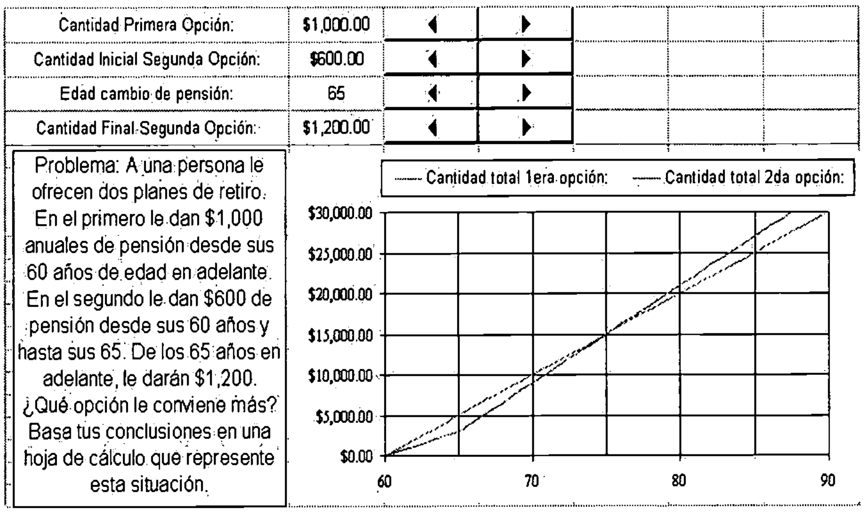

Figure 3: Spreadsheet containing a problematic situation

Figure 4 shows a spreadsheet where two waves (one coming form the left and one coming from the right) are added. We can change with the controls the amplitude and the wavelength of each wave and the time in a dynamic way to see the whole system moving.

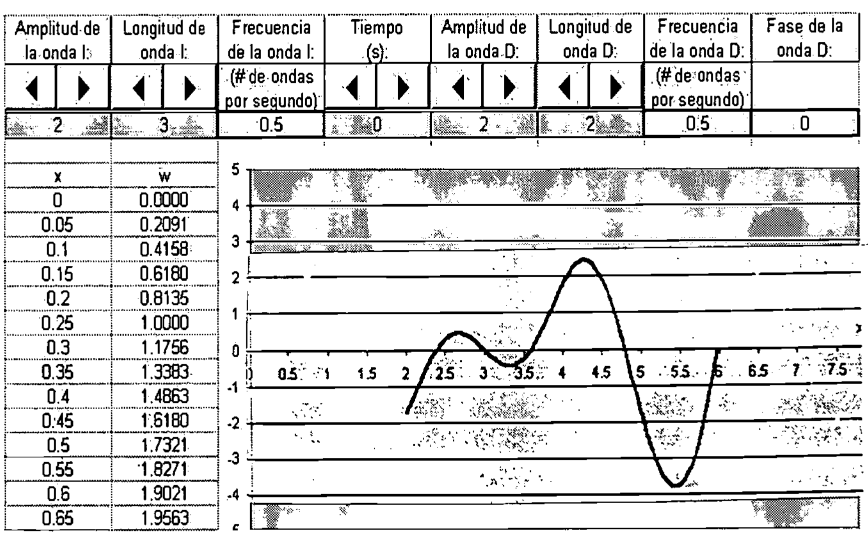

Figure 4: Spreadsheet where two waves are added

Figure 5 shows a spreadsheet with a graph (temperature versus time) where heat is supplied to a piece of ice and the phase changes to water and then to vapor is represented. In it, the pressure, the mass and the rate of heating can be varied with controls to observe the effects.

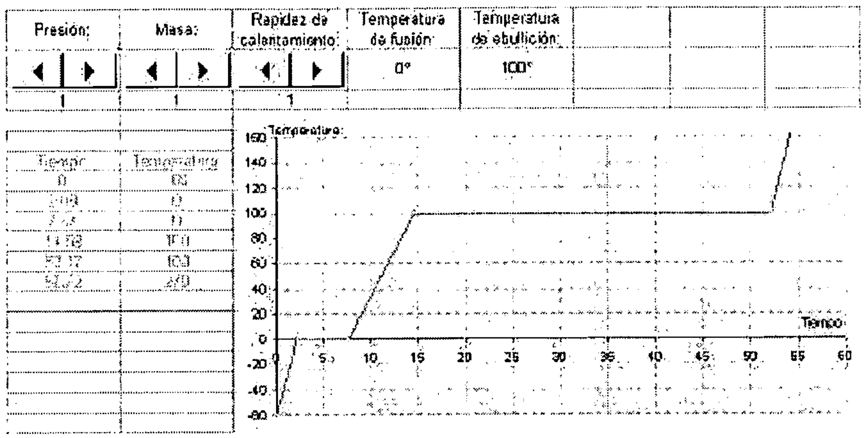

Figure 5: Spreadsheet where phase changes of water are represented graphically

Structure of the Worksheets

Within the classroom, we have used very effectively a teaching strategy that in part consists of coupling a math modeling approach with worksheet guidance. A recent antecedent of this method is a collaborative Mexico/UK research project (Sutherland et al, 1996) aimed at investigating the role of modeling with spreadsheets across a range of subject areas (physics, chemistry, and biology). In this research, the spreadsheet was introduced into the students' science classrooms to construct models, "artificial worlds" (Mellar et al, 1994), that were explored and analyzed and which enhanced students' understanding of the scientific ideas related to the model.

The construction of spreadsheets falls into two different categories. In the "expressive" type, the students built their own spreadsheets with the guidance of a worksheet. In the "exploratory" kind (like the ones shown above with controls and others without them), the students get a previously designed spreadsheet to explore some important ideas, also through the guidance of a worksheet. Here we will talk briefly of both cases.

For expressive type activities, we developed a structure that is useful to follow in designing the worksheets. In the next lines we give the sequence followed and explain its purpose:

A. Posing a problematic situation. A real specific situation as a context helps the student to give meaning to the mathematical concepts and the methods he is learning.
B. Intuitive questions to reflect on the problem. The purpose of these questions is for the student to understand the problem posed and to draw some expectations about the results he will get afterwards with the computer.
C. Solving the problem with the technology at hand. This is the main part that contains the didactical objective defined for the activity.
D. Questions about results, challenges and open questions. Here the student should analyze the results obtained and be able to apply them to other situations. In this stage, the student should be left to explore his own ideas (the teacher should encourage this).
E. Discussion and conclusions. It is important for the student to summarize his conclusions and present them to the whole group. This is a very rich interaction between students, which the teacher should only steer in the right directions.
F. Extra work. A group is always heterogeneous. For those students that finish the main sections listed above, the worksheet should provide with extra, more challenging work (of course, if this is done, not all the students should finish completely with the worksheet given).

As can be observed, the worksheet starts with very directed tasks and progressively leaves the student with more freedom to try his own ideas.

On the other hand, for exploratory type activities, like the ones shown with controls in this article, the structure of the worksheet is more relaxed, but anyway is needed to guide the student in searching in relevant directions. To illustrate, the following is a worksheet associated with a spreadsheet shown before, containing the graph of a quadratic equation:

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Graphical exploration of the equation: $y = a x^2 + b x + c$

We know now that an equation of the form: $y = a x^2 + b x + c$ $(a \neq 0)$ *has a parabolic graph. In this activity you will discover the effect that the values of a, b and c have on the graph. For this, open the Excel file "CuagMove.xls".*

First, increase and decrease the control corresponding to the value of c. Describe in the following lines your observations. Does the shape of the parabola change or only its position? (If you are not sure, copy the parabola in a piece of paper and compare it when you change the value of c):

____

In particular, look at the graphs with c = 5, 4, 3, 2, ... to determine what this parameter represents graphically. Write your conclusion:

____

Reset c to the value zero. Increase and decrease now the control corresponding to the value of a. Describe in the following lines your observations. Does the shape of the parabola change or only its position?

____

Last, increase and decrease the control corresponding to the value of b. Describe your observations. Does the shape of the parabola change or only its position?

____

Keeping the value of "a" fixed at 1, vary the value of b. Observe in each case the x position of the minimum. What conclusion can you reach?

____

In general, the position of the minimum (maximum, for "a" negative) occurs at $x = -b/2a$. *Verify that your previous conclusion agrees with this expression for* $a = 1$.

There are an infinite number of parabolas with the minimum (maximum) at $x = 0$. *What value of b all of them should have? ______. Your task now is to describe these parabolas according to their values of a and c:*

____

There are an infinite number of parabolas that cut the x-axis at –4 and 0. You task is to discover the relationship of their coefficients a, b and c. Describe your conclusions:

____

Discuss with the whole group and your teacher the conclusions of this investigation.

Pedagogical Model

The pedagogical model for the project mentioned in the introduction has several important components, some of which will be enlisted as follows (we should clarify that this model can be applied very well to a normal classroom where other technologies or none are used):

- ✓ The work of the students is directed through worksheets. These have the main objective to guide the students to "discover" the particular knowledge that the teacher is interested in having them learn.
- ✓ The students become the most important element in the classroom. Through active participation and their own reflection, the students construct their concepts and develop abilities.
- ✓ Communication is a very important element in the learning process of the student. Thus, the work is done in groups of two or three students, to foment interchange of ideas between them.
- ✓ The role of the teacher in the classroom is mainly as an advisor to the students. He has three different ways to interact with his students:
  - Through the design of the worksheets themselves.
  - Inside the classroom as an assistant to students' work.
  - With whole class discussions to bring out the most important ideas of the worksheets (even here, the teacher should let the students be the most active part of the discussion).

Conclusion

The use of controls in spreadsheets has the potential to revolutionize the educational practices in math and other sciences where mathematical models with graphs can give a good image of the situation involved.
It is not enough to design appropriate interfaces for a particular open software, in particular for spreadsheets. These must be accompanied by worksheets directing the work of the students so they can discover relevant ideas. We suggest that these worksheets could start directing the students in the right path and then giving them more freedom with challenging problems and open-ended questions. Also a more appropriate pedagogical model is needed for these circumstances.

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Creating microworlds for exploration of mathematical concepts

Nicola Yelland
Queensland University of Technology
Centre for Mathematics and Science Education
n.yelland@qut.edu.au

Abstract: This paper describes the strategies and interactions of pairs of children (average age 7 years 4 months) while they worked on novel tasks in a computer microworld embedded within a mathematics curriculum. The curriculum encouraged the active exploration of ideas in both on and off computer tasks, which complemented each other. Observations of the children supported the notion that the active construction of knowledge in a computer supported collaborative learning context, enabled the children to engage with powerful ideas and use metastrategic strategies. Further, their spontaneous comments and persistence with tasks indicated a high level of interest and enthusiasm for the tasks.

Introduction

Papert (1980) conceptualized a microworld as a "place, a province in mathland, where certain kinds of mathematical thinking could hatch and grow with particular ease" (p.125). In this context, a microworld was perceived as an incubator of ideas and intellectual structures. More recently, Noss, Healey and Hoyles (1997) have suggested that the term has come to include almost any exploratory learning environment that includes a computer. They noted that originally a microworld was "simultaneously rich and simple enough to study learning behavior (originally, of machines)" (p. 210) and promoted the notion that both of these components should be considered in any conceptualization today. Papert (1980) considered microworlds as powerful environments for learning because they provide the opportunity for children to make sense of ideas in a context where true and false, right and wrong are not the decisive criteria. In a (computer) microworld the learner is able to actively explore concepts in new and dynamic ways which would not have been possible without the technology, and in doing so constructs knowledge that has meaning for them.

The teaching of mathematics has undergone many and significant changes in the past decade. The emphasis placed on the development of a deep understanding of mathematical concepts and processes via active learning, inquiry and problem solving has spearheaded the reform movement (National Council for the Teachers of Mathematics, 1989, 1991). Further, mathematics has been characterised much more in terms of the learners ability to do it rather than know about it. Mathematical contexts which engage the learner with the processes of the discipline have been encouraged so that deep understandings and engagement with concepts is promoted. These have specifically focussed on such processes as, generating and solving problems, looking for patterns, formulating and testing hypotheses, conjecturing, evaluating constraints, predicting, justifying, to name a few and all of which serve to indicate the dynamic nature of the subject rather than a view that it is a body of knowledge. As a result of this thinking, those interested in the teaching of mathematics have spent a great deal of time thinking about activities and tasks which embody the new philosophy. "Tasks convey messages about what mathematics is and what doing mathematics entails." (NCTM, 1991, p. 24) and as such have become important contexts for teaching and learning. Noss et al (1997) have suggested that we should be exploring the potential of environments that help students to make and build connections and derive mathematical understandings using tools that may assist them in the process. Here the concept of a microworld takes on particular meaning since tasks are embedded within an environment that has been specifically designed to support the learners understanding.

Method

The study was designed to examine the social cognitive interactions and learning of pairs of students as they engaged mathematical tasks in a computer microworld. The unit of work used was How Long? How Far? Which is part of the

Investigation in Number, Data and Space series that incorporates the use of Geo Logo. How long? Is a Year 2 module that enables children to explore the concept of length and in doing so incorporates the use of many other concepts and processes inherent to mathematics, since learning does not occur in isolation. The sequence of activities fitted within the scope of local curriculum documents (Education Department of Queensland, 1987) but facilitated exploration with the inclusion of the computer based problem solving tasks.

There were 28 children in the study who worked in one of three types of pairings, boy, girl or boy/ girl. The children were in their second year of schooling in an Australian State which does not have an introductory (compulsory) kindergarten year. The average age of the sample was 7 years 4 months with a range from 6 years 10 months to 7 years 11 months.

The sequence of tasks in How Long? How Far? included both on and off computer tasks. The content of the unit related to the exploration of linear measurement and involves the processes of determining, analyzing and comparing both arbitrary and standard units of length. Traditionally the concept of length is introduced with the application of arbitrary units of measure so that children can explore the relationship between distance and the number of units needed. Once the need to keep the number constant and relevant to the size of the distance is realized children can use standard units of measure to construct paths and determine their lengths. In How long? How far? This process is developed via both computer and pencil and paper based tasks that are characterised by active exploration and investigation.

In the first computer based task, called Steps, the pairs of children took turns to direct their individual turtle to a randomly generated item with steps of the same size (Figure 1). In the next activity, Giant Steps, although their items were placed at an equal distance from each turtle, they had to use different sized steps in order to reach the item (Figure 2). Next there was a maze task (Figure 3) in which the children were required to collaborate in order to take a mother turtle to her baby, located at the end of the maze. The final two activities of the unit were completed first off the computer and then on it. They involved directing an ant and turtle respectively around a make believe town in order to visit various locations. An integral part of the task was that the turtle had to be "recharged" at a battery stop after ten distance moves.

Results and Discussion

Throughout this research it was evident from the spontaneous comments of the children as well as the time on task that they were engaged in the activities with a high level of concentration and that they found them both challenging and fun to complete. The *How Long? How Far?* length microworld seemed to be a useful media in which to explore concepts in a way that would have not been possible without the technology. It was also apparent from the transcripts of the videotapes that the strategies and interactions of the children were different and task dependent. Additionally, their conversations revealed knowledge about the relative lengths of distances, which they articulated in comments to each other. The data from *Steps, Giant Steps and Maze* will be presented and discussed in this paper.

Steps and Giant Steps

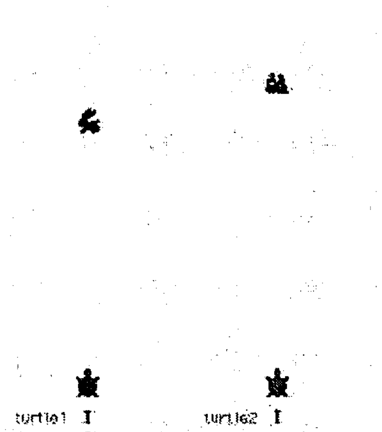

Figure 1 Steps Task

In *Steps* the children were able to explore and compare the number of steps needed to reach two randomly placed objects. It was interesting to note that this activity did not encourage collaboration, as each child in the pair had their own turtle. However, in many instances the partners helped each other in order to decide what number should be used for the move. It was also interesting that only three boy pairs made the game a competition with a winner (and loser). None of the girl or boy/ girl pairs did this but rather helped each other with offers of advice and suggestions, irrespective of whose turtle was being moved. The spontaneous comments of the children also indicated that they perceived the further away the object from the turtle the harder the task. This was evident especially in the competitive boy pairs, just mentioned who made comments like, "it's not fair, mine is more than yours!" or "I always get the long one… it is more…"

The other notable feature about the children completing the task was that they tended to be conservative in their estimates of distance and number. Each of the 14 pairs had three turns on this activity and only 5 "overshoots' of the object were recorded. Thus, the predominant strategy was to edge up to the turtle. This has also been noted in previous studies (Yelland, 1993, 1994a, 1994b, 1995) and has serious ramifications for completing tasks that incorporate the use of turns which will be discussed in relation to the maze task which followed steps and giant steps. The most successful pairs, that is those who got to the object using the least number of moves, were those that used a visual approximation strategy using the step size as a guide to reach the object and related their present move previous moves ones. It was apparent that these children could then link these skills to their previous knowledge about number and operations in order to ascertain the distance that needed to be traveled by the turtle in order to reach the object.

In *Giant Steps* the importance of using connections between step size and number became even more important and the most successful were those who made their number connections explicit. Again they did this in basically two, inter-related ways, namely by visual approximation and counting and with reference to previous moves. This is illustrated in the following vignette:

B2: (counts up the screen with his fingers and squints as he decides on the amount) f2 (then deletes) … 7 …(and reaches the turtle on the first go!) YES!!!!…. on my first go!
B1: He got it on the first go (clicks on turtle 2)
B2: Do double 7 'cos yours are half the size
B1: No… let me (as he looks at the screen) … 15… 16
B2: No… go forward 14! Because this is double the size of that (points to screen)
B1: OK forward spacebar 17
B2: NO!!!! It's 14
B1: It's going past… Thanks a lot V! (he blames the partner who in fact suggested the correct move)
B2: Excuse me… hey… I did 7 steps and double 7 is 14. Now you are going to have to go back 3
B1: forward.. no back 3

In some cases the relationship between moves became complicated and the children had to ask for assistance or use a calculator to figure it out.
In one game two girls had completed the first move with stepsize 2 and had entered f 12 so that the turtle was just short of the object. They then ask the researcher:
G1: What's 2 lots of 12?
R: What's two lots of 10
G1/ G2: 20
R: and two lots of 2
G2: 2 plus 2 is 4
R: so what's 20 and 4
G1: 24! Forward space 24…. No it has to be a bit more… shall I do 25 or 26 (asking advice of her partner who shrugs her shoulders) forward space 26. (As she presses return and the turtle moves to the object and arrives right on it) … Whew! I got it!

It was thus apparent that in the computer based tasks the children were not only gaining experience with measurement in terms of estimating, determining and comparing distances as they were in the off computer tasks, but also that the computer environment was conducive to interactions between the pairs which forced them to use number and compare numbers in new and dynamic ways not evident in the off computer contexts.

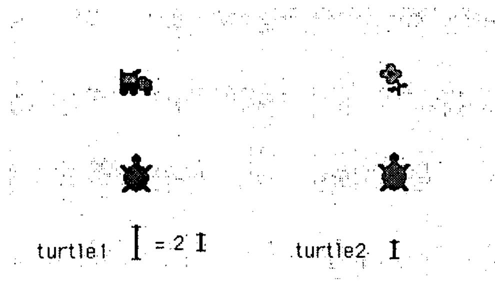

Figure 2 Giant Steps

Maze

The ability to use steps of different sizes to complete the task was also evident in the Maze task. The pairs completed the task twice, using different sized steps ranging from 1 to 3 (1 being the smallest and 3 being three times longer). Additionally, in this task, turns were introduced for the first time.

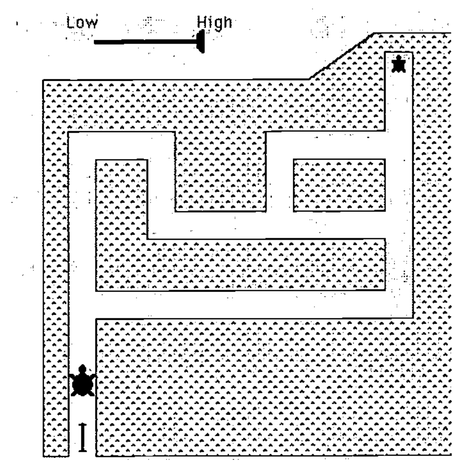

Figure 3 Maze

As with previous research (e.g. Bartter, 1988; Geva & Cohen, 1987; Yelland 1994b, 1995) it was noted that young children experienced more difficulty with turns than for distance moves. With reference to this particular task, many children were in fact, not only having problems with distinguishing left from right but also did not position the turtle correctly before attempting a turn. Most frequently they did not direct the turtle far enough down the path segment before attempting the turn. This meant that they became frustrated when they subsequently turned, to discover on the next move forward the turtle would hit the side of the maze. They always needed help to get out of this situation, as they were reluctant to delete moves as demonstrated to them in the introduction. All "hits" to the side were as a result of this. None of the children made moves which were overestimates of distances, and would have resulted in the turtle hitting the side of the maze. This "edging up" the path was similar to the strategy deployed in Steps and Giant Steps.

If the children made a turn which resulted in the turtle facing in the opposite direction to head down the maze they considered this to be a wrong turn. None of the children in this study used the back command to send the turtle back down any stretches of the maze. They all used forward after positioning the turtle at a corner.

With respect to the distance moves, that is the forward moves required to get the turtle through the maze to the "baby", all of the pairs seemed to adopt a strategy of edging up the paths, as previously noted. There was no evidence to support the idea that they were adhering to the task requirement to use a minimum amount of energy as shown on the energy making in their decision making. This was a stark contrast to previous work with older children (Yelland, 1998) where

the desire to conserve energy was a prime factor in decision making at every stage of the planning and monitoring of progress in the task. The children in this study were reluctant to change distance moves once they were made. When a move was short they would add on the required amount rather than delete the move and enter the number that would take them to the precise point where the turn could be effectively made. In these initial experiences in a novel computer context the children were attempting to make sense of their ideas (Noss, 1984) by playing with the turtle in a number of different ways. They were also demonstrating their ability to use metastrategic processes (Davidson & Sternberg, 1985) in novel problem solving contexts. This was evident when they, revealed that they understood the task demands and developed a plan to complete the task requirements which involved the selection of suitable processes for solution, monitored their progress, and responded to feedback from the system as they moved on to the next part or revised their plans to accommodate new information as it arose. It is hypothesized that this active exploration enabled them to use concepts of number and measurement in new and dynamic ways by virtue of this computer context.

All the children in the study completed the task without running out of energy. It was evident that some pairs were monitoring their progress along the way by noting their comments, such as, "we are going ok"... " we have enough (energy) left to get to the baby ..." "We are nearly there and the mummy is pleased". It would seem as if the task structure was such that the pairs were not forced to reconsider their initial plans at each stage of progress. The energy meter did not put pressure on the children to change their moves as it does in the next unit of the Investigations series (Yelland, 1998).

The final point to note about this task was that the children did not spontaneously collaborate in order to complete the activity. The most salient observation was the regularity of the alternate turn taking whereby each child had a turn at the keyboard. Some listened to the advice of their partner while it was their "turn" and others did not. This aspect would warrant further investigation as one of the main findings here was related to the observation that the pairs of children did not seem to want to discuss aspects of the task with each other, at length. In fact the only pairs to ask for information or advice about moves were in girl pairs. However, they often seemed to seek reassurance from each other.

As previously stated each pair completed the maze on two occasions. This meant that they had the same maze but with different sized steps so the input numbers needed to be varied. Only 3 pairs out of the 14 made statements to indicate that they were making connections between the different sizes and the relative sizes of each in these initial experiences. All the other pairs completed the tasks as if they were two separate ones.

In one example of making connections two girls have the following discussion on their second maze
G2: They're smaller steps.... This way again (pointing)
G1: Do you think so? Yeah!
G2: So they are smaller so the number will be bigger more... what was it last time?
G1: was it 2 or 3?... 2!
G2: No 3 – look ...1,2,3... so this time it will be 6. No that's too many. It is less!
G1: how about 5?
G2: No try 4 and then we can change it if it's too much...
G1: forward space 4 (the turtle goes too far) OH!! It's too much it should be forward space 3 (she deletes the previous move and enters f3 as she speaks)... That's it. Now your turn to turn.

Conclusions

This study explored the strategies and interactions of children in a computer based microworld related to the concept of length. The context for the study were tasks that included both on and off computer activities which enabled the children to explore ideas in ways that would not have been possible without the technology. At all times the children were engaged with the ideas that were embedded in the tasks and revealed a high level of interest and enthusiasm throughout the study. It was apparent that the children were working mathematically using the ideas inherent to the concept in effective ways and indeed able to examine their actions in detail and develop skills in metastrategic thinking during their problem solving.

Additionally, it was observed that the type of task influenced the nature of the interactions between the pairs of children. In Steps and Giant Steps where each child had a separate turtle to direct, we noticed that some pairs of children took this as a sign to develop the activity into a competition to see who could get their turtle to the object first. In contrast in the

Maze and Tina the Turtle activities the pairs of children were more likely to confer about the nature of the task and suggest moves to each other, even though this was to a lesser extent than with older children (Yelland, 1998).

The most salient observation was related to the ways in which the children were able to experience the concept of length in the microworld context. Curriculum documents note similar sequences of activities to develop the concept in the early childhood years and the range of activities presented in most text and activity books are somewhat limited. In this particular microworld the children have the opportunity to make sense of the ideas in a variety of contexts and we observed them achieving this while at the same time extending their problem solving and communication skills. The work in this microworld complimented other studies using this environment (e.g. Yelland, 1998; Yelland & Masters, 1997), which have revealed similar results in terms of making sense of ideas, developing conceptual understandings in new and dynamic ways and extending metastrategic thinking. Finally, one of the most revealing aspects of the work has been the high level of enthusiasm with which the children embark and maintain throughout the tasks, from children who, at the start of the study indicated that they thought mathematics was "boring sums".

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A Computer Simulator Can Transform "Dictums of Authority" into "Evidence" For Model Construction in Physics

Valerie K. Otero
Center for Research in Mathematics and Science Education
San Diego State University
United States
votero@crmse.sdsu.edu

Fred Goldberg
Center for Research in Mathematics and Science Education
San Diego State University
United States
fgoldberg@sciences.sdsu.edu

Abstract: Urban systemic reform initiatives call for increased use of computers in K-12 science classrooms. It therefore becomes increasingly important to understand how particular types of computer software and pedagogical structures can support interactions that lead to meaningful learning by students. In this paper, we describe some results from our research that focuses on learning in a collaborative-inquiry science classroom. We have found that the computer can make a difference in this environment. We discuss how special computer simulators made it easier for groups of students to construct explanatory models. It did so by providing the opportunity for students to make model-like observations that could not be made using hands-on apparatus. Model-like computer results helped students bridge the gap between phenomenological and conceptual domains.

Introduction

In the science classroom, students often have difficulty distinguishing between observation and inference. When asked to form an explanation or explanatory model that can account for an experimental result, many students end up either repeating the experimental procedures or simply describing the result (Kuhn, 1993). This difficulty can serve as a barrier to learning because constructing conceptual models is often the goal of an inquiry-based science course. The problem is particularly acute for prospective elementary teachers because they typically have little science or mathematical experience. Our research in a physical science classroom during the unit on static electricity and magnetism revealed that the computer played an important role in the type of explanatory models that students constructed. Relevant factors seemed to be the red and blue coloring model represented in the computer simulator. The learning environment in a collaborative guided inquiry physical science classroom often consists of small groups of students, laboratory apparatus, and pedagogical materials. In this case computers also played a large role. We consider the small group, the computer, laboratory apparatus, and pedagogical materials to be a *cognitive system.* We seek to understand learning in this complex environment by looking for things that *transform,* or change the nature of interactions within, this system. We therefore look not only at how ideas evolve within a group, but also at the roles that various components of the system play in mediating discussion and sense-making activity. In this paper, we describe how the static electricity and magnetism computer simulator transformed a cognitive system by providing a type of evidence that could not be obtained through laboratory apparatus.

Research Setting and Methodology

This article draws on research conducted in a physical science course for prospective elementary teachers at San Diego State University. The course is taught using a collaborative inquiry pedagogy that focuses on the building of conceptual models and makes heavy use of computers in the classroom (Goldberg, 1997). The course design was part of a five-year NSF funded project entitled Constructing Physics Understanding in a Computer

Supported Learning Environment (CPU Project)[1]. In a CPU course, students are in control of inventing science ideas. There is no textbook for the course; instead, students construct their own "textbook" from printouts of the computer activities they engage in a majority of class time. The main role of the CPU instructor is to guide periodic whole class discussions. The instructor provides very little direct information involving the content of physics but sometimes asks questions that lead to rich discussions in the whole class or in small groups.

Our research data were taken in a regularly scheduled CPU classroom. Students were videotaped during large class discussions, while they worked in groups of three with activity sheets and white boards at their desk, and while they worked in groups of three performing hands-on experiments and "computer experiments" using the computer simulator. Videotapes of the groups' discussions were transcribed and analyzed in several different ways. We also interviewed students outside of class and sometimes asked them to explain an event or comment they made in the videotaped data. Hypotheses about ways in which students used the computer screen, the computer documents, and the computer simulator were formulated and triangulated using additional data from videos, interviews, and other sources.

The CPU Pedagogy and Simulator Software

Each unit in a CPU course focuses on the conceptual aspects of a specific subject area in physics, such as static electricity and magnetism. A major goal of the CPU pedagogy is for students to construct explanatory models of phenomena they observe. Many of the activities require that students to predict the results of an experiment and then to test their prediction by performing a hands-on experiment and/or a "computer experiment" using the computer simulator. In each case, students are expected to explain their reasoning and then to compare the results of their experiments with their predictions. When a group of students comes to a consensus on a prediction or explanation, they enter it into the computer either as text or as a picture. A whole class consensus discussion is held at the end of each cycle, in which the whole class is expected to come to a consensus on a small set of powerful ideas that can explain a majority of the observations made during the cycle.

The CPU simulator software includes both phenomenological and conceptual representations. The simulator shows what would happen in a hands-on experiment and overlays representations of a corresponding conceptual model. For example, the CPU static electricity simulators use red and blue lines to represent charge. The simple red and blue model is general enough to be consistent with several different conceptions of certain phenomena. This allows students at different stages of conceptual development (some students are initially intimidated by terms such as "electron" and "charge") to communicate with other members of the class and to begin to build an understanding of static electricity. An example of phenomenological simulator results is attraction or attraction between two charged objects. An object of conceptual simulator results is a *red-charged* pendulum that is attracted to a *blue-charged* insulator and repelled from a *red-charged* insulator (see Table 1). This property of dual representation helped students to make connections between their hands-on experiments and their evolving conceptual models of observed phenomena (Goldberg and Bendall, 1995). The red and blue coloring representation can serve as a conceptual bridge between students' initial ideas and the scientific model that would be the target of instruction.

The conceptual results offered by the simulator allow students to make "observations" that they could not make with apparatus. These model-like observations can help students make inferences more easily. The static electricity simulators provide a variety of tools and set-ups which allow students to make observations that are relevant to concepts in static electricity such as charge transfer by touching, charge polarization, and charging by induction. Selected examples of the simulator's phenomenological and conceptual components and how they are associated with formal inferences is shown in Table 1.

The simulator's model-like representation does not depict charge as discrete units and does not use the convention of positive and negative in the visual representations. These simulator results are governed by electrostatic theory but the interface between the theory and the students is a representation of red and blue lines.

With this red and blue coloring scheme, students can *predict* how an object should be colored to explain particular observations that they make in hands-on experiments. They can then perform a *computer experiment* and obtain model-like *evidence* to check against their coloring prediction. We therefore consider the

[1] The CPU Projet is supported by the National Science Foundation grant No. ESI-9454341. For more information about the CPU Project and software distribution please see http://cpuproject.sdsu.edu/CPU/.

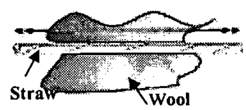
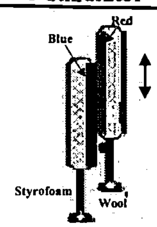
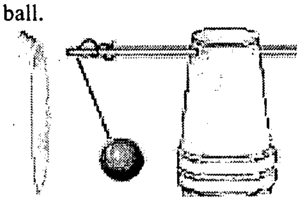
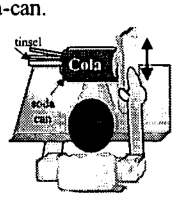
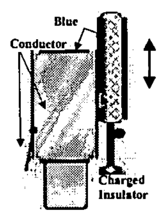
Phenomenological Observations Made With Apparatus	Phenomenological Observations + Conceptual Observation Within the CPU Simulator	Formal Inference With Scientific (Expert-like) Explanation
A straw is rubbed with wool. Once rubbed, the straw and wool exhibit electrical effects such as attraction and repulsion. 	 Insulator surfaces, when rubbed together, become colored red or blue with lines of equal thickness.	**Charging**: When two objects are rubbed together, negative charges are transferred from one object to the other leaving one with an excess of negatives and the other with a lack of negatives (or excess of positives).
A wool-rubbed styrofoam plate repels a hanging wool-rubbed styrofoam pith ball. 	 Red-charged ball is repelled from red-charged insulator.	**Repulsion:** Similarly charged objects repel each other.
Conducting tinsel sticks out away from a soda-can when charged object is rubbed against soda-can. 	 Blue line on insulator gets thinner as insulator is rubbed against conductor. A blue line appears on conductor.	**Charge Transfer**: The conductor is initially electrically neutral. After rubbing, negative charge is transferred from the insulator to the conductor. Since the tinsel is also a conductor it acquires the same charge and repels from the end of the conductor.

Table 1. Conceptual tools provided by CPU Static Electricity Simulators. Formal inferences (column 3) can be made from model-like representations (column 2) of the phenomena (column 1).

prediction of how to color an object to be a *concept prediction* and the simulator results to be model-like or *concept evidence* for that prediction.

The computer is not necessary for the introduction and use of this type of analogical model in the classroom. Students can make concept predictions using white boards, chalkboards, or paper and pencil. The difference is that with the computer simulator, relevant formal information is not given in the back of the book and is not revealed as the "right answer." Instead, it is revealed in the form of model-like evidence from a computer experiment that is performed by students themselves. Our data analysis suggests that students used concept evidence (model-like simulator results) in a way that was very similar to the way they used phenomenological evidence (what they actually observed with apparatus). Students did not seem to differentiate between the two even though from our perspective, they are somewhat different (see table 1). This suggests that students were not viewing a simulator result as a dictum from authority to be memorized and forgotten after the test. Instead, they were using this model-based information as evidence about which they needed to make sense to further develop their understandings of the phenomena.

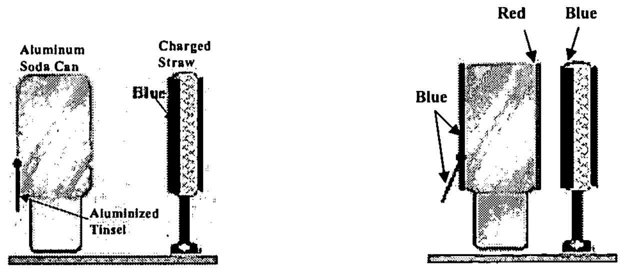
Research and Results

To illustrate how students used the simulator, we provide an example from an activity in the unit on static electricity and magnetism called the "Soda Can Electroscope". A soda can electroscope is an aluminum soda can, turned on its side and taped to an inverted styrofoam cup as shown in table 1, column 1. (Morse, 1992). Several

pieces of aluminized tinsel are taped to one end of the soda can. When a charged insulator is brought near, but not touching the soda can, the tinsel moves out away from the end of the conducting soda can.

A simple explanation, in terms of the scientifically accepted model of static electricity, is as follows. The aluminum soda can initially contains an equal number of evenly distributed positive and negative charges. When the negatively (blue) charged insulator is brought near the soda can, the freely moving, negative charges within the conducting can are repelled as far away from the negatively charged straw as possible, since like charges repel each other. As these charges move away from the end of the soda can nearest the straw, positive charges (which are not mobile) remain in place. Therefore this end of the can is left with a deficit of negative charge (or excess of positive charge) and is thus, positively charged. The far end of the can (the end with the tinsel) now contains an excess of negative charge and is therefore negatively charged. Since the tinsel is also a conductor, negative charges move through it also. Since the tinsel and the end of the can are now both negatively charged, the tinsel, which weighs very little and is semi-mobile, moves out away from the can. This separation of charge in the conducting soda can is a phenomenon known as charge polarization.

The CPU simulator result associated with this phenomenon is shown in figure 1. This model-like representation depicts a soda can that is colored red on the end nearest the blue-charged straw and blue on the end to which the tinsel is attached. The tinsel is also shown colored blue.



(a) (b)

Figure 1. The simulator results. (a) Before the charged insulator is moved close to the soda can. (b) After the charged insulator is brought near, but not touching the soda can. This is a fluid-like model of charge showing charge polarization in the soda can when a charged object is brought near.

The process of charge polarization is not fully explained by the representation offered by the simulator. The simulator depicts charge polarization in terms of a bipolar representation (red on one end and blue on the other). Although this can assist students in the framing of an explanatory model, it certainly does not explain why the tinsel moves out away from the soda can. The simulator result still requires interpretation by the students.
For the remainder of this section, we provide a specific example of how students interpreted and used the concept evidence provided by the simulator. In this example, a group of three students, Janet, Abby, and Max were working on the Soda Can Electroscope activity at their computer. During the first part of the activity the students brought a wool-rubbed straw (charged straw) near the end of the conducting soda can.

One question in the activity asked the students to color pictures of the objects (soda can and straw) in the computer documents using the red and blue coloring scheme. The directions required that the group decided on a prediction about how the soda can, tinsel, and straw should be colored to account for the observation. While framing their prediction, there was an interesting disagreement among the group members and a long discussion. They immediately discovered that they did not agree on how to color the soda can, even though they seemed to be aware of no disagreement when they had entered the answer in text in the previous step. The analysis of our data suggests that part of the problem was that each of their predictions of how to color the soda can seemed to be based on different fundamental assumptions. Throughout their discussion, they seemed to be inhibited from making progress toward a resolution because they did not make their assumptions explicit to each other, and perhaps to themselves. These assumptions involved whether the tinsel was repelling from the soda can, the charged straw, or whether charge was being transferred from the charged straw to the soda can, jumping the air gap.

We believe that because of the very different ways that the group members seemed to be thinking about the phenomenon, they could not come to a consensus on how to color the soda can. The discussion ended when Max suggested to Abby that they go to the simulator to "help clear [her] up." This is significant because it illustrates the group's expectation that some sort of "evidence" to help them evaluate their coloring prediction would follow.

After running the computer simulator, the group was faced with the task of interpreting the simulator results. This led to a collaborative construction of a robust, model-based, explanation.

When the students first saw the simulator results (see figure 1b) they were all very surprised. None of the students had predicted that the soda can would have two colors. Abby had previously argued for a coloring scheme that assigned red to the soda can and tinsel and blue to the straw. Janet had argued for a coloring scheme that assigned blue to the tinsel and straw. Max had argued for a coloring scheme that assigned blue to the soda can and straw. The students were faced with the problem of accounting for the red *and* blue that appeared on either end of the soda can on the computer screen. The discussion that followed led to the convergence of the three students' ideas and to the development of a group explanatory model that could make sense of the phenomenological results.

The three students began to work together to make sense of the simulator results as soon as they appeared on the computer screen. In the face of this new evidence, the students shifted from tenaciously adhering to their initial ideas and began to consider alternative points of view. The model-like simulator results provided a context for the members of the group to evaluate their own ideas as well as the concept evidence directly on the computer screen. The computer screen served as shared space for representing their ideas. By simultaneously interpreting these results and applying their ideas, each student was able contribute sense-making insights that led to the group construction of a model. For example, Max noticed that the end of the soda can that was closest to the straw was colored red and the straw was colored blue. He therefore suggested that the soda can and the straw were attracting each other since opposite "forces" attract. Abby then continued to say that the blue charges in the soda can must therefore be repelling from the straw and moving to the other end of the soda can, making it (and the tinsel) blue charged (see figure 2a). After this, the group members began to support each other's ideas, finish each other's statements, and converge on a conceptual model of charge polarization that was supported by a discrete model of charge. Immediately following the construction of their explanation, Max suggested that they repeat their explanation using the actual apparatus. At this time, Abby picked up the straw, pointed toward the soda can and began to reiterate the group's model (see figure 2b). An excerpt from this dialogue is given below.

Janet	So we're making blue charges [as Abby rubs the straw with wool].
Abby	We're making blue charges [rubbing the straw with wool].
Abby	And this is red charges [pointing to part of the soda can]. And when we're doing this, all the red charges [in the soda can] are coming up [towards the straw] (see figure 2b).
Abby	They are coming to get this [the charged straw], because it's attracting the opposite.
Janet	Cause it's attracting the opposite
Abby	So all of those reds are coming here towards the blue - In turn making this blue [pointing at the end of the soda can with tinsel attached].
Janet	cause there is no red ones left down there [on the end of the soda can near the straw] or whatever.
Abby	And the tinsel is blue so it's (Pause) It's repelling from it.

In the dialogue above, Abby and Janet were jointly explaining the explanatory model that the group established after interpreting the simulator results.

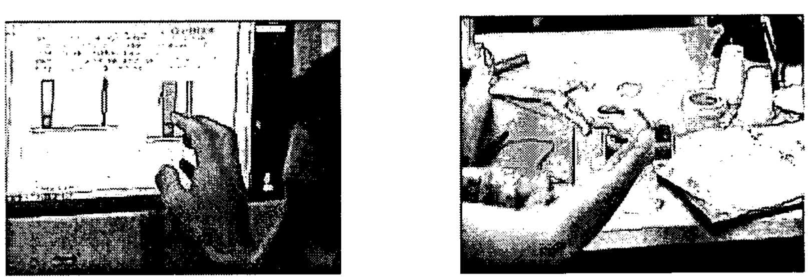


Figure 2. The coloring model helps bridge the gap between phenomenological to the conceptual domains. Students use concept evidence (a) to help them make sense of the phenomenon (b). The picture on the computer screen in (a) is similar to the computer results shown in 1(b).

The final model with which the group ended this segment of the activity provided a mechanism by which the soda can obtained a different charge on both ends. This explanatory model made use of their prior knowledge that opposite charges attract and like charges repel and that conductors differ from insulators because charge can move freely through a conductor. It also made use of newly developed knowledge; that, to begin with, the conductor contains equal amounts of both kinds of charges. Although their model was not exactly the target model for the course, by the end of this initial sequence of questions, their individual models had evolved into a group model that was much more closely aligned with that held by the physics community.

The Computer Simulator Transformed the Task of Constructing Explanatory Models

The computer simulator played a significant role in the process of knowledge construction. The inclusion of a concept prediction, a computer experiment, and concept evidence transformed the task of constructing an explanatory model. This process is outlined in Table 2. In traditional inquiry courses, students make predictions, perform experiments, and make observations and obtain evidence. They are then expected to jump directly into the task of constructing an explanatory model (see column 2 in table). In the CPU static electricity and magnetism unit described above, students still made predictions, performed experiments and made observations in the phenomenological domain. However, instead of having to jump directly into the task constructing an explanatory model, they made use of the *conceptual tools* provided by the computer. The conceptual tools allowed them to make a prediction, perform a computer experiment, and obtain evidence *in the conceptual domain* (see column 3 of table). As they evaluated concept evidence on the computer simulator, these students moved easily from the phenomenological to the conceptual domain and then were able to relate their resulting model back to the phenomenon (see figure 3).

Domain	Traditional Inquiry Approach	Using Model-representing tools
Phenomenological	♦ Make Prediction ♦ Perform Experiment ♦ Make Observation & Obtain Evidence	♦ Make Prediction ♦ Perform Experiment ♦ Make Observation & Obtain Evidence
Conceptual	⬇	♦ Make "Concept Prediction" ♦ Perform Computer Experiment ♦ Obtain "Concept Evidence"
Both	♦ Construct Explanatory Model	♦ Construct Explanatory Model

Table 2. CPU simulators transform the model building task by providing conceptual tools.

Summary

This paper has elucidated ways in which the computer simulator transformed the cognitive system. The simulator results were used as a sort of evidence to assist in the formulation and development of explanatory models. Students treated this type of information more like phenomenological evidence than like "the right answer," or dictums from authority. We believe that this is due to the fact that they actually performed their own computer experiments in order to obtain the information. Students used this information to help them to *develop* their conceptual models rather than to *replace* them. The process of making a concept prediction, performing a computer experiment, and obtaining concept evidence transformed the task of model building by providing conceptual tools as well as phenomenological tools.

The Physics Education Research Group at San Diego State University continues to look deeply into the *process* of knowledge construction in a computer supported learning environment for prospective elementary teachers. These future teachers will ultimately find computers in their own classrooms. We feel that it is important to provide these teachers with experience using the computer and an understanding of ways in which the computer can influence the pedagogy. In addition, we continue to look closely at the influences that the computer has on the process of learning so that we can better understand and extend the usefulness of computers in the science classroom.

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From the Abstract to the Practical: How Motion Media Grapher Helps Students Understand and Interpret Abstract Mathematical Concepts

Evangeline S. Pianfetti
Office of Educational Technology
College of Education at the University of Illinois, Urbana-Champaign
esecaras@uiuc.edu

Brian M. Pianfetti
Department of Educational Psychology
College of Education at the University of Illinois, Urbana-Champaign
bpianfet@uiuc.edu

Abstract: Hiebert & Carpenter (1992) state that "school-learned procedures often cannot be used flexibly to solve problems other than those on which they were practiced, and thus, do not transfer well (p. 79). The Motion Media Grapher (MMG) is a Web-based software utility created by the authors of this paper to help students make the link between the abstract mathematical concepts they learn in the classroom and their occurrences in the real world. The students may easily interact with the MMG and it may be efficiently adapted by classroom teachers for integration into an existing curriculum. The MMG attempts to enhance the students' internal representations with socially situated events. Hence, the concepts are taught through their application in familiar environments and not in abstraction. Based on a yearlong research study, this paper introduces its readers to the MMG and discusses its efficacy as a visualization tool for high school mathematics students.

Introduction

Hiebert & Carpenter (1992) state that "school-learned procedures often cannot be used flexibly to solve problems other than those on which they were practiced, and thus, do not transfer well (p. 79). The Motion Media Grapher (MMG) is a Web-based software utility created by the authors of this paper to help students make the link between the mathematical concepts they learn in the classroom and their occurrences in the real world. The students may easily interact with the MMG and it may be efficiently adapted by classroom teachers for integration into their existing curriculum. The MMG attempts to enhance the students' internal representations with socially situated events (Lave, 1988). Hence, the concepts are taught through their application in familiar events and not in abstraction. Based on a year-long research study, this paper introduces its readers to the MMG and discusses its efficacy as a visualization tool for high school mathematics students.

Functionally, this Java-based utility consists of three interconnected components that can communicate with each other over the Internet. Succinctly stated, the Motion Media Grapher uses the interconnected components: digital video, a graph and a numeric table, to present students with multiple and situated representations of a single event (Feltovich, Spiro, & Coulson, 1989). Specifically, for this research project the events represented either a linear or a non-linear function. Students can plot a point on either the video or graph component or enter numbers in the table component. The same data is then automatically represented on the other two components; thus, the students can see how ideas have application in both the abstract (represented by the graph and table) and in practical forms (represented by the video component). More importantly, this network tool is designed so that students may generate their own problem sets and integrate their own digital video. By so doing, the MMG may be used as a performance assessment tool. For example, armed with a camcorder, students may videotape events that represent the concepts they are learning about in class. Familiar events such as shooting a free throw then become one of many practical applications of an abstract concept such as non-linear functions.

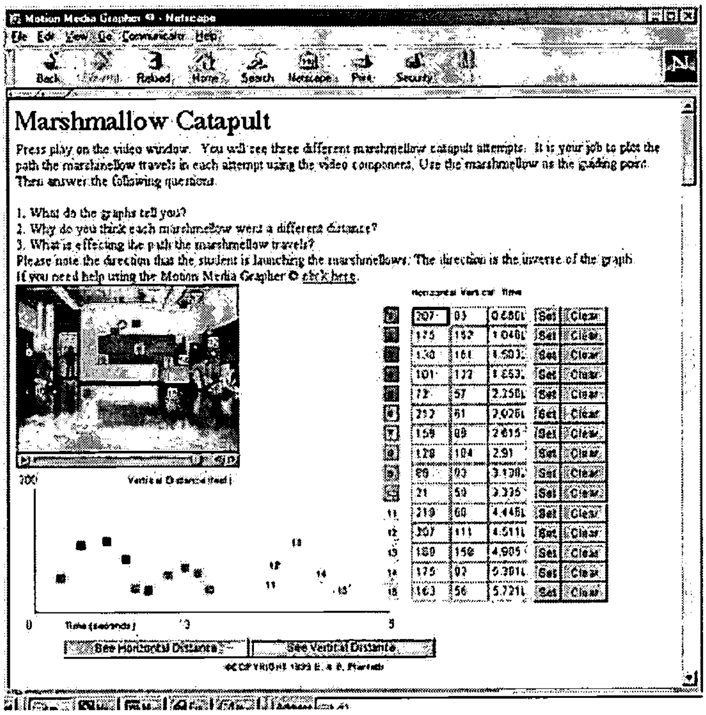

Figure 1: Screen capture of the Motion Media Grapher (MMG)[1]

The Research Study

The questions addressed in this study were:

1. How can technology, specifically digital video, be used to help students understand and interpret functions in applied settings?
2. What impact does technology have on the way students learn to understand and to interpret functions in applied settings?
3. How can technology, specifically the Motion Media Grapher, be integrated within a high school mathematics classroom?

These questions center around three core issues. One is a cognitive issue that deals with the students' interpretation of visual representations and their ability to apply abstract concepts to familiar events. The second one is a technical issue that deals with determining the appropriate technology for presenting this knowledge. The third is an instructional issue dealing with how best to integrate the selected technology.

This year-long study was conducted in three phases. In the development phase, four high school upperclassmen adapted the Motion Media Grapher for use on a Web site they created for freshmen algebra students. This Web site, the MathNet Web site, included mathematical problem sets developed by the upperclassmen. In addition, the upperclassmen videotaped and digitized the content displayed by the video component of the Motion Media Grapher. In the evaluation phase, six high school sophomores conducted formative evaluations on the MathNet Web site that aided the upperclassmen in their final design of the site. In the end-user phase, twelve high school freshmen used the MathNet Web site to supplement their classroom instruction on functions. An adaptation of a situated evaluation was employed as the chief methodology (Bruce & Rubin, 1993).

Theoretical Foundation

[1] http://www.cuout.com/education/mmgrapher/Motion_Media_Grapher.html

The literature suggests that students have a tendency to develop distinct, preconceived notions of what a graph should look like and these notions frequently foster misconceptions of what is actually represented. Kaput (1994) suggests that this phenomenon occurs because in average mathematics classes, teachers tend to present a reductive view of mathematical concepts. The complex math concepts are oversimplified with the hope that the students would better understand them. Consequently, the students tend to perceive what they learn in their mathematics classes from a textbook perspective. What the "textbook perspective" means is that students perceive mathematics as only applicable to problems as they appear in their textbooks. Thus, the students have difficulty transferring what they learn in class to events they may encounter in their daily lives. These misconceptions tend to flourish because the students have difficulty comprehending abstract concepts, such as distance over time, and applying them to concrete events, such as a car driving down the road (Mokros & Tinker, 1987; Barclay, 1985).

In an attempt to help students better understand these abstract concepts, technology is used in many math classrooms. For instance, programmable graphing calculators facilitate the efficiency by which students can solve and graph equations. The cumbersome longhand calculations are no longer necessary. Computer software packages, such as Geometers' Sketchpad, offer students the ability to draw and manipulate geometric shapes in ways that are not easily possible with pencil and paper. Technologies similar to these are touted for their ability to let students spend less time performing the actual calculations and more time interpreting and conceptualizing the ideas represented by numbers, by a graph or by a set of functions (Kaput, 1994; D'Ambrosio, 1985). However, Stanic & Kilpatrick (1988) suggest that "problems have occupied a central place in the school mathematics curriculum, but problem solving has not" (p.254). Although the technology affords the students the opportunity to spend time conceptualizing and interpreting, they still have difficulty understanding what the quantified solutions represent in terms of real world applications.

Similar to technologies being used in mathematics classrooms, video as a technology has been readily utilized in a variety of classrooms (Valmont, 1995; Fabel, 1991). The inclusion of visual technologies has fueled debates over their effectiveness. But there is not enough significant research to determine definitively the effect of video as an instructional tool. In this area more research is still need. Yet, research has shown that video is engaging and motivating (Heinich, Molenda, Russell & Smaldino, 1996). Moreover, it offers students the abilities to witness situations that they otherwise might not have had the opportunity to experience because of physical and personal barriers (Valmont, 1995). Additionally, teachers use video technology to maintain the students' attention,

> while people growing-up with more traditional forms of education have been more print-oriented, today's students' cognitive learning styles and information processing abilities might be heavily influenced by exposure to mass visual information offered by television and video. (Valmont, 1995, p.12)

Considering the advances in network technologies, the MMG blends the advantages of both video and the Internet so that students may be actively engaged in authentic learning activities.

The Study Results

Results from this study suggest that learning may occur in new and often unforeseen ways with the introduction and integration of an emergent technology such as the Motion Media Grapher. In addition, three key issues emerged: 1) Digital video may be used as a situating medium. In so doing, it may help students visualize abstract mathematical concepts by representing their application in familiar events. As a result, selection of visuals was of utmost importance; 2) The use of multiple representations may demonstrate the interconnectedness of ideas, but students do have difficulty reconciling multiple representations to determine whether or not an answer was reasonable given the context of a problem; and, 3) The newness of a technology such as the Motion Media Grapher challenged the end users because they were not accustomed to using multiple representations to solve problems.

Discussion of the Results

Importance of visuals

One of the upperclassmen participating in this study showed significant growth in her understanding of functions as well as in her understanding of how visuals can empower students by authenticating what they are learning. Conversely, she came to understand that the inappropriate selection of visuals could in fact misrepresent the content. She learned that technology should not transcend learning. In her own words,

> I think like we almost have to pump them up with math. You know take it a little away from the focus of 'wow, look at the graph, look at the movie' and say, 'okay so why does this work' ... we [shouldn't] take away from the purpose of the page - learning math.

The upperclassman was working on a problem set that centered on the descent of a fire escape. She wanted the students to determine if the fire escape descended in a linear or non-linear path. In shooting the video, the upperclassmen were limited in where they could position the camera. Consequently, when the video was digitized, She realized that in considering the Cartesian plane, the fire escape moved solely within the second quadrant. Hence the corresponding plots on the graph would have negative numbers for the 'x' and the 'y' axes, but a positive slope. She believed that this perspective would confuse the freshmen who had only completed one semester of algebra; therefore, she attempted to horizontally flip the video.

> The freshmen students might think that the slope was negative because of the negative 'x' and 'y' values and because visually the students would see the fires escape moving downwards. [The freshmen] may associate the downward movement with negative numbers and forget that a negative divided by a negative number is positive. They might think it had a negative slope.

She was considering the larger impact the video might have on the students. She did not want to confound the understanding of math by misrepresenting the mathematical concept because of a limitation of the video. She knew that the video she collected was misleading and did not want the visuals to "obscure the math" and subsequently obscure the learning.

Challenges with multiple representations

One of the problem sets created by an upperclassman questioned the amount of time a basketball was in the air upon shooting a free throw. Of the twelve freshmen answering this question, only one team of two answered correctly. They answered the problem correctly because they reconciled all three perspectives. In their own words,

> Well, we looked at the video and found the spot where the ball left the [player's] hand and then we looked at the graph and the table and subtracted those numbers. We didn't just look at the numbers in the table because then you wouldn't know when the ball was like really in the air and not in the girl's hand. And then you needed to look at the graph to make sure we were measuring the right distance. Looking at all three [components] helped us like, well, you know, think about what the answer should be. Like on the [TI-82s] you don't actually see the ball in the air - just the graph so yea, this helps.

The students who answered incorrectly stated that they relied on the graph and just subtracted the numbers and did not consider looking at all the perspectives to see if the answer was truly reasonable given the context of the problem. One student commented,

> It's like when you are asked to [calculate] the distance of something you usually just take the highest number and the lowest and subtract. I guess I didn't think about what the question was really asking. I mean, yea, now that you mention it I guess it makes sense to look at the video because then I know that exact place the [basketball] leaves her hands.

Articulating Ideas

From the data collected, it was apparent that the freshmen end-users had a more concrete understanding of function. They were able to articulate their ideas about functions more directly than before their interaction with the MMG.

> A linear function is where you put something in and get the same thing out. Like when you talk on the phone and someone talks back. ... and like gas, the more miles you go, the more gas you need.
>
> Or like when you are reading and fall asleep. You're taking your time, then you slow down and then you fall asleep ..
>
> ... and the line on the graph continues going, but the number of pages your read stay the same.

Although pre and post survey results indicated that the freshmen still had difficulty when tested on functions, dialog exchanges such as the one above suggest that the students were able to transfer the knowledge to familiar events when they are asked to articulate the association.

Conclusion

The data collected during this study suggest that digital video can help students visualize abstract concepts by making them more familiar to the students. The interconnectedness of the components would encourage more emphasis on interpreting what is visually represented. This research suggests that the digital video component helped to engage the students, as they became active participants in their learning process. As such, within a proper framework, the students could be engaged in interpreting the visual representations aided by the digital video.

Moreover, the National Council of Teachers of Mathematics (1989) has declared that " the 9-12 standards call for a shift in emphasis from a curriculum dominated by memorization of isolated facts and procedures and by proficiency with pen and paper skills to one that emphasizes conceptual understanding, multiple representations and connections, mathematical modeling and mathematical problems solving" (p.125). The use of various media as a means to present multiple, interlinked representations of a single concept is a key feature of the Motion Media Grapher. The interconnected components encourage the student to see how the different visual representations are related to each other. Ideally, these different perspectives would foster problem solving because the students would have to learn to negotiate the different representations and the meanings of the variables. Moreover, the digital video component offers a representation of a natural event and as such encourages the use of contextual problems to motivate and apply theory.

Although the Motion Media Grapher attempted to incorporate a majority of the NCTM standards, the data collected in this study suggests that students still may need additional guidance in learning how to reconcile the meanings of multiple representations. In essence, the effectiveness of the technology is largely influenced by the students' abilities to accept and interact with multiple representations of a single concept.

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Issues Involved in a Large Scale Implementation of Web-Based Mathematics Instruction

Michael S. Pilant
Department of Mathematics
Texas A&M University
United States
Michael.Pilant@math.tamu.edu

Robert Hall
Department of Educational Psychology
Texas A&M University
United States
bobhall@tamu.edu

Janice Epstein
Department of Mathematics
Texas A&M University
United States
Janice.Epstein@math.tamu.edu

Yvette Hester
Department of Mathematics
Texas A&M University
United States
Yvette.Hester@math.tamu.edu

Arlen Strader
Department of Educational Psychology
Texas A&M University
United States
strader@tamu.edu

Abstract: As the capability of the World Wide Web (WWW) for delivery of mediated instruction increases, it is natural to consider it as a primary delivery mechanism for distance education. Several issues must be addressed, however. Two of these issues, access and ease of use, are primarily matters of technology. As equipment gets better and more affordable, we move closer to the goal of "universal access." Two other issues, assessment and motivation, are more complex due to human factors, thus, involve long-term research efforts. This study addresses each of these issues but focuses principally on problems associated with assessing student performance and increasing motivation in mathematics via self-contained, interactive, web-based instructional modules. For the past several years, a traditional finite mathematics course has been the testbed for developing web-based instructional methods. Results from this long-term project are summarized.

Introduction

Texas A&M University has the nation's third largest campus (45,000) and the Department of Mathematics has over 13,000 students enrolled in courses annually. Two of the largest courses, *Finite Math* and *Business Math*, have more than four thousand students enrolled per year. The traditional format for these courses consists of three hours of lecture per week. Both courses require a graphing calculator (TI-83), but neither includes a computer laboratory component.

As part of a long-term project to explore the uses and impact of technology-mediated instruction (*Finite Math on the Web*©), the authors have developed a series of web-based instructional modules for finite mathematics. The instructional modules themselves are based on a series of Java applets, with supporting material and exercises written in JavaScript and standard HTML. The modules are designed to be self-contained and accessible through any current web browser (with Java, JavaScript, and stylesheets enabled). Tracking student progress through the modules is accomplished through JavaScript cookies.

The goal of this project has been to develop a series of interactive modules that present concepts in finite mathematics in an interactive and visual way. Modules include an assessment component to measure student learning. A total of 10 modules are planned. Beta versions of the first 4 modules (lines and slopes, least squares, sets, probability and statistics) have been incorporated into the finite mathematics curriculum during the past 2 semesters (Spring and Fall, 1999). See *http://www.math.tamu.edu/FiniteMath/Demo/* for access to demo versions of modules.

In the process of developing these materials, a number of issues had to be addressed before the modules could be incorporated into the standard curriculum. Initially, issues associated with student access (how are students going to find computers to log onto the program?) and usability (how can we ensure that students with different versions of different browsers running on different operating systems easily access the material?) dominated courseware development.

During the past two years, the University has provided thousands of computers in open-access labs funded by student computing fees to ensure that computing facilities are available to students. In addition, all campus residences have been networked with high speed Internet connections. Personal computer ownership among students has risen from about 30% to over 85% over the last seven years (Goetz et al., 1995 and Hall et al., 1999). The bottom line is that problems associated with physical access to computers have decreased dramatically and most students report that they are comfortable using computer software and network-based materials (Hall et al, 1999). One remaining problem occurs when large numbers of users try to access databases concurrently, typically during the first two weeks of class. A larger database server would eliminate this problem.

Once problems related to physical access were resolved, attention was directed toward problems associated with usability. Through classroom implementation, as well as student and reviewer feedback, we arrived at acceptable combinations of fonts, colors, screen sizes, styles, and frame arrangements that work for the majority of current browsers and operating systems. For maintenance of courseware, these have been incorporated into common JavaScript and stylesheet libraries.

Initially, it was thought that by making the courseware accessible and easy to use, we would encourage students to spend time online, interacting with the material, thereby enhancing their understanding of the course content. We developed Java applets that were flexible, interactive, and easy to use, to help students understand difficult core concepts associated with major topics in finite mathematics. For example, concepts related to slopes and least squares have proven difficult for students to grasp through static, two-dimensional illustrations. Through Java applets, however, visualization and interactive student experimentation (i.e., rapid prototyping of "What if..." scenarios) allow students to "step into" discovery-based learning environments. These environments have been promoted in the educational literature as foundational components of learning in contemporary classrooms. The popular belief seems to be,

> *If you put it out on the web, make it interactive, make it easy to use, then students will participate and they will learn...*

Data collected during the first semester that beta versions of the applets were made available (Fall 1998), indicated that students spent relatively little time, if any, exploring underlying mathematical concepts in these interactive environments. In other words, "we built it, but they did not come." When the applets were used by instructors during classroom presentations, student participation was high, interest levels were piqued, and it seemed to be easy to engage students in discussions about mathematical concepts and consequences. Why didn't we see evidence of this behavior continuing outside of class even when the applets could be used directly to solve problems on homework assignments or projects? What was missing?

At least four things, present in the classroom, were not a part of early versions of the courseware. Missing factors included instructional context, feedback (assessment), directed study, and reasons for students to participate. In the classroom, instructors did not use applets in an open-ended fashion. Rather, through guided questioning and demonstration aided by applets, instructors provided students with frameworks that could be used to interpret concepts. In other words, applets were embedded in specific instructional contexts. Student discussions provided opportunities for instructors to address gaps in student understanding and to provide feedback encouraging further questioning. In addition, demonstrations and guided questions directed students to explore important aspects of concepts not covered in previous discussions.

In the next iteration of the courseware (Spring and Fall 1999), we attempted to address the first three issues. To emulate the "directed study" aspect of instruction, we developed a series of *module activities* which introduce basic concepts (declarative knowledge), provide practice for basic algorithmic manipulation (procedural knowledge), and introduce more structured exercises to test advanced problem solving ability (strategic knowledge). This taxonomy was motivated by recent work in intelligent training systems (ITS) and work by Anderson (1998) and his colleagues in the areas of cognitive processes in learning.

To simulate the "instructional context" of the classroom, we developed supporting web pages to provide explanatory material within each activity. We provided instant feedback for **every** student response within each activity, as well as a series of practice problems at the end of each module, culminating in a graded quiz. Only the results of the final quiz in each module were sent to a central database (which is accessible by instructors).

The fourth issue, student motivation, is extremely complex. There are two components present in student motivation - internal and external. External motivational factors (such as grades or other performance measures) can be more or less directly influenced by instructors through incorporating the modules into the curriculum, for example, by offering points for participation and performance. Internal motivational factors (such as intrinsic desire to learn the material) are much more problematic. We have addressed some external motivational factors in the current version of the Finite Math courseware. In addition, we have some ideas concerning how to stimulate internal motivation. The next section discusses in more detail the pedagogical design of the modules, and of the component activities. The sections following that discuss motivation and assessment respectively.

Pedagogical Design

When the traditional finite mathematics course content was analyzed, it was clear that the subject matter was topical in nature, and could be organized into a small number of reasonably self-contained modules. Although the order may vary, the following form the central core of the business mathematics and the finite mathematics curriculum at Texas A&M University.

1. Lines and Slopes,
2. Least Squares,
3. Matrices,
4. Linear Programming,
5. Counting,
6. Sets,
7. Probability,
8. Statistics,
9. Applications (usually having to do with interest or finance)

Within each area, we noted that there were one or two core central ideas that could benefit from the development of a series of Java applets - primarily through interactivity and visualization of mathematical concepts. This led to the development of a web-based module, revolving around a core Java applet, with accompanying expository material. After several implementations, the following was adopted as a model for each module:

a) **Introduction**. Here the basic ideas and concepts were presented. The major goal was the motivation of the central idea of each module. The applets appear in a "tutorial" mode, with limited potential for interaction.

b) **Declarative Section** - Basic Understanding (Facts): After each block of factual material is presented, a series of multiple choice questions are presented. The student must answer these before progressing to the next activity.
c) **Procedural Section** - Algorithmic Understanding: To reinforce the basic algorithms in each module, activities center on using the applets to facilitate computations and answering simple straight forward questions.
d) **Strategic Section** - Problem Solving: After the student is familiar with the basic concepts in the module, and is comfortable with the applets, more complicated multi-step questions are presented. This reinforces problem-solving strategy.
e) **Graded practice exercises**. At the end of the activities in each module, a series of exercises is presented to the student. They are graded, and are intended to give immediate feedback on areas that might need further work. Each problem is graded and the student is told whether they are correct or not.
f) **Graded Quiz**. After the practice exercises, a series of questions is given to the student. They focus on the procedural and strategic components of the module. The number of correct answers is reported to the student, but not which problems are correct.

Student Motivation

From the beginning, one of the most important goals of the Finite Math project was to maximize student participation. In the early days of the project, participation by the students was optional, and implementation by instructors was optional. Apart from low response rate, it was difficult to measure the impact of participation on student performance. In the next phase of the project (Spring and Fall 1998), a grade was given to the students based purely on "participation." Participation obviously increased, but relating this to performance on exams was difficult. In the current implementation (Spring and Fall 1999), there are quizzes built into each module which allow for more detailed analysis of performance in outside-of-class activities. This in turn places a heavy burden on assessment and reporting.

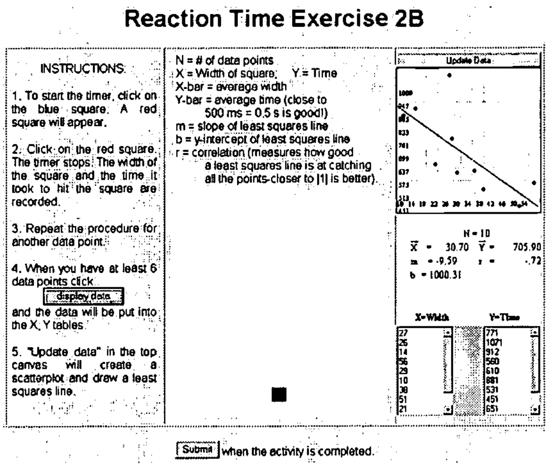
We have found that one of the strongest motivational aspects for students is the ability to repeatedly take practice tests in a controlled environment, in a timed fashion (to simulate some of the stress of in class exams), and with extensive reporting (diagnostics). We have pursued this as a separate research issue (see *http://onlinetesting.tamu.edu/*) but have incorporated aspects of this within the Finite Math project. It is clear to us that motivation, interactivity and feedback (through continuous assessment) are strongly related. If students can see the benefits of participation in outside of class computer mediated activities (e.g., through structured reviews and practice problems), this will increase their level of involvement in such activities. This is the direction of our efforts to influence internal motivational factors.

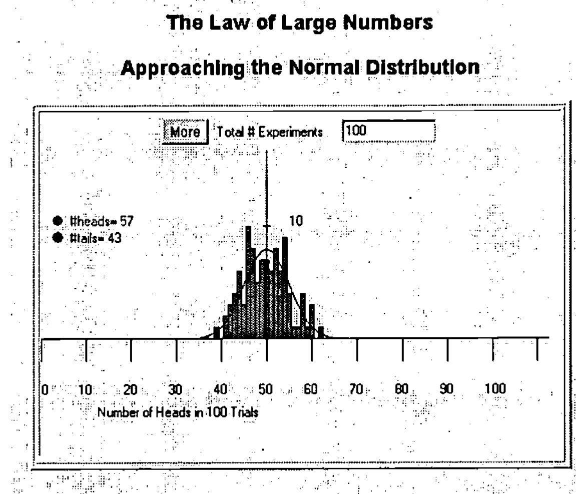
In last year's *MSET99* conference, we presented a statistical analysis of the impact of web-based-testing on student performance in an applied statistics course (Hall et al, 1998). A sample of approximately 45 students (3 semesters) were given the opportunity to participate in an *OnlineTesting*© program developed by Hall, Pilant and Strader. Because participation was voluntary, students self-selected into three groups. The first group interacted in a serious manner, as evidenced by response and time data. The second group interacted in a more superficial manner, and merely download the diagnostic output. The third group did not log into the system. A careful analysis of demographic information did not show any statistically significant differences in prior mathematics preparation, grades, performance goals, expectations for the course, etc. The only significant difference was in classroom test performance. The first group scored approximately 10% higher than the second group, and 20 % higher than the third group, over the semester. This is consistent with other published data on the effect of computer tutors on exam performance (Koedinger et al., 1995).

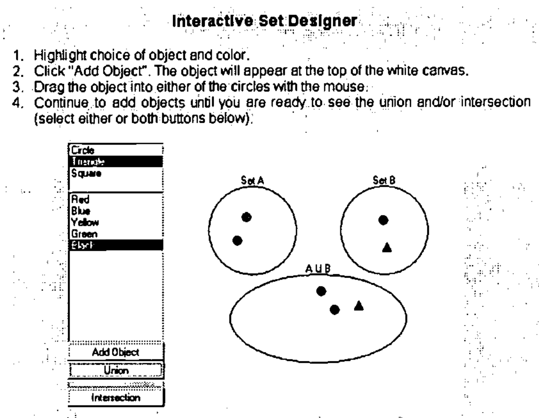
Assessment

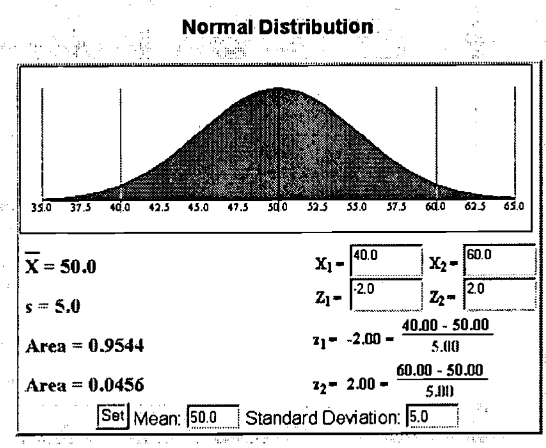
In addition to the simplest possible assessment tools (multiple choice and true false) which permit immediate feedback to the students, more elaborate question and answer dialogs were developed depending on the use of mathematical concepts via the applets. The ability to track students' computations, intermediate results, even their decision making, through the applets gives a much richer variety of questions and problems which can be posed. At the end, a small "vector" of information is passed to a central database for recording purposes.

Sample Screenshots









Summary

To summarize a number of observations we have made during the last two years of developing and implementing countless iterations of a series of web-based finite mathematics modules:

1. Physical access to computing facilities is becoming less of an issue, as prices for computing equipment decrease and network bandwidth increases.
2. Current browsers (Netscape 4.X and Internet Explorer 4.X) both provide extensive support for Java, JavaScript, and stylesheets. This allows effective maintenance of courseware through common JavaScript and stylesheets libraries.
3. The best designed instructional material, with the best available technology and best assessment instruments will be for naught in an asynchronous learning environment if the student does not utilize them or utilize them correctly!
4. "Assessment informs instruction." This means that in an asynchronous learning environment, with no teacher or other human interaction, it is necessary to make sure that the student is mastering concepts before going on to subsequent activities.

5. Students learn more when they are actively engaged in (and not just passively reading) content. This has become one of the main functions of the applets - to engage the student continuously as new material is introduced and tested.
6. Don't underestimate the importance of student motivation. In a voluntary, asynchronous learning environment, the emphasis has been on increasing student motivation through interactivity, through careful design of goals, and the availability of immediate feedback on performance.
7. When designing content where there is the flexibility of using student generated data, asking students to perform tasks, which then generate data to be used in subsequent activities, gives them ownership and increases participation.
8. One primary purpose of the applets is to reinforce mathematical concepts visually through interaction with a graphical user interface.
9. The applet (and courseware) interface must not interfere with the primary goal, which is learning the concept (not learning the interface!)
10. Simple applet interfaces based on mouse click or drag actions are very effective. Complicated interfaces, with pull down menus, and many options and parameters may look nice, but are very likely to distract and confuse a student.
11. Applets should be multi-functional, controllable through HTML tags
12. Cookies are very useful, keeping useful information on the client machine, and decreasing server-client traffic.
13. Directed paths for instruction are extremely useful.
14. Students are very concerned about accurate and timely reporting of assessment scores.

We believe that we have made substantial progress in incorporating web-based instruction into a large, freshman level, introductory math course. Our goal is to eventually develop a standalone, web-based finite mathematics course. A publicly accessible web site is available at *http://www.math.tamu.edu/FiniteMath/Demo/* although it asks for a login, this is for tracking purposes only, and no password is necessary.

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Technological Tools to Enhance Performance in Calculus I

Olga M. Ramirez,
John E. Bernard,
William Heller,
Wendy A. Lawrence-Fowler*,
Gerald Brazier,
Roger Knobel
Department of Mathematics,
*Department of Computer Science
The University of Texas-Pan American
Edinburg, TX
(USA)
oram@panam.edu , bernardjet@panam.edu

Abstract: In 1998, the Minority Student Improvement Program at the University of Texas- Pan American, Edinburg, Texas began the process of developing and implementing an enhanced instructional model for Calculus I that integrates technological tools for teaching and evaluation of learning purposes. The objectives of this work focus on developing and disseminating an affordable, highly interactive, student-centered learning environment which will increase success rates for minority science and engineering students enrolled in Calculus I. As a result of the project, faculty aim to better help students gain understanding of different types of significant mathematical knowledge that will further assist them to succeed in Calculus I and beyond. A questionnaire was developed to assess descriptive and content knowledge variables. The preliminary results of the data collected via the questionnaire comprise a part of this paper, as well as the ramifications of the students' level of preparedness as measured by key questionnaire items, and some specifics about the instructional modifications that are being made to meet the students' needs.

At the University of Texas – Pan American, the traditional teacher-directed, skill-driven, student-passive lecture model has primarily characterized instruction in Calculus I. 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. The Minority Student Improvement Program is currently offering Calculus I curriculum revisions that embody an interactive, hypermedia learning and teaching environment that incorporates student-centered activities. The locally created hypermedia Calculus I curriculum modules serve as medium for presentation and demonstration and provide a personalized environment for each student. 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. Nonetheless, even now, as a result of the project, mathematics faculty aim to better assess students' level of mathematical preparedness, offer enhanced instruction to help them gain greater understanding of different types of significant mathematical knowledge (e.g. concepts, generalizations, procedures, and facts). 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.

To date, the results of the locally constructed questionnaire reveals that for the data available on 100 of 143 students enrolled in five sections during the Spring, 1999 semester, approximately 63 % are males, and 37 % percentage are females and that the majority of the students, 87%, are either classified as freshmen, sophomores, or juniors, with only 2% classified as beginning freshmen, and 11% as seniors. The overall mean grade point average for these students is 2.75 (SD = .699; Median = 2.825), for male students the mean grade point average is 2.69 (SD = .774; Median = 2.80), and for female students the mean grade point average is 2.85 (SD = .547; Median = 2.85). Approximately 44% of the students were repeating the course, 26% had taken the course the previous semester, one of them almost 20 years prior. Furthermore, the greater portion of students, 35%, are majoring in engineering (e.g., Electrical, Manufacturing, Mechanical, Engineering), and 16% are majoring in either Biology or Chemistry, 13% in a medical field (e.g., PreMed, PreOptometry, Pharmacy), and the same percentage in mathematics. The rest are either majoring in business, computer science, education, or another field. Interestingly, while 24% out of those that took the questionnaire expected an A only 12% actually got A's, and while 54% expected a B only 15% actually got B's. Overall, 84% expected either A, B, or C, but only 51% actually got an A, B, or C. Overall, on a revised version of the Aiken Attitude Scale (Aiken, 1972), the students' measured a mean of .976 on a scale from –2 to 2, indicating that they

had a slight positive attitude towards Calculus I. The only item on the scale for which the students indicated a slight negative response revealed that they were not necessarily "happier" in a Calculus I class as compared to other classes, but overall the scores revealed that students enrolled in Calculus I were not fearful of the course nor did they dislike the course. Collecting and analyzing these data help point out elements in the students' affective backgrounds not otherwise available via mere content examinations. Additional data is in the analyses process and final outcomes are not yet available; yet, it is anticipated that as a result of the project, a clearer profile of Calculus I students will surface and the information will be helpful in enhancing instruction to meet their needs.

Assessing Conceptual Understanding for Calculus I Readiness

The level of readiness for Calculus I is important to the project and was measured using a six-item instrument checking selected calculus-specific prerequisites. The items included: embodiments of the concept of distance, questions on understanding graphing calculator output and limitations, the applications of algebraic and trigonometric principles, and relating the size and direction of changes between independent and dependent variables in functions or compositions of functions. It is expected that the gains in understanding students' readiness levels will help with the alignment to supplementary leveling instruction that will bring students up to par where gaps in their mathematical content background exist.

Analysis of Variance (ANOVA) of the readiness and course grade information available for 100 of the 143 Spring 1999 Calculus I students was non significant ($p = 0.126$) at the $\alpha = 0.05$ level when all grade levels were considered, including drops and withdrawals. However, interesting patterns were noted. There was, for example, a statistically significant relationship ($p = 0.039$) in the B - C grade range: students getting B's for the course scored, on average, about nine percentage points better on the readiness instrument than those getting C's [43% versus 34%, respectively (The overall readiness success rate was 36%.)]. The variance in readiness performance was greatest by far among the students who failed the course, than for any other subgroup. Additionally, there tended to be more variability in the readiness performance of the A-students than either of the B or C groups. Two sample readiness items are discussed in the following.

Readiness item #3, presented to the right, showed a consistent relationship to grades ($p = 0.011$) in general, and B-C grades ($p = 0.012$) in particular ($\alpha = 0.05$). The item assesses the ability to recognize the use of prerequisite algebraic and trigonometric principles essential in understanding and processing, for example, limits of difference quotients in the fundamental construction of derivatives.

#3. Which FOUR(4) of the following principles are essential in the transformation from $\frac{\sin(x+h)-\sin(x)}{h}$ to

$$(\sin(x))\left(\frac{\cos(h)-1}{h}\right)+(\cos(h))\left(\frac{\sin(h)}{h}\right)?$$

Note: Encircle only 4 choices.

A. $\sin(x)+\sin(h)=2\sin\left(\frac{x+h}{2}\right)\cos\left(\frac{x-h}{2}\right)$	B. $\frac{ab}{c}=a\left(\frac{b}{c}\right)$
C. $\sin(x+y)=\sin(x)\cos(y)+\sin(y)\cos(x)$	D. $\frac{a}{b}+\frac{c}{d}=\frac{ad+bc}{bd}$
E. $\sin^2(x)+\cos^2(x)=1$	F. $ab+ac=a(b+c)$
G. $\sin\left(\frac{x}{2}\right)=\sqrt{\frac{1-\cos(x)}{2}}$	H. $\frac{(a+b)}{c}=\frac{a}{c}+\frac{b}{c}$

Readiness item #4, to the right, showed a statistically significant ($\alpha = 0.05$) relationship with B-C grades ($p = 0.013$), but not grades in general ($p = 0.280$). The latter might be influenced by the rather low success rate, 11%, for this item. This item checks intuitive foundations for understanding and doing "epsilon - delta" proofs.

#4. Given the real number a, what is true about all of the random numbers generated by $a+\frac{\frac{-1}{2}+rand}{1000}$ where *rand* is a calculator/computer command that returns real numbers less than or equal to one.

A. They are all less than or equal to a
B. They are all within d units of a where $d = 0.01$
C. They are all within e units of a where $e = 0.0001$
D. They are all greater than of equal to a
E. They are all greater than a

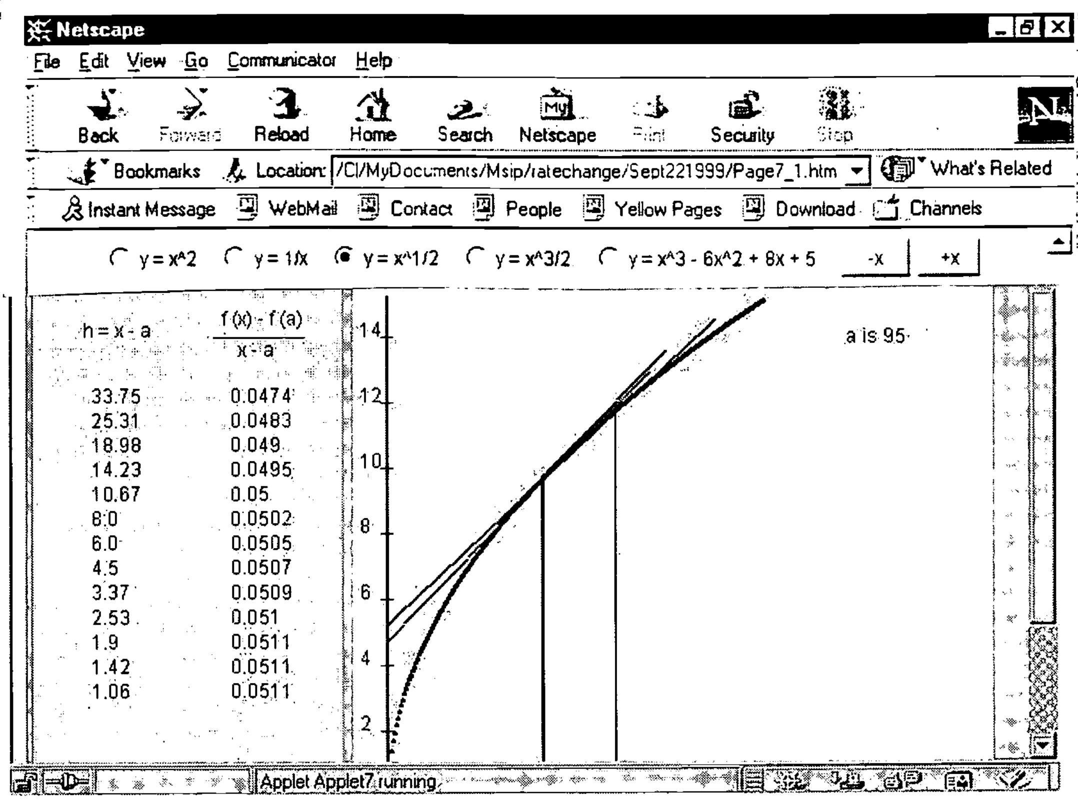
As final notes in this section, there was a statistically significant relationship between final grades and self-reported study time ($p = 0.044$). About half of the students indicated being employed: mean ≈ 25 hours per week, standard deviation ≈ 11.832 hours per week. Employed students tended to do less well grade-wise and on the readiness test, although this was not a statistically significant difference. Perhaps most employed students adequately compensated in budgeting their time as their self-reported study time (mean 4.619) was greater than that for those not employed (mean 3.538), though not at a statistically significant level.

Sample Modules

While the profile and readiness levels for Calculus I students are being determined, providing an electronically enhanced teaching and learning environment conducive to active, discovery-oriented, group-supported learning that will help students learn better has also been a means to learn how the students react to diverse means of instruction. In particular, technological implementations such as WEB-accessible modules are being developed to engage students in supplementary instruction that aligns with homework covered in the course.

For example, Module 1 **(see Figure 3)** is an animated limit process for determining the slope of the tangent line to a curve at a point. The graph of the curve is displayed (in blue), along with the tangent line (in red) at a point chosen by the student user. The x-coordinate of the selected point is displayed in the upper right hand corner. The program then displays the secant line (in green) from the user chosen point to a second point chosen by the program. The distance between the two points is reduced by moving the second point along the curve closer to the fixed point by clicking on the "-x" button. The program updates the graph to show the new secant line and reports the slope of the secant line in a table. After clicking several times the program produces a table showing the horizontal distance between the points and the slope of the secant line joining the two points. The user clearly sees the table of slopes approaching a limit, and can then verify whether that limit is indeed the slope of the tangent line, which the students determine by direct calculation using the formulas discussed in class. The module has several different graphs of common functions for the students to experiment with (see the bar at the top of the applet).

Figure 3: Animated Process for Determining the slope of the Tangent Line to Curve at a Point



In **Figure 3** the student has chosen the x^(2) function (blue curve) and the point a=95. After clicking the "-x" button several times, the student sees the secant line (in green) gradually approach the tangent line to the curve at the point x=a (in red). The table of slopes of the secant lines is converging to the value 0.0511, which is approximately the slope of the tangent line. The student can then verify that the slope of the tangent is indeed 0.051 by direct calculation.

The second module (**see Figure 4**) has the students approximate the area under a curve using Riemann sums, the Trapezoid Rule, and Simpson's Rule. After selecting a function and a method of approximation---either left, midpoint, or right Riemann sums, or the Trapezoid or Simpson's Rules---the student picks a left endpoint and a right endpoint along the x-axis. The endpoints selected are displayed in the upper right-hand corner. The student then clicks "+n" to draw two area elements---rectangles for Riemann sums, for example. The applet displays the number of area elements and the area covered by those elements, as well as graphs the area elements on the same axes as the graph of the function. By clicking "+n" the student doubles the number of area elements. After clicking "+n" several times, the student generates a table showing the number of area elements and the total area of those elements (**see Figure 5**). The students observe that as the number of area elements increases, the total area values approach a limit, which is the area under the curve between the endpoints. The students can then verify that the area under the curve is indeed approximately equal to the values given by the last few entries of the table by computing the exact area using the antiderivative. The utility of this module is that the students are relieved of the time-consuming and tedious task of computing the Riemann, Trapezoid, or Simpson's sums by hand. This is especially advantageous in those examples where one must use many area elements to obtain an acceptable level of accuracy. Furthermore, students do no need to purchase software, such as Maple, nor spent time learning the software package's syntax. The goal of this WEB-accessible modules is to help the students visualize the process of finding slopes of tangent lines using the definition, i.e., taking the limit of the slopes of secant lines. The advantage of this WEB-accessible module, as well as the others developed for the project, is that no special software is required-----the students simply run the applet in a browser. The time students spend familiarizing themselves with the operation of the applet is small, usually less than five minutes. Since the modules can be accessed remotely, students can easily obtain supplemental course instruction, and or reviews, to enhance their learning of Calculus I. To date, the students making use of the WEB-accessible modules find them helpful in their learning process.

Figure 4: Computing right Riemann sums for the function y=16-x^2 over the interval [0.5625, 3.275]

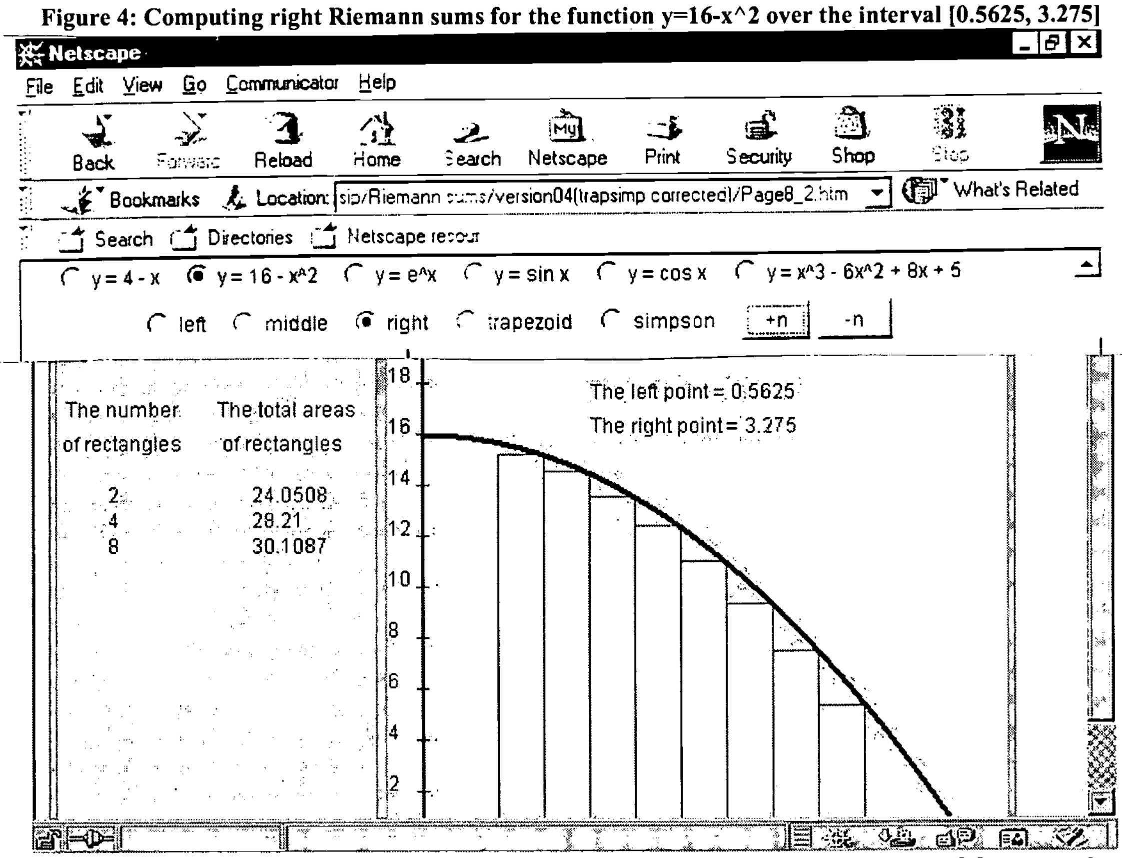
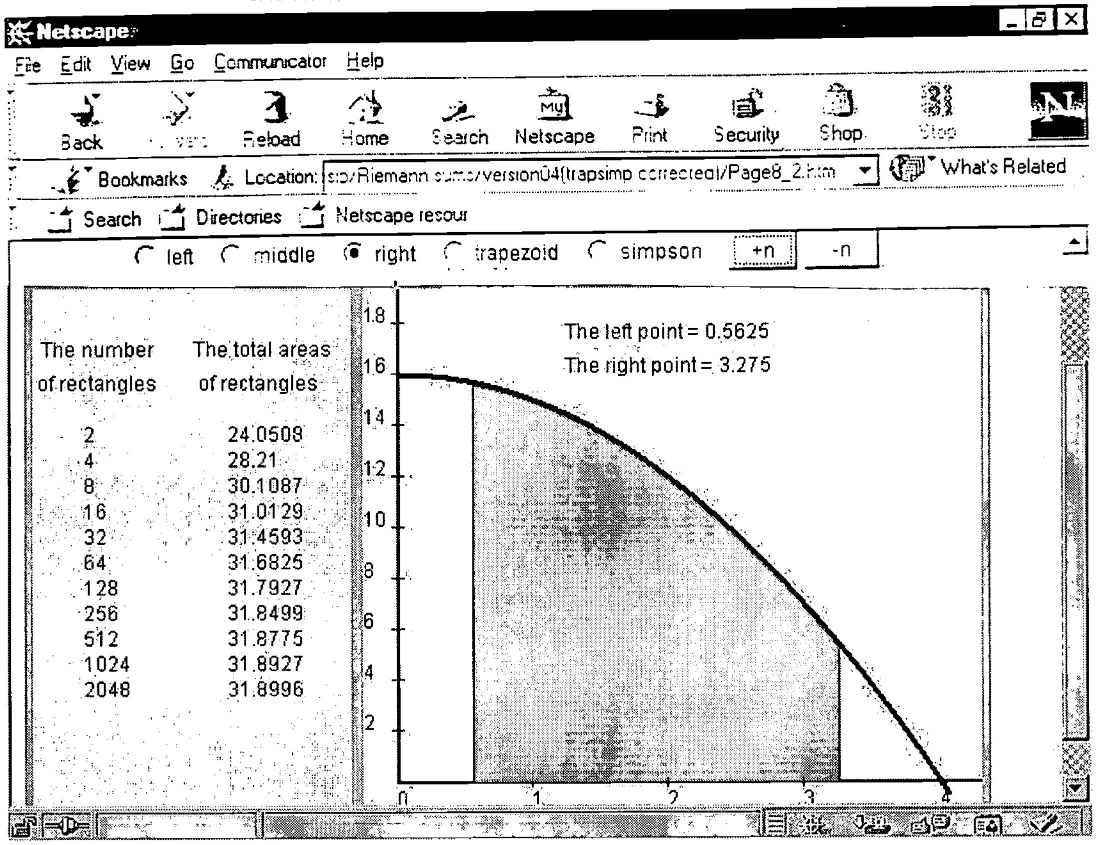


Figure 5: After clicking "+n" several times, the student observes that the sum of the areas of the rectangles for increasing "n" approaches a limit, which is the area under curve between the endpoints.



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MATH SCIENCE & TECHNOLOGY:
A Liberal Arts Major?

Dr Timothy D. Riegle
triegle@turbo.kean.edu
Department of Technology
Kean University
Union, New Jersey, USA

AAbstract:@ This is a report of a current developmental efforts for a Liberal Arts based academic major in Math, Science & Technology. There are still a number of serious issues that need to be addressed. There are discipline specific views that could be seen as having very little common ground. The flexible and equitable resolution of those issues can lead to an exciting and valuable program.

Let me begin by stating, totally up-front, that this is definitely a work in progress. While my primary goal is to come to you and present the history, up to this time, of efforts toward the development of a Math Science & Technology major at Kean University, it is also my hope is that I will leave with critical comments, other ideas, and possibly some encouragement regarding this undertaking. We are still resolving some serious issues.

Kean University is a public institution that is part of the New Jersey system. It was founded in 1855 as a New Jersey Normal School, and for more than 100 years was devoted to the training and development of certified educators for the K-12 classroom. However, in the past 45 years the institution has changed dramatically in size, character, and scope, to become a broad comprehensive ATeaching University@ (state of New Jersey designation) which now serves more than 12,000 students. There is a strong Liberal Arts based General Education Program (currently 52 credits, 18 of which are 6 specifically required courses) supporting more than 50 undergraduate and graduate academic degrees, many among them are nationally accredited professional programs.

About a year and a half ago, I was asked to attend a meeting suggested by the Dean of The School of Education. At first, It didn't seem to be unusual. Although I coordinate a B. S. in Industrial Design program in a Department of Industrial Technology within the School of Business, Government, and Technology, I had been asked by this Dean to get involved in a number of projects over the years. Usually the request was due to the fact that there was a project or grant application that needed some input regarding facilities planning, ergonomics, human factors, staff development related to computer applications and educational technologies; or, due to the, sometimes regrettable fact, that I had worked well with this individual or group in the past. I had recently worked on a successful private grant from A.T.&T. in support of instructional development, for faculty in the School of Education, to bring technology into their classrooms; and, a successful N.S.F. grant to support a systemic, problem solving approach to integrate the teaching of scientific and mathematical materials with field practitioners. Although I do not teach courses in the School of Education, or courses specifically developed for education majors, I did have considerable experience with its staff, students, and graduates. I have always found that the community in general, and the Academy in particular, is full of bright, intelligent people with lots of great new ideas: and, like it or not, a good number of those new ideas I am in agreement with, and want to have some part in seeing them through to their fruition. What I have promised my wife, and have tried to live by, is that it is not necessary to chair or co-chair every initiative that walks through the door.

Coming from the Dean of the School of Education as it did, I made the mistake to Aassume@ (totally forgetting that tried and true Felix Unger-ism related to that mistake) that it was about some revision or addition to one of the

institution=s programs for teacher education. Perhaps she wanted to revive a Technology for Children class. A course that, I was told by the more senior members of my department, was a service class that my department used to provide for Education majors. Of course, way before my time. Or perhaps, a new computer applications course, a number of which had recently been developed in my department. I was to find the error of my ways very quickly. This request was very different because the topic of discussion was the development of a new major on campus.

I don=t know if this is the case for education programs in other states; but, in New Jersey, all students with majors in Early Childhood Education or Elementary Education are also required to have a second Liberal Arts academic major. It seems that over the years, many if not most, students gravitate toward the fields of Psychology or Sociology. While these disciplines certainly cover valid topics of study in a liberal arts based undergraduate program, and have real values for understanding the dynamics and socialization of students in the classroom, there is, however, a lacking of actual content that the teacher preparation student can take with him or her from the institution's classroom to the pre-6 classroom upon graduation. A recently arrived professor on campus, Dr. Tom Banit, had taken over the coordination of the Elementary Education Program. He had make some inroads in encouraging students to consider a more classroom content oriented major, such as history or English; but, was still concerned with a critical shortage of exposure and experiences in the areas of math, science and technology.

In fact, after that first meeting, I reviewed the student information cards over the past several years of teaching, and coordinating, a required General Education Core course of Science, Technology and Society. In that time I had more than two hundred education majors, and of those that had included their required second major, only sixteen listed one of the sciences or mathematics. Since I am seeing them in their freshman or sophomore year, I would venture to say that some of those sixteen changed their minds before reaching Botany, Zoology, & Genetics, or, Discrete Structures, Calculus IV, & Differential Equations.

It was also shared with us that, not surprisingly, our graduates had a somewhat less than a stellar record in passing the general knowledge sections of the National Teacher=s Exam. Education majors themselves, and their future principles, administrators and supervisors, are fully aware that most were least prepared to teach subjects and topics that were scientific, mathematic, and / or technical in nature. The resulting affect of these conditions on the students in those classrooms is profound. A teacher who does not feel comfortable or competent with a particular subject matter will very likely not do that subject justice in the classroom. This level of competence and confidence can be readily picked-up by the students in that classroom; and, may contribute to those student=s lack of interest in topics that are scientific, mathematical, and technical in nature. An unfortunate aspect of this situation is that young women are, not only, more often than not in front of these classrooms; but also, for whatever combination of social and cultural reasons, more likely to shy away from these topics to a greater extent than their male classmates. This is evidenced by the National Science Foundation reporting that nationally, only about 25% of all scientists and engineers are women; and, that the level drops to below 20% when only considering private industry. A true Catch-22 exists when those uninspired young women go on to become teaching practitioners in the Pre-school through 6th grade classroom.

Having been presented with the current situation, the group that was called together was charged with developing a new academic major on campus with the working title of Math, Science and Technology. Faculty from the departments of Biology, Chemistry / Physics, Earth Sciences / Geography, Elementary and Early Childhood Education, Mathematics / Computer Science, Industrial Technology, Instruction and Curriculum, Mathematics Education, and Science Education were consulted with, and invited to provide input. The working group was trimmed down to those who truly had the interest and willingness to put in the necessary time and effort. There were representatives from Biology (Dr. Robert Schumacher), Industrial Technology (myself and Dr. Marvin Sarapin), Instruction and Curriculum (Dr. Tom Banit), Mathematics Education (Dr. Lucy Orfan), and Science Education (Dr. Sharon Brendzel) which made-up the nucleus of the resulting committee. The first meeting was basically the dissemination of the information and situations outlined above; a survey of the invites for a willingness to participate; the selection of a convener (I sat on my hands) to schedule and preside over the subsequent meetings; and the assignment to return in a few weeks with a list of what we thought would be the important issues that needed to be addressed.

I should add here that while the Dean convened the first meeting and gave us our charge, she was not part of the committee; and, save for periodic updates, pretty much left us to our own doing. She was very respectful of the tradition of faculty driven program change and development; and, probably also considering the faculty make-up of department and school curriculum committees (course approval), the University Curriculum Committee (program approval), and the Faculty Senate (final recommendations). Also, like all administrators, having personally invited each of the individuals participating to be part of the committee, she likely was confident that the resulting product would be acceptable to her vision.

Having recently gotten the University Curriculum Committee's approval, after three years of work, for a proposed new degree on campus for a Dual-Housed Bachelor of Industrial Design (B.I.D.) degree, I was more than intimate with the kinds of challenges that were bound to emerge when multiple deans, departments, chairpersons, and faculty are asked to agree on and endorse something that each of them as individual entities is probably going to be neither entirely happy about

nor completely satisfied with. Needless to say, there were quite a number of items on table as we returned to that next meeting. Some questions dealt with the theoretical framework for justification of the efforts we were contemplating; and other questions were more in the nature of, once we decide what we think should be done, just how in the hell are we going to go about doing it. Not the least of which, included among those questions were the following: 1) What exactly what did the other members of the group see as the definition of Technology?...... 2) If this is a true academic major, how would a non-education major benefit from selecting this as field for undergraduate study?..... 3) Is this program going to consist of specific new courses developed for the major; or, be made up of currently existing courses in those Departments contributing to the program?..... 4) What kind of structure will there be for the classes to be taken?...... Some from column AA@, some from column AB@, some from column AC@?..... Required core and electives?..... Required core with Aguided@ electives?..... Required core with optional tracks?..... 5) Given the climate of department and discipline based majors: Where will this type of interdisciplinary program be housed?..... What will be the curriculum path for initial program approval, and for new and/or revised courses?..... Who or what will have the overall coordination responsibility?..... How will advisement take place?.....

The first and, in my opinion the most fundamentally important, issue to be addressed was, for this group and its goals, just what is the definition of ATechnology@? Is it just how to use a computers? I certainly didn=t think so...... Is it the frequently used term Athe application of science@? I often have friendly discussions with my science colleagues here on campus and elsewhere, that today=s cutting edge science is really Athe application of technology@. I would argue that there is little that would go on, save for areas such as theoretical mathematics, if it were not for that which is provided by the electrical engineer, mechanical engineer, and industrial designer...... Is it the Paul DeVore and David McCrory of the University of West Virginia view of AThe Systems Model of Technology@, including communication systems, construction systems, energy systems, manufacturing systems, and transportation systems?

I would start, and in some aspects end, the discussion of what is the definition of with a look at what is found as the definition in a typical college edition dictionary. A(1)Technology is the application of science especially to industrial of commercial objectives. (2) Technology is the entire body of methods and materials used to achieve such objectives. (3) Technology is the body of knowledge available to a civilization that is used in fashioning instruments, practical arts and skills, and extracting and collecting materials.@ As it describes designing, creative thinking, and problem solving, the latter is of course my preference. A basic technological literacy, and a sound understanding of the historical relationships of technological developments and their interconnectivity to social and cultural change is fundamental to becoming an informed participating citizen as we start in the third millennium (...there, I just had to get that word in once... because I=m sure every other presenter at this conference, and every other conference for the next several years, will be using that descriptor...please note that it is the first time it has been used here and I promise it will be the last....unless you force me into something during the hopefully enthusiastic questioning and discussion that will follow this presentation.) If one would take just a few minutes to look at the definition given above, one could come to a conclusion rather quickly, that technology is pretty much the overall description of what we are and what we do. Some have questioned that perhaps in the latter half of the 20th century (or the latter twentieth of the 2nd M--word); technology has become autonomous in that it influences us more than we influence it. They would argue that there is more to us than the tools that we chose to make and the things that we chose to do with them. Jacques Ellul and Willem Vanderburg would insist that there are four things that make-up what we are. Those four things being culture, technology, science, and faith; and, that, by nature, all are, and must be viewed as, interrelated if we are to be successful and satisfied as a species participating in and contributing to the success of the planet. Putting faith aside to stand for and represent whatever the individual chooses it to be, there can be no denying that technology must be an integral aspect of that which remains.

There was much discussion about the true definition of Technology. In my mind, the broad systemic approach to the discipline, in and of itself, was also the answer to the second issue. That, the established definition and place in society of technology, speaks immediately to its justification as an academic major that can be defended for non-education students. There are many paths in business, government, graduate school, industry, and not-for-profit advocacy that could be successfully traveled by an individual with a background built on a solid foundation of the principles of math, science, and technology. A creative problem solver is a valuable asset to almost any worthwhile undertaking.

The next issue of discussion was the nature of the courses that would make-up the major requirements. The working committee was of the opinion that these courses should be developed from scratch. We envisioned a systemic approach, and felt that department based and developed courses would not serve this need. A core majority of this committee was also involved in the previously noted National Science Foundation SSI project. Perhaps some introductory courses could come form the current offerings; but, the interdisciplinary approach to the content would require developing a framework different from traditionally discipline/departmental developed courses. Although there were strong opinions, this was a view that had to be put aside for the current deliberations. First there was the time frame in which we were to accomplish this task. The Dean wanted it done yesterday. The development of new courses, especially new interdisciplinary courses, would easily add a year to the process. Also, the implementation for the new framework of the General Education

Program was currently being discussed. This newly developed model has a place for interdisciplinary courses within each of the traditional distributions (Behavioral Sciences, Humanities, Mathematics, etc.). There would very likely be new guidelines for interdisciplinary courses, and possibly a new home for interdisciplinary programs; so, a revision of the program would likely begin with its introduction.

With the definition of, the justification for, and the urgency of the need for the discipline completed, the work now moved on to establishing just how such a major would look. This was an issue of discussion for which I had some very specific opinions. These opinions were, unfortunately, not shared with all of those on the committee, and definitely not shared with any of those departments whose cooperation and sign-off would be necessary for the proposal to move through the curricular process. It was my opinion, and it seemed that those in the working group initially agreed, that if there was a foundation of knowledge, skills, and values that is important to the successful graduate; then, we should be specific about what those experiences should be, and not have optional tracks or more than one or two elective courses within the major.

The School of Education majors have their required thirty-credit education major to help them build on the components of the Math, Science, & Technology program. The focus of serving this population was to provide them with a broad foundation of content material. Materials that many were deficient in, when compared to other possible selections for the academic majors. If the three basic areas were to have relatively equal representation in the forty-five credit distribution, the make-up would be something like the following: 4 (4 credit) lab science courses (Biological, Earth, Physical), 4-5 (3 credit) computer science / math courses, and 4-5 (3 credit) technology / computer application courses. This would be in addition to encumbering a Biological Science, a Physical or Earth Science, a Computer Science, and a Mathematics course with the newly revised required General Education Program. This newly approved General Education framework also allows for three Interdisciplinary courses (Physics for Poets??), and a nine credit mini-minor. These will provide the opportunity to further develop a solid foundation, within the General Education Program, for those students selecting the Math, Science, & Technology major.

Those selecting this as a standalone liberal arts major would have those same or similar encumbrances and/or opportunities within the General Education Program. As these students would not have the required education second major, they would have approximately twenty-four credits of free electives. There is more than ample opportunity, within those twenty-four credits, for exploration in any specific aspect or discipline that make-up the academic major. These could also be used either to build an even broader range of experiences across the curriculum of the institution; or, to develop a complimentary concentration in areas such as Afracania Studies, Global Studies, Latin-American Studies, Political Science, Public Administration, or Women=s Studies.

There was some initial agreement within the committee that we should establish, and fight for, what we think are the important experiences students should have for this newly envisioned major. It shortly became clear that this would not be a point of agreement across the institution. A sampling of the opinions could be described with the following: AIf it=s going to have Science in the title, then it must include this@; AIf it=s going to have Math in the title, then it must include that@; and, AIf it=s going to have Technology in the title, then it must have this and that@. It seems that we may have been a little naive about the height and thickness of the walls that surround the AAcademic Turf@ on campus.

Every discipline, my own included, has what it feels are the basic experiences we deem as necessary for a sound understanding of that specific field at the academy. We also have those advanced classes that are usually our favorite to teach, and that we normally, by nature, get most excited about. What would the preferences be?... Composition or Chaucer?.... College Algebra or Calculus IV?... Intro to Politics or American Institutions and Public Policy?... Intro to Biology or Neuroscience?... Design Fundamentals or Senior Design Studio. In my opinion of what the model should be, the interdisciplinary nature of this major did not philosophically allow for courses of that nature. Also, with a goal of a true generalist, there is physically not enough room in the forty-five credit major for each discipline to have those kinds of courses. Unfortunately there was not enough support for my personal vision of the best model for this type of major. In the past few months, I have gotten involved with yet another new interdisciplinary major with the working title of Natural & Human Systems. That group is in total agreement that there will be no tracks or options within the forty-five credit major. If so desired, the electives will allow for that type of concentration..

As mentioned earlier, this Math Science & Technology major is a work in progress; so, even though I am inn the minority at this time, this is still an issue that is not yet fully resolved.

The current proposal has a forty-five to forty-seven credit major divided into a twenty-seven-credit core and an eighteen to twenty credit specialization. At this time the core is made up of nine credits is Mathematics / Computer Science, four credits in Biology, four credits in Earth Science, four credits in Chemistry / Physics, and six credits in Technology. The current options for specialization are Biology, Chemistry / Physics, Computer Science / Mathematics, Earth Sciences / Geography, and Technology. The Technology option is well defined with specific required courses followed by some selectivity. I lost that same argument in my own department. I did come out on top of the issue of not having a minimum of mandatory upper level courses. The Biology option is a list of specific courses with twelve credits at the 3000 level or higher. The remaining options= requirements are for any twenty credits, with the stipulation that twelve credits be at the

3000 level or higher.

Well, there is a brief description of the journey thus far; and, it does seem that the goal is within view. While many things have been accomplished, and many new paths paved, there is still much to be done. The curricular path, program housing, release time for coordination, and student advisement issues have yet to be addressed. While the committee does not see these as insignificant, it feels those obstacles already overcome tower over these minor details. Could it be that our naivete is yet again overexposed? There is also the issue of who gets the credit for the FTE=s in the program. Around this institution, I am told, the dollars always follow the FTE=s; although, there seem to be special exceptions almost everywhere one chooses to look.

An issue, of which we recently became aware, is the state requirements for upper level courses in an academic major. It seems that a sister institution in the state has successfully addressed this with a similar interdisciplinary program, and we anxious for discussions with individual faculty involved there. Another problem has evolved with the Math / Computer Science department=s realization that the current concentration structure allows the students an apparent shortcut to a mathematics second major, and for education majors a second certification. Is seems the insistence on tracks has encountered a number of bumps in the road.

Thank you for entertaining this report of our experience at Kean University. As there is a full two months between this writing and my presentation, it is hoped that I have some additional progress to discuss; and, unfortunately, may have additional problems to address

Evaluation of Web-Based Instruction: A Case Study in Brazilian High Schools

Dietrich Schiel, University of São Paulo (USP), Brazil dietrich@cdcc.sc.usp.br

Joan Dassin, Fulbright Commission, USA, jdassin@bellatlantic.net

Mônica G. M. Magalhães, State University of São Paulo (UNESP), Brazil, monica@rc.unesp.br

Íria M. Guerrini, Physics Teacher (retired), São Carlos, Brazil, iria@cdcc.sc.usp.br

Abstract: This paper describes the evolution of a distance education program where students perform physical experiments in their school assisted by a distance tutorial system. 20 public high schools in 14 cities in the interior of Brazil participate. Using an already described evaluation method which works on-line, it were collected the opinions of a sample of 228 students from an universe of 2200 participants. The results indicate a positive impact on students learning and success in helping a distant teacher and his (her) students in the innovating experimental activities.

Web Based Instruction (WBI) and Instructional Design

The explosion of interest in Web-based learning resources has stimulated instructional designers to capture the pedagogical principles distilled over decades of experimentation with computer-based instruction and create "macro-contexts" or intentional, computer-simulated learning environments based on advanced, multimedia technologies (Means, 1994). Examples of the latter include CSILE, developed at the Ontario Institute for Studies in Education (http://csile.oise.utoronto.ca/), Northwestern University's Learning through Collaborative Visualization Project - CoViS (http://www.covis.nwu.edu/), the Concord Consortium's Genscope (http://www.concord.org/genscope), and the Peabody School's Jasper Adventures (http://www.peabody.vanderbilt.edu). These computer-supported environments break down disciplinary and institutional barriers and enable diverse groups of teachers and learners to work together on scientific and mathematical concepts through direct manipulation and experimentation.

Pedagogically, the learning environments are based on the premise that a given instructional strategy takes on meaning only as it is used or "situated" in a particular context. (Hewitt and Scardamalia). Whether found in the natural world or created through use of computers' multimedia resources, these contexts involve learners in attractive "goal-based" scenarios. The scenarios simulate *natural* learning goals that provide individuals with incentives to complete compelling tasks, such as trying to get places, communicate effectively, or utilize objects in a productive way. To achieve these *natural* learning goals, even in a simulated context, the user will have to master relevant skills and subject matter. For example, a child who loves trucks would be eager to learn to read by reading about them. He or she would learn physics by smashing trucks together and learn math by calculating mileage and distance for truck travel. Computer-supported environments can easily create such "domains of interest," which then become a medium through which particular subjects can be taught. This approach has been shown to be much more effective than conventional subject-driven curricula, which serve *artificial* learning goals such as producing easily testable knowledge, but are rarely compelling to students (Schank).

The computer-supported learning environments also draw on proven "experiential learning" techniques to develop users' higher-order thinking skills. Simulated cases or situations can present learners with a problem or a complex task from which they need to draw conclusions and establish general principles that may explain or predict outcomes in similar cases. These kinds of cognitive tasks help learners develop the capacity for analysis, synthesis, and evaluation--fundamental building blocks for the creation of new knowledge. Small-group interaction, in-depth discussion, interchange of ideas among participants, and collaborative problem-solving activities are other instructional techniques known to work in this type of learning situation (Romiszowski, 1997).

The CDCC Experiment in Web-Based Instruction

In this context, successful experiments in developing countries with WBI merit careful analysis and interpretation. One of the most promising, known as the *Educ@r* Program, has been carried out since 1996 by the

Center for Cultural and Scientific Dissemination (CDCC) at the University of São Paulo in São Carlos, Brazil. The *Educ@r* Program is comprised of Web-based interactive learning programs in graphical mechanics, environmental education, mathematics, and a new optics course still in the initial design phase. The distance learning programs are intended for various combinations of primary and secondary school students and teachers, with an emphasis on physics instruction for high school students. *Educ@r* Program's various sub-programs, connected via Internet to the CDCC, reach schools in the state of São Paulo and throughout the country.

The Graphical Mechanics Course

The course in graphical mechanics is of particular interest to local evaluators. (Schiel et. al., 1998). The course itself is based on experimental work conducted by students with the assistance of both their regular teachers who are present in the classroom or laboratory and a distant mentor based at the CDCC in São Carlos. The regular classroom teachers provide direct instruction in related physics topics and supervise the students' experimental work. However, the students are also free to generate their own experimental results, incorporate the corrections and responses sent via WWW by the CDCC staff, and consult other physics texts and materials which are available via hyperlink on the course website. In part because the number of computers is limited to two for each participating school, students are expected to spend 80 percent of their time on experimental work and quantitative analysis and 20 percent interacting with the CDCC instructors via the Internet.

In their work, students perform quantitative experiments to measure changes in the position of an air table puck and resulting values of velocity and acceleration. Values obtained in these experiments are recorded in specially formulated tables and then sent via the WWW to the CDCC (http://educar.sc.usp.br/fisica/fisica.html), where they are verified automatically through the main server. If errors are detected, the particular table is immediately sent back to the student, with the incorrect results now blinking on the computer screen. The student returns to the previous page, corrects the errors, and resends the table. The main server then routes both the correct and incorrect tables via email to the CDCC distant mentor, who analyzes the results. The distant mentor's review adds an important qualitative dimension, since at present the software can only automatically detect mathematical errors, while the distant mentor immediately recognizes both measurement and mathematical errors. Finally, after reviewing the results, the distant mentor sends comments back to the student or school via email. Sixteen interactive tables are completed in this fashion, using software developed in the Perl language by the CDCC staff during the course of the program.

In a second phase of the work, the student simulates the physical experiment on a computer. He or she does this by programming in LOGO language to obtain the same trajectories and orbits (corresponding to the previously measured physical movements of the air puck) on the computer screen. The programs written in LOGO are sent to the CDCC staff.. In this way, students are stimulated to identify and apply the mathematical foundations of the physical phenomena in question.

In terms of physics instruction, the course content begins with an analysis of movement with constant velocity and ends with computer-based programming of planetary movement in a Kepler ellipse. The idea of presenting mechanics in a graphical way is nearly as old as Newtonian Physics. In the 17^{th}. Century, graphical presentation of physical phenomena was even more usual than analytical discussion. Newton (1686) concluded that it would be impossible to represent continuous planetary motion by applying calculation in non-continuous intervals. He developed a new analytical mathematical tool, calculus, to obtain exact solutions for this problem. The solution was mathematically elegant and the only one possible in Newton's time, since the alternative would have been to perform calculations on a very great number of small intervals. The first argument (elegance) is still correct today. However, a great number of calculation steps can now be done very easily with a computer. In the centuries after Newton, the analytical approach advanced considerably. This was a great advantage for the development of professional Science, but not particularly helpful to students with a limited knowledge of advanced mathematics.

In the 1970s, Elisha Huggins (Huggins 1979) from Dartmouth College returned to the problem of calculation on non-continuous intervals of planetary motion and graphical representation of motion by students who had difficulty using calculus. Huggins' students analyzed stroboscopic photos of movement using Basic language in the presence of an advisor.

Implementation of the Network

Twenty schools distributed over 14 cities located at distances ranging from 50 to 200 kilometers from the program headquarters in São Carlos have been involved in the graphical mechanics program (See Fig. 1). The schools are all public secondary institutions with largely lower-income students. Under the terms of the program, each school was provided with at least two computers connected to the Internet. The costs of a telephone line and

an IPS for the Internet connection at each school were also included in the program budget, along with the required experimental equipment.

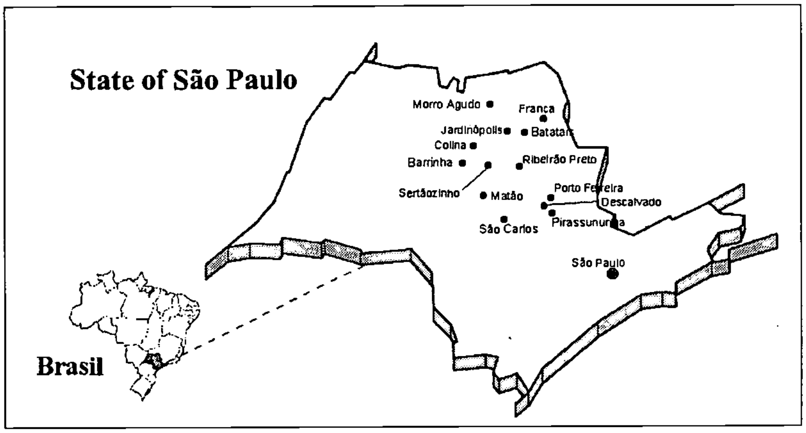

Fig. 1 Distribution of locations of participating schools

The teacher training consisted of two 40-hour courses, offered in January 1997 and January 1998, respectively. In terms of student participation, 2,200 students, divided into groups comprised of three to four students each, conducted the requisite measurements, calculated the results and completed the sixteen interactive tables that comprised the core of the on-line graphicals mechanics course.

Evaluation

The graphical mechanics course was evaluated when it was first offered on an experimental basis in November and December of 1996 (Magalhães and Schiel 1997) at one school. A more extensive evaluation was conducted online in July 1998 at the conclusion of the second year of the Program. Results based on responses from 228 students and 14 classroom teachers continue to indicate, as in the 1996 and 1997 evaluations, positive results in terms of overall course quality, pedagogical method, and student interest. As in the early evaluations, the 1998 questionnaires were based on ideas about formative evaluation (Flagg 1990; Willis 1992; Thorpe 1993; Preece et al 1994) and were interpreted using a 5 point Likert scale, where 1=very poor, 2= poor, 3=average, 4=good, 5=very good. (Peck and Wallace 1993; Preece et al 1994). In addition, the 1998 questionnaires included pedagogical questions that were adapted from material prepared by the São Paulo-based Carlos Chagas Foundation to evaluate a state program for teacher training.

Specifically, the 1998 questionnaires elicited the students' opinions through close-ended questions about the computer equipment, the distant mentor, the classroom instructor, the Internet connection, the experimental equipment (air table puck), and programming in LOGO language. Open-ended questions also enabled *both* students and classroom teachers to register their opinions about course quality, the contribution of the material to the construction of scientific concepts, and related interests. In addition to data obtained through these questionnaires, direct testing of a limited number of students assessed the impact of the course on academic performance.

Results

Student Reponses

Quantitative results based on student responses are indicated in the following table (Fig.2). As is evident, the average responses for each indicator fell between "Good" and "Very Good" for all aspects of the course. The one exception (with an average rating of just under "Good") was the LOGO-based work, which was in fact carried out by fewer students and therefore generated fewer responses than was the case for the other indicators.

In terms of qualitative indicators, similar answers from at least 15 percent of the student respondents were grouped together to constitute representative opinions. The students judged the hands-on techniques and equipment that permitted their *active* participation in learning tasks--experiments with the air puck, the use of the computer, and programming in LOGO language--to be the best part of the Educ@r Program. In this same vein, all student

respondents felt that the activities had advanced their learning because the experiments aided understanding and because they were more engaging than conventional "talk-and-chalk" instructional methods.

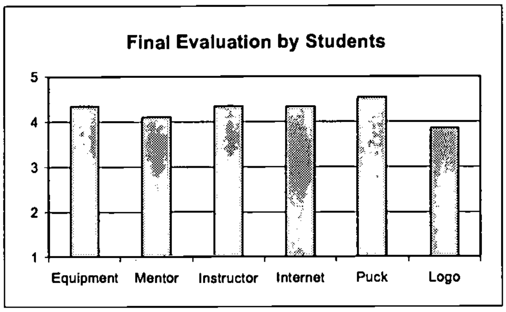

Fig. 2 Evaluation by students

Virtually all (99 percent) of the student respondents felt that there was a continuous evolution of scientific concepts in the course. Furthermore, nearly as many (96 percent) judged that the course helped them to understand physical phenomena present in their daily lives, such as how to relate velocity with the time and distance of travel. Ninety-nine percent of the student respondents indicated that the course corresponded to their interests, both in the subject matters of physics and mathematics and because the activities stimulated their interest in computers and made learning easier and more enjoyable.

On the negative side, students suggested that LOGO needed to be explained better and that contact with the classroom teacher should be improved. Specifically in regard to technology, 55.5 percent of the student respondents acknowledged having difficulties in using the computers. This was predictable given that for the majority of students, the course constituted their first contact with computers. In addition, many complained that the two computers provided for the course were insufficient for the required work.

Classroom Teacher Responses

The teachers' qualitative responses echoed the student replies on many key points, while also touching on topics related to their own professional development. For example, the teachers indicated that the most successful aspects of the graphical mechanics course, in addition to their own increased knowledge, was the possibility of developing *new strategies and non-traditional methods* to teach the physics content. The teachers felt that the new approach enabled them to build more directly on the students previous understandings and concepts. Like the students, the teachers noted the *motivating* effect of the hands-on, active learning afforded by the use of the experimental equipment and the course computers. Similarly, they commented on the *motivating* effect of the program's *communication* features, especially the mentor feedback supplied via email.

In the teachers' view, classroom practices as a whole began to change as a result of the new interactions, as the students worked better in groups and were more inclined to ask questions and even criticize the teachers. The new classroom dynamics stimulated the teachers to revisit concepts and activities that students might have inadequately understood, rather than pushing on automatically to the next topic. Overall, 100 percent of the teachers reported that the students' understanding of concepts involved in the course improved, as indicated by both testing and group discussions.

On the negative side, the teachers were concerned about the *Educ@r* Program's possible lack of continuity. Specifically regarding technology, the teachers felt the need for increased technical support for the schools and greater number of networked computers with Internet connections.

Student Performance

The final element in the evaluation of the graphical mechanics course was its direct impact on student performance. Testing was carried out by teachers on a non-standard basis, but more or less significant improvements in student performance were reported by all the participating schools.

A particularly important result was the *decline in failure rates*. In one school, for example, one of the participating teachers compared the performance of a 2nd year high school physics class that used the Educ@r Program in the first semester of the 1997 school year to the same class' performance later on in the school year, when the Program was *not* in use. The failure rate jumped from 1.7 percent to 25 percent from one semester to the other. The teacher also compared the performance of two 1st year classes in the same school. In this case the failure

rate for the students participating in the Educ@r Program was 23 percent, as opposed to 53% for the non participating students (Costa et al 1998).

Interpretation of the Evaluation

As in the 1996 and 1997 evaluations (Magalhães and Schiel 1997), the *quantitative* results tabulated in the 1998 student questionnaires are surprisingly good. Even in schools where there were difficulties connecting to the Internet, the students evaluated this specific indicator as between "Good" and "Very Good." Adding open-ended questions to elicit *qualitative* opinions encouraged the student respondents to deepen their answers and consider various aspects of the Program. On both quantitative and qualitative criteria, the impetus of the new experimental equipment and technology led to improved learning of the physics content.

The students' qualitative responses are particularly revealing. Brazilian schools normally have very few practical activities. For the students, the experimental work and the improved understanding of theory in relation to quantitative experimental results was especially rewarding. The novelty and fascination of the Internet were equally attractive. Yet, given the cost and technical difficulties associated with the introduction of networked computers to the schools, were they really an essential part of the program design? Why not simply train teachers in experimental techniques?

The answer is that the classroom teachers and the CDCC mentor and staff became a learning community, where each problem encountered in the course of the Program could be immediately discussed and solved. The CDCC support--both the mentor's knowledge of physics and the technical staff's support in installing and using the computers--was especially critical in enabling the teachers to implement innovative classroom practices. The Internet connection created a rapid, direct "Help" system for the students as well. Hence the *communications* features of the program design, supported by computers connected to the Internet, were indispensable in creating its many positive effects.

More generally, the Internet connection enabled the students at least to glimpse the potential of rapid information retrieval and exchange, while familiarizing them with practical computer-supported operations (e.g. sending email). Indeed, improved computer skills were an important by-product of the course--one that was much salued by the students who are acutely aware that professional advancement is increasingly tied to computer competence.

Finally, in regard to student performance, failure on tests and retention of students, particularly in the early primary grades, has been identified as one of the major problems in Brazilian education. Retention causes elevated repetition rates, leading directly to bottlenecks in student flows through the school system, poor utilization of scarce resources, and school drop-out. In order to lower retention and repetition rates, educational authorities have on occasion asked teachers to lower the requirements for passing grades. Evidence from the graphical mechanics course, however, indicates that methodological innovations can also lower retention rates, *without* lowering the level of knowledge, at least for the topics covered in the Program.

Conclusion

The evaluation of the graphical mechanics course within the *Educ@r* Program makes clear that the combination of experimental work in the classroom and the orientation of students at a distance can have a measureable, positive impact on student learning in the exact sciences. Moreover, the communications capability of computers with Internet connections can be purposefully exploited to reinforce learning advances for both teachers and students, while also introducing new interpersonal dynamics in the classroom. In general, the São Carlos experience demonstrates that distance education involving the World Wide Web can provide a powerful tool for *educational innovation*--even in poor public school settings with limited access to experimental equipment and computers.

The policy implications of the CDCC experience with WBI should also be emphasized. Along with the issue of relative costs and benefits at the implementation stage, education planners have to consider the *sustainability* of educational technology projects. Especially when projects are dependent on external funding, as is the case with the *Educ@r* Program, the question of continuity looms large. Nor is this concern unwarranted. A follow-up survery of 13 teachers who had participated in the graphical mechanics course found that only 62 percent of them were still using the air puck in their laboratory classes. Only 22 percent still had students sending the interactive tables via Internet connections, and only 30 percent were teaching LOGO to their students. The reasons were varied but predictable, ranging from increased pressure from school administrators to "cover" required content to technical and financial difficulties associated with maintaining Internet connections and having access to the

requisite number of computers. Despite these problems, however, many of the teachers recognized the educational value of the Program and were eager to find ways to continue utilizing the innovative methodology (Guerrini, 1999).

Moreover, the CDCC experience demonstrates that the cost-benefit discussion about which technologies merit the most support is short-sighted. Even relatively *small-scale* experiments based on the *partial* use of computer-supported, Web-based distance learning environments in *sub-optimal conditions* can create "mini-change" scenarios with substantial transformative power in the key domain of formal education. Insofar as we are all operating in the midst of a sweeping "Knowledge Revolution" that has already changed the nature of the global economy but portends even greater, as yet unknown, changes in society and culture, this is no mean achievement.

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Learning Environments for Meta-Competencies in Software Engineering

Mildred L. G. Shaw & Brian R. Gaines
Knowledge Science Institute
University of Calgary, Alberta, Canada T2N 1N4
mildred@cpsc.ucalgary.ca, gaines@cpsc.ucalgary.ca

Abstract Industrial priorities for the competencies of both undergraduate and graduate software engineers include not only technical knowledge but also meta-competencies which are not normally addressed in standard computer science learning environments. These meta-competencies include the capability to operate effectively in teams and to be able to communicate with customers, suppliers and co-workers. This article describes the underlying principles, practical implementation, and several years experience with the learning environments at both undergraduate and graduate level that support the rapid development of such meta-competencies within the framework of normal academic courses.

Introduction

The Software Engineering Research Network (SERN) at the University of Calgary was founded as a joint venture between the University, a number of major industry partners and the province of Alberta to support the emerging software industry in Alberta. It has resulted in the funding of an industrial chair in software engineering and the development of new undergraduate and graduate programs in software engineering. As part of this development extensive consultations have taken place with industry partners about the education of software engineers. A typical report from the moderator of such a session was: "The general consensus is that we are more interested in having students improve their soft skills rather than their technical skills." The comments on "soft skills" include:-

- Teach students how to learn. We live in times of constant change and there must be continuous learning.
- Ensure students work in teams so that they have teamwork skills.
- We look for maturity, enthusiasm, positive attitude, good communication and interpersonal skills, and students msut be able to communicate at all levels within an organization
- Students should have experience in making presentations

These comments also have to be taken in the context of a general ethos that we are a liberal arts, research university that values a breadth of education and the capabilities of inter-disciplinary reflection.

The challenge in this rapidly-changing, post-modern world of providing university-level learning environments that develop the foundational competencies of an applied discipline, the meta-competencies necessary to be effective in a modern organization, and the meta-competencies associated with academic breadth is a major one in many areas. In software engineering it is exacerbated by the immediate demands of an industry that is desperately short of highly qualified personnel.

There are those who question the existence of effective solutions to this challenge. Barnett (1994) in *The Limits of Competence: Knowledge, Higher Education and Society*, questions the notion of meta-competencies as providing a model for the fundamental outcomes expected from higher education. He sees industry as demanding operational competence which is largely in opposition to academic competence, contrasting an epistemology that focuses on knowing how with one that focuses on knowing that, learning that is experiential with learning that is propositional, critique that is for practical effectiveness with that which is for better cognitive understanding, and so on. However, he also attempts to transcend these dichotomies with an epistemology based on reflective knowing, metalearning, and critique for better understanding.

We have approached the curriculum design issues discussed in this article with the deep personal belief that any dichotomies between industrial and academic requirements can be transcended, that the same learning environment can promote the development of soft skills and technical skills in a unified way, and that

the issues of software engineering are rich enough to provide a framework for, and a context to, a liberal education.

The following sections illustrate our approach through examples of learning environments for software engineering education at a variety levels: the development of team and communication competencies in a 3rd level undergraduate software engineering course; the development of research, team and communication competencies in a 4th level undergraduate 'hot topics' course; and the development of critical self- and group-reflection competencies in a workplace, graduate master's program.

Team Competencies through Role-Playing in Customer and Supplier Teams

Nonaka and Takeuchi (1995) emphasize "the central role teams play in the knowledge-creation process—they provide a shared context in which individuals can interact with one another. Team members create new points of view through dialogue and discussion. This dialogue can involve considerable conflict and disagreement, but it is precisely such conflict that pushes employees to question existing premises and to make sense of their experience in new ways. This kind of dynamic interaction facilitates the transformation of personal knowledge into organizational knowledge."

This quotation provides a framework for the role of team experience in learning, that it is not just the management of roles and interactions but also the use of conflict and disagreement to actively create solutions that is an important competency. In software engineering, the role of conflict in creative design is well-exemplified in *requirements engineering* where customer groups often have conflicting needs and supplier groups have to clarify and resolve them in an effective design (RE, 1993; Shaw and Gaines, 1994).

The curriculum for CPSC 451, a required 3rd level software engineering course for all Computer Science majors at this University, follows a more technical 2nd level course where students are introduced to object-oriented and structured methodologies. It encompasses a range of technical competencies that are all brought to bear on a requirements engineering project that involve the students playing roles in teams representing customer and supplier organizations. Each student is assigned to two different groups of 12 students. In one group she is one of the supplier team, and in the other one of the customer team. The students are assigned based on a number of factors such as: having taken the human-computer interface course, having taken a theory course, and length of time in the program, to try to make each group as varied as possible but at the same time as similar as possible to the other groups. The total class size in the past has been around 50 to 60 students, but in recent years has increased to 120 to 150 due to financial constraints.

The process starts in the last 5 minutes of the very first class, when each customer group is allocated a project at random. The course web site gives a very short, informal and vague description of the problem. For example:

> Write a specification for a student timetabling system which allows students to select courses (with available spaces) they wish to take, and displays the resulting schedule. It should help students find alternative sections, labs etc in the event of a clash, and take into account prerequisites for courses. When completed, the system should allow the student to register for the selected courses, and maintain class lists that are updated as a student registers in or drops a course.

Each group gets a different problem, but they are all of a similar level of complexity. Each customer group has two days to prepare an informal requirements document for the project and post it on the web. They are subsequently responsible for its evaluation and criticism as it progresses; that is, they are the customer for the system. They are expected to be present at all presentations to ask questions, and comment on all the write-ups and documentation. Each grade, given by the instructor not by the students, depends on how thoroughly the evaluation is carried out, the extent to which it is fair and reasonable and the extent with which it agrees with a well-founded methodology. Groups are advised to show all drafts to the teaching assistant, and discuss any problems or disagreements. It is not very long after the start of the project that the customer and supplier groups reach the conclusion that the interchange cannot be done entirely by web-based documents, and that they need to meet and negotiate problems, expectations, and what will be included in each version of the software.

The supplier group works for the customer group, receiving informal requirements for a system, annotating the requirements on the web with queries and suggestions, producing a formal specification, a management plan, the analysis and design in the form of an overall and a detailed design document including

test plans, a user manual, coding a prototype, evaluating and refining it, and presenting a final (prototype) product according to the details given. Public (to the whole class) oral presentations and discussions are required at various points within the project, and are evaluated and assessed by the customers. It is certainly not required, but often the students will arrive in their best business clothes for the presentations, and fully enter into the roles they have been given. Every 3 to 5 days another part of the project becomes due for submission to the customers, and students are quickly made aware of the social pressures to conform to due dates. This may be the first time that any of them have considered that due dates are not altogether arbitrary, and that other people's deadlines depend on them. In turn, each student may be inconvenienced by other people's last minute rush to complete work, not only in the other group, but also in their own where, for example, an editor may require input from several people before a final document can be prepared.

It is not necessary to make explicit the psychological and sociological perspectives of the academic curriculum in CPSC 451. In any event, the science curriculum to which most of the students have been exposed encourages linear thinking and objectivist values, and is a poor foundation from which to understand the life world. The students *experience* the significance of roles, conceptual systems and inter-personal interactions. The alternation of their own customer and supplier roles brings them to terms with the nature of conceptual systems, both their subjective artificiality and their ethical implications in terms of role consistencies, responsibilities and accountabilities. Being responsible for conceiving and articulating *requirements*, in particular, is a new experience for most students, and leads them to be more thoughtful about how those requirements arise.

Reflective Competencies through Comparison of Constructs on 'Hot Topics'

Advanced information systems provide a field where social perspectives are readily seen to be essential to redress technological bias. In developing the curriculum for CPSC 547, an optional course on 'hot topics' advanced information systems for Computer Science majors, it was known that the final year students already had theoretical foundations for technologies such as object-oriented programming and databases. In addition, many of the students who were attracted to this course also had substantial industrial experience. For example, they understood object-oriented technology in terms of type theory, modularity, and so on, and they understood that it was having a major impact on industry, but they had few sources available on how to bridge the gap between theory and practice: for example, to be able to see object-oriented databases as providing a more effective enterprise modeling technology than relational databases; from there, to go on to the questions of the interplay between organizational needs and technological capabilities; from there, to go on to the question of the influence of the technology on organizational design; and so on.

The design of an environment for reflective learning has been influenced by the recommendations and beliefs of Carl Rogers (1961) for generating a positive atmosphere in which students exhibit mature everyday behavior, are less defensive, more adaptive, and more able to meet situations creatively. This involves treating each student as an individual, being available to discuss problems individually and help with students' decision-making, creating a supportive and empathic class atmosphere in which each student is given positive encouragement to discuss issues of concern, and making the instructor's thoughts and views genuinely available for discussion. According to Rogers, this allows each student to experience and understand aspects of her/himself which may not have been previously available, to become more integrated and more able to function effectively, to be more self-directing and self-confident, to become more self-expressive, to be more understanding and accepting of others, to be able to cope with new problems more adequately and more comfortably.

In CPSC 451 they learn experientially from playing the relatively well-defined roles of customers and suppliers. In CPSC 547 they learn both experientially and intellectually from playing the open-ended roles of being researchers and educators in their own right. Each presentation tends to set a new standard of excellence which those in the later groups are determined to transcend, and find they must cooperate strongly to do so. Whereas CPSC 451 is a compulsory course, CPSC 547 is optional, and the fact that it has been one of the most heavily subscribed of our 500-level courses attests to its perceived value by students. It provides a bridge from their roles as students to their roles as industrialists, managers, researchers, members of, and contributors to, our rapidly changing post-modern age and information society.

Collaborative web-based construct elicitation tools (Shaw and Gaines, 1995) are used in CPSC547 to support the conceptualization, requirements analysis, and presentation for the small group projects which are, however, broader than those of CPSC451 in that they involve the analysis of major areas of computer technology and its impact rather than the development of specific systems.

However, the most important transition in CPSC547 is that the tools are used also to encourage meta-reflection about the course and the nature of the learning experiences involved. The agenda for the course outlined above is made explicit to the students at the beginning of the course—they become *owners* of the course at every level from day one. The web of previous student projects and commentaries is available to them so that there is collaboration not only within the course but across instances of it, a sense of a continuing learning community where their contributions will be valued by the next generation of students.

Research Competencies through Concept Maps and Master Classes

The primary dynamic of SERN is industry-university collaboration with an emphasis on real-world research and industrial good practice. The graduate software engineering thesis-based master's specialization was established to encourage students to undertake research projects as part of their full-time industrial employment. On the one hand this enables the university to train students in research methodologies and to develop their capabilities to undertake major research projects and to analyze and communicate the outcomes. On the other it provides a source of research activities to SERN and its members which is firmly grounded in industrial practice and relates to issues of immediate industrial significance.

The learning environment for the courses is unconventional and reflects the industrial experience of the students. After the first background lecture the students take over responsibility for presentations on the various topics in the 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. In addition, an experienced industry manager participates as a second facilitator, typically entering a debate when it has come to a dead end or become unbalanced. The overall aim is to provide a supportive and nurturing learning environment in which experience and knowledge can be shared and ignorance displayed and errors made without censure but with ready access to diagnostic help. It becomes clear to the 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 answers generally have very limited applicability. An up-to-date specialized library is maintained specifically for this program. Students rapidly become fluent in the latest software engineering literature, initially through background research for their presentations and ultimately through searches for material relevant to their research.

An overlapping cohort model has been found to be highly supportive of the processes outlined above. There are two major intakes into the program, one in September and one in January, of approximately equal size. The core courses are taught only once a year so that on each course there is a roughly equal mix of new students and those who have already taken courses and are experienced in the learning environment. Students work in teams to develop presentations and those with prior experience of doing this essentially mentor those who are new to it. This has proved very effective in bringing new students rapidly into the learning culture of the program.

As in our undergraduate software engineering courses, student assignments are submitted on the World Wide Web making them accessible to others. A 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 allocate them to work in other locations, 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. We are currently beginning to address the challenge of making more material formally available to remote students and this early experience of students becoming remote through circumstances beyond their control, but maintaining effective ongoing participation, is proving very valuable in designing for the distance mode.

The research for the thesis is expected to be based on the ongoing activities in the workplace. It is expected that students will be employed in the software industry, and will work on their projects at the industry

sites. This has made it important to address intellectual property issues from the outset. For example, in an experiment in which a particular approach to process improvement is investigated and software metrics are kept for a particular development, the final thesis need give no details relating to confidential information but would present the characteristics of the software being developed, the experience with process improvement and the plots of the relevant metrics. A similar approach can be taken for other topics and students are asked to develop a research plan that they can share with their employers from the outset so that difficulties over intellectual property rights are minimized.

Since the primary deliverable for a research degree is the thesis and the degree will be awarded principally through an examination committee assessing the thesis and the student's defense of it, a research methods course is essential to the program. The majority of students already have substantial experience of software development in industry, and some have come into contact with research issues, but virtually none of them have any experience in developing a research program, setting up experiments, collecting data, analyzing it appropriately, drawing appropriate conclusions and presenting all this effectively in a substantial, coherent document.

We have found in the past that the basics of research methods are best assimilated when students can perceive a need in their own experience or that of others, and hence a case-based approach has been adopted for this course with the cases being the ongoing research of students in the program. The course commences with the presentation and detailed analysis of the concept map for a research program shown in Figure 1.

The objectives defined on the left follow a logical sequence and also correspond to the typical chapter structure of a computer science masters thesis. The required activities to carry out these objectives provide the students with the framework for a research program. The students develop a concrete instance of this concept map for their own research program, and can do this in an active concept mapping tool (Gaines and Shaw, 1995b) that also links to material on the World Wide Web (Gaines and Shaw, 1995a, 1995c).

The learning environment for the research activities uses the concept maps and presentations as the basis for master classes in which a student's approach to the research is critiqued step by step. The focus of the critique is not on the content but rather on the research techniques entailed by the choices made in content and objectives. Is the overall aim well-defined?; do the objectives address it effectively?; how will data be gathered and analyzed for each objective?; what literatures are relevant?; what statistical approaches?; what evaluation techniques?; and so on, with a continual emphasis on the meaning, significance and value of the outcomes. Students at different stages in their research learn from the way in which students at other stages of their research are addressing these issues, and join in the discussion from different perspectives. The outcome is a team environment for individual and group reflection.

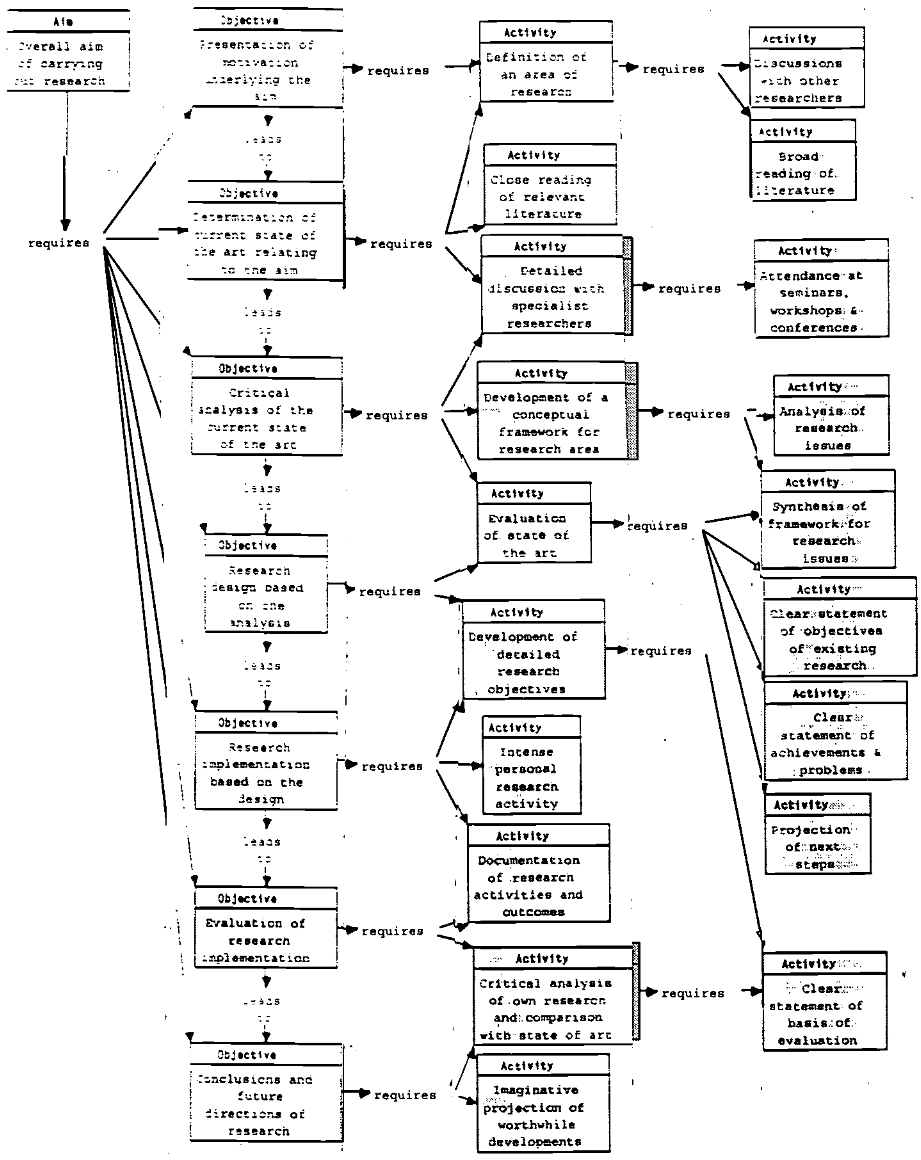

Figure 1 Concept map for a research program

Conclusions

This article describes the approach of the Software Engineering Research Network (SERN) at the University of Calgary to the needs of industry in the education and training of highly qualified personnel. While the early undergraduate courses focus on technical skills, the senior undergraduate and graduate courses emphasize the "soft skills" of meta-competencies such as the capability to operate effectively in teams and to be able to communicate with customers, suppliers and co-workers.

In a required 3rd level software engineering course the students learn experientially from playing the relatively well-defined roles of customers and suppliers. In a 4th level advanced information systems course they learn both experientially and intellectually from playing the open-ended roles of being researchers and educators in their own right. This course provides a bridge from roles as students to their roles as industrialists, managers, researchers, members of, and contributors to, our rapidly changing post-modern age and information society.

At the graduate level the software engineering thesis-based masters' specialization was established to encourage students to undertake research projects as part of their full-time industrial employment. On the one hand this enables the university to train students in research methodologies and to develop their capabilities to undertake major research projects and to analyze and communicate the outcomes. On the other it provides a source of research activities to SERN and its members which is firmly grounded in industrial practice and relates to issues of immediate industrial significance. Special attention is given to the development of research skills such as developing a research program, setting up experiments, collecting data, analyzing it appropriately, drawing appropriate conclusions and presenting all this effectively in a substantial, coherent document.

We are now involved in extending the approach reported in this paper to support professional development and lifelong learning in software engineering. This entails further modularization of course material, more extensive coverage of topics at senior undergraduate and graduate level, and more effective use of Internet technology to support workplace and distance learning. We see the need to partner with other institutions to do this cost-effectively and to sustain excellence in the program, and hope that this article will lead to new partnerships.

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Grades 4 and 5 Teachers' Perceptions of Technology Implementation in Mathematics Instruction

Scott W. Slough, Department of Early Childhood Education and Reading, Georgia Southern University, Statesboro, GA 30458 USA, sslough@gasou.edu

Gregory E. Chamblee, Department of Middle Grades and Secondary Education, Georgia Southern University, Statesboro, GA 30458 USA, gchamblee@gsvms2.cc.gasou.edu

Abstract: The purpose of this paper is to examine and describe the change process as technology is implemented in grades 4 and 5 mathematics classrooms. For this study technology is defined as manipulatives, calculators and computers. The Concerns Based Adoption Model (CBAM) provided a theoretical framework for data analysis. Data was collected through open-ended ethnographic interviews of six (n=6) grades 4 and 5 demonstration teachers identified by the university. Results were organized into four major themes: perceptions of technology (personal), availability and use of technology (technological), implementation of technology in the mathematics classroom (curricular), and technology's role in teaching mathematics (philosophy).

Objectives/Purposes

The National Council of Teacher's of Mathematics *Curriculum and Evaluation Standards for School Mathematics* (1989) calls for an emphasis on integrating manipulatives, calculators and computers in the upper elementary (grades 4 and 5) mathematics classroom. Many staff development and university courses have been developed and implemented based upon this belief. . But what exactly are upper elementary mathematics classroom teachers doing to implement technology in the classroom is still not well documented.

Fullan (1982) posits that all curricular change is a process, not an event. Hall & Hord (1987) further suggest that such changes are highly personal and can only be accomplished one individual at a time. The purpose of this pilot qualitative study was to determine how grades 4 and 5 mathematics teachers in a rural setting in a southeastern state implemented manipulatives, calculators and computers in their classrooms and the factors that influenced their decisions to use these technologies.

Theoretical Framework

The National Council of Teacher's of Mathematics *Curriculum and Evaluation Standards for School Mathematics* (1989) states that "(1) appropriate calculators should be available to all students at all times, (2) a computer should be available in every classroom for demonstration purposes, (3) every student should have access to a computer for individual and group work, and (4) students should learn to use the computer as a tool for processing information and performing calculations to investigate and solve problems (p. 8)." Specifically, in grades 4 and 5, calculators and computers must be accepted as valuable tools for learning mathematics and a wide variety of physical materials and supplies must be available for learning mathematics. Only through such instruction will students be able to master the concepts taught in middle grade and secondary classrooms.

The Concerns-Based Adoption Model (CBAM) generally states that the needs or concerns of individual teachers must be addressed before change can occur (Hall & Hord, 1987; Bailey & Palsha, 1992). Further, CBAM suggests that 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). Presently, many teachers are in the process of addressing the teaching implications or barriers to technology-based curricular change. These barriers include: (a) a lack of consistent goals for teacher technology literacy; (b) training; (c) money; (d) teacher attitude; (e) a lack of technology-based textbook materials;

and (f) perhaps most important, time (Becker, 1991; Dwyer, Ringstaff & Sandholtz, 1991; Becker, 1994; Chamblee, 1995; Sandholtz, Ringstaff & Dwyer, 1997; Chamblee, Sliva, Slough & Louden, 1999). Overall, these barriers can be partitioned into four themes: personal, technological, curricular, and philosophical. These barrier themes along with the teachers' personal philosophy about technology's role in the teaching and learning of mathematics were used to organize and discuss teachers' responses to the interview questions.

Methods

The population for the study (N=15) was defined as grades 4 and 5 teachers who had been identified as math demonstration teachers by the College of Education. A math demonstration teacher was defined as a teacher who taught math in a nonself-contained classroom (teachers generally taught math only or some combination of math, science, and social studies) who had demonstrated innovative teaching strategies and effective mentoring capabilities for supervising preservice teachers in their classrooms. Each demonstration teacher submits an application that includes principal, college faculty, and self-evaluation assessments. Final decisions are made by individual departments within the college, both Early Childhood and Middle Grades demonstration teachers were utilized in the study.

Seven of the fifteen grades 4 and 5 demonstration teachers that were mailed requests to participate in the study, agreed to participate. Of the seven affirmative respondents, two were not selected to participate in the study because their teaching assignment had recently changed and they were no longer teaching mathematics. One non-demonstration teacher was included in the study based on peer recommendations. Thus, a total of six teachers (n=6) were interviewed for this study, four grades 4 and two grade 5 teachers. Demographics indicated that these teachers had been teaching an average of almost eight years, with several possessing advanced degrees (three M.Ed. and 2 Ed.S. degrees).

Data Sources

Data was collected through open-ended ethnographic interviews with each of the six participants at their respective schools. Interview questions were adapted from a qualitative study of teachers' concerns related to technology implementation in secondary science (Slough, 1998), a quantitative study of teachers' concerns related to the implementation of graphics calculators in first-year algebra (Chamblee, 1996), and the Stages of Concern Questionnaire (SoCQ) (Hall, Wallace, & Dossett, 1973; Hall, George, & Rutherford, 1986). Each interview consisted of ten questions about integrating technology in their mathematics classroom and their schools in general. For this study, technology was defined as manipulatives, calculators, or computers. The interview protocol is shared in Table 1.

Question 1: What is your background as an educator?
Question 2: Describe your background and experience in technology (manipulatives, calculators, or computers).
Question 3: How are you using technology for your professional activities?
Question 4: Describe the overall picture of technology at your school district.
Question 5: Describe how your students use technology in your classroom.
Question 6: What are the barriers to implementing technology in your school?
Question 7: What are the supporting conditions for implementing technology in your school?
Question 8: How, if any, has technology affected students' learning?
Question 9: How, if any, has technology changed mathematics teaching?
Question 10: Describe the specific role of manipulatives, calculators, and computers in the teaching and learning of mathematics.

Table 1: Interview Protocol

Additional probing questions were used to solicit more detailed responses where needed. Interviews were transcribed and analyzed for consistency of responses. Additionally, the personal, technological, curricular, and philosophical themes were used to frame the data analysis.

Results

Teachers reported a variety of barriers to implementing technology. These barriers included: (a) availability, (b) classroom management concerns, (c) ITBS's (Iowa Test of Basic Skills) perceived emphasis on computational skills (standardized testing focus), (d) technology was less appropriate in math than other subjects, (e) professional development opportunities that did not match their needs, (f) money to purchase additional technology, and (g) time to learn how to use and implement new technology. Four major themes were used to organize teacher responses: perceptions of technology (personal), availability and use of technology (technological), implementation of technology in the mathematics classroom (curricular), and technology's role in teaching mathematics (philosophy). Each of these themes is expanded in the following sections.

Perceptions of Technology (Personal)

Respondents stated they used manipulatives extensively to introduce concepts. Their focus was often to increase computation skills rather than build conceptual knowledge. One teacher reported frustration with classroom management when *any* technology was implemented, especially manipulatives. Calculators were reported as useful tools to check computations by all six teachers. In particular, three of the six teachers reported using calculators to aid in "longer computation" when another concept was the goal of instruction (i.e., problem solving). As one teacher noted, " Why not use the calculator if they have proven they understand the process?" Computers were reported as useful for reinforcing math skills, and remediation in the math classroom. Several teachers mentioned using programs like "Math Blasters" for skills practice. Teachers did mention using computers to increase their own personal productivity (i.e., word processing) and to a lesser extent, the students increasing their personal productivity (i.e., researching topics on the Internet—mostly in other subjects, and record keeping for Accelerated Reader).

Infringement on teachers' personal time was a critical issue for all respondents. Teachers reported that they were unable to find the time to learn how to use what they had now, much less what they would be getting. As one teacher described the situation, "I am teaching fourth grade now. Next year it will be kindergarten. I don't have time to make all of the manipulatives or learn the computer programs." The teachers generally did not recognize supporting conditions in place with the exception of the support by the administration. As one teacher reported, " We need the administration, including the principal and board, to buy into technology and support it."

Availability and Use of Technology (Technological)

Manipulatives, calculators, and computers were generally available in the classroom. But, importantly, they were not always implemented for a variety of reasons. In fact, two teachers noted, "entire closets of manipulatives," which they seldom used. One respondent reported having to create classroom sets personally due to lack of school funds. Teachers used manipulatives in a variety of ways. One teacher even called them "essential, I use a lot of base 10 blocks, geometric shapes, things that can be felt and touched." The most commonly reported use was to introduce a concept.

Although not available in all classrooms, class sets of calculators were generally available and were used almost exclusively to check computations. Access to calculators outside of the classroom was a concern. One teacher reported that only six students were able to bring in calculators when class sets were not available. The number of computers ranged from one to six per classroom with four classrooms having two computers. The Internet was available through the library at all of the schools, but was only available in one classroom. The Internet was beginning to be used as a resource for planning by three of the six teachers. Math games were the most common use of computers. Teachers recognized the investment that had already been made for technology; however, they felt that more was needed to keep technology—especially computers—current. Several teachers noted that although they had not fully implemented computers, they were more likely to if they were provided better computers and better access to the Internet.

Implementation of Technology in the Mathematics Classroom (Curricular)

Teachers stated that implementation of technology has been slow and inconsistent. Calculators are not allowed on the fourth grade ITBS test, thus the fourth grade teachers did not use them in the class. In fact, this non-use was

mandated by the principals in two of the four fourth grade classrooms. Four of the six respondents stated that their principal's focus on Iowa Test of Basic Skills (ITBS) scores and ITBS's perceived emphasis on computational skills (standardized testing focus) lead to very little use of technology school wide to teach mathematics. One teacher reported "the focus here is to push paper/pencil type work. [The] curriculum is ITBS driven. She further explained, " three hours a day in language arts and the rest in math. "

Even though the calculator is allowed on the fifth grade ITBS test, calculators were not used extensively in instruction. Where they were used, calculators were still being used to "check answers" rather than being used to learn. A concern was "the students don't know why they're punching in numbers. [They] don't always know what the answer is and they leave the answer alone—they won't recheck it."

Although not explicitly stated by all teachers, there was a general sentiment that computers were more appropriate in other subject areas. As one teacher noted,

> "Math is the least subject used when it comes to computers. I use it more with other content areas. Good for drill and practice, but I don't really use it—it is not related to math a lot." The other subjects, stick in where you can."

Professional development situations were available but most of these teachers were self-taught. One teacher reported, "sure, they have lots of classes. But, they want me to take them on my tine or drive to RESA (Regional Education Service Agencies -- Georgia)." For example, computers were perceived not to be implemented uniformly for a variety of reasons. According to one teacher:

> It seems we've come a long way in the past two or three years as far as putting the net in the classroom. As far as learning to use the computer to support the curriculum, I feel they have offered very little to the teachers—or required of the teachers as far as that is concerned. ... Mainly, the technology classes that are offered through the school are for Internet use and to me that's something that you can explore on your own.

Technology's Role in Teaching Mathematics (Philosophical)

Individually and collectively, the teachers' philosophical views were consistent with the Standards view on implementing technology in the mathematics classroom. All six teachers considered manipulatives useful in the teaching and learning of mathematics. Simply described by one teacher, "I am for it because it is necessary. Some pick up the skill automatically and others need to see it, feel it, and move it around to master the skill at the fullest level." Five of the six teachers considered calculators and computers useful in teaching and learning mathematics. Calculators were described as "important, but they are not used like they should be. I see calculators as an addition, not taking the place of. I believe that students should learn the basics and the calculator is a bonus." In regards to computers, one teacher stated:

> [computers] changed the classroom environment. Creating a more cooperative environment as opposed to the individual rows and desks that I have now. I see how they become active learners when you put them in front of a keyboard. [You] don't have to spend much time with them because they have no fears. I see it as a great way of breaking down learning barriers. I think we should have a Utopian classroom, a computer for every child—really, there's no reason why we can't. I think we can get rid of math textbooks and teach math through a computer system. It's perfectly possible. Students still need to work math problems on paper and pencil, but we can do a lot more than we are doing now.

On the surface these positive comments were encouraging, the concern is that this strong philosophical stance on the importance of technology in the teaching and learning of math did not manifest itself in action. All respondents stated that the focus at their school was to improve ITBS scores. Grade 4 teachers stated that since the ITBS did not allow calculators, their emphasis on technology was limited. Grade 5 teachers used technology more since grade 5 students could use a calculator on the ITBS test.

Educational Importance of Study

In general, the respondents were very supportive of integrating technology in the classroom. But a major contradiction between practice and philosophy was evident in their responses. Respondents stated that non-curriculum forces, particularly their principal and standardized testing, were the most powerful influences on their decision to use/not use manipulatives, calculators, or computers to teach mathematics. However, at the same time, the interviewees stated that they still used technology, primarily manipulatives, to teach mathematics.

The list of barriers and supporting conditions identified by the teachers support and extend those identified by others (Becker, 1991; Dwyer, Ringstaff & Sandholtz, 1991; Becker, 1994; Chamblee, 1995; Sandholtz, Ringstaff & Dwyer, 1997; Chamblee, Sliva, Slough & Louden, 1999). The most significant of these barriers was the pressure that standardized testing places on the teacher and the curriculum. Teachers in this study consistently reported pressure to teach to local perceptions of skills tested on the ITBS. The most significant new supporting condition was the specific role that the local school board plays in support of technology—especially in small rural school systems.

Perhaps the most important finding was that the interviewees were found to have a positive philosophy about using technology to teach mathematics that was not dampened by their non-use of technology due to external factors. Further study is needed to determine how (1) teachers use technology to develop mathematical concepts in an environment where computational skill fluency is a directive and (2) school administrations' influence individual teacher's decisions to use technology to teach mathematics. Based on these initial findings, the researchers intend to develop a quantitative instrument and a more in-depth protocol instrument to assess the interactions between philosophy, external control factors, and implementation of manipulatives, calculators, or computers to teach mathematics.

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Interactive Distance Education: A Database Model to Facilitate Peer Interaction for Asynchronous Learners

G. A. Stringer
Department of Physics
Southern Oregon University
United States
stringer@sou.edu

J. J. A. Smit
School of Science, Mathematics and Technology Education
Potchefstroom University for Christian Higher Education
South Africa
fskjjas@puknet.puk.ac.za

P. J. Enslin
Information Technology and Management
Potchefstroom University for Christian Higher Education
South Africa
itbpje@puknet.puk.ac.za

Abstract: A pilot project at Potchefstroom University has tested the feasibility and effectiveness of using a database to store and retrieve peer interactions for asynchronous telematic learners. The study involved twelve members selected from a cohort of 43, enrolled in the second year of Project SEDIBA, a residential certificate program designed to upgrade the skills of science teachers from black rural high schools. A telematic module consisting of three units on basic electricity was developed using the database model. Practical work required in the module was done using a inexpensive electronic parts kit. Pre- and post-testing made use of an instrument called DIRECT developed and tested at North Carolina State University. Normalized learning gains of 0.10-0.12 were measured for the pilot and control groups.

Introduction

The educational system in South Africa is under political pressure to upgrade outcomes as a means to individual empowerment. One important constraint in science education is low levels of preparation for teachers. Working in isolated schools scattered across the country, these teachers often have subject matter preparation no higher than the level they are trying to teach. In addition, their minimal preparation in didactics perpetuates ineffective instruction, consisting primarily of rote learning the answers to questions found on the matric exam. Their training certainly doesn't prepare them for the intricacies of the outcomes-based approach that is being mandated in Curriculum 2005 (Taylor & Vinjevold 1999).

Many universities have developed residential programs to upgrade the preparation of in-service schoolteachers both in didactics and in content. But these programs are only able to reach a small percentage of the teachers who need assistance. Economic, geographic, and family factors prevent them from attending residential programs. Distance education via mail-delivered written course materials has long been used by University of South Africa to bridge this gap but the WWW will soon be a viable option, even in rural South Africa. Several companies, e.g. http://www.siyanda.co.za/, offer direct satellite Internet connectivity to remote rural areas. "The Shoma Education Foundation, http://www.shoma.org.za/, uses multi-media technology to meet the needs of educators who are faced with the challenge of implementing outcomes-based education in local schools with the inherited legacy of an apartheid education system." "SchoolNet SA, http://www.school.za/, is a national non-government organization developing and expanding the use of the Internet in South African schools."

The question addressed in this paper is whether Internet Technology can provide effective training for the target group of inservice science teachers. The key words in this question are "effective" and "science teachers." What is needed for telematic materials to be an effective educational alternative to traditional classroom/laboratory science instruction? A pilot study was designed to address this question.

A Model for Implementing Effective Telematic Education

Physics education research has shown that education is more effective when peer learning and peer collaboration is encouraged (Mazur 1997). Effective educational strategies use this constructivist philosophy to help learners recognize, express, and change, as necessary, their current knowledge framework and then build new knowledge from this base. Studies of interactive engagement (IE) methods in introductory physics courses show normalized learning gains of 0.3 - 0.6 compared with traditional instruction at one-third this level (Hake 1998). Thus there is incentive to use IE not only in a normal classroom but also in telematic instruction. Instructional Management Systems (IMS) has published comprehensive requirements to guide the development of telematic learning systems that would facilitate IE methods if fully implemented by the providers.

Numerous products have been developed to assist faculty in the preparation and delivery of educational materials via the Internet, e.g. WebCT and Blackboard. Typically emphasis is on the course management and support functions, and leaves the pedagogy up to the instructor. Thus telematic materials do not necessarily contain effective IE methods even though HTML supports features that can facilitate IE for asynchronous distance learners. A schematic diagram of the interactive engagement model used in our pilot study is shown in (Fig. 1).

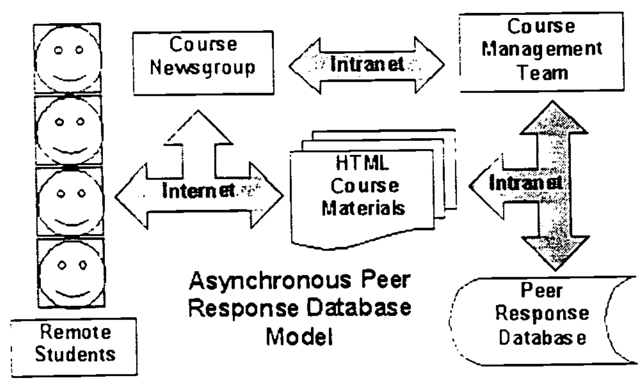

Figure 1: The asynchronous peer response database model (APRDM) stores the naive responses generated by remote asynchronous learners in their interaction with the HTML course materials. The learner is then encouraged to edit and resubmit their responses after reviewing earlier responses from their peers as shown in (Fig. 2).

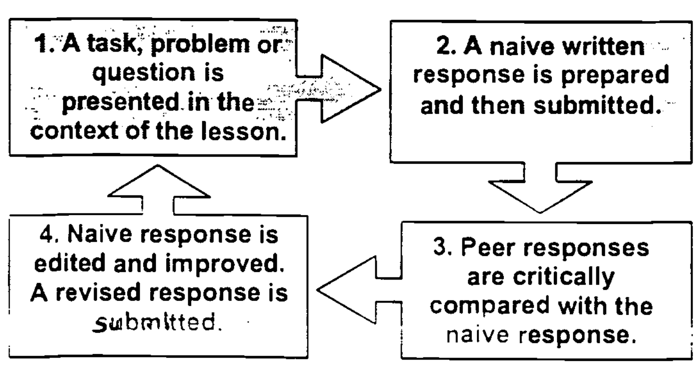

Figure 2: The learning cycle expected using APRDM. In the pilot study the steps anticipated in the bottom two boxes were only partially realized because of difficulty in hiring students to pre-load the database.

Thus the faster TTTP students had few if any stored peer responses to view. The slower students were able to see and use the ideas of their faster peers to amend their naive responses.

In addition to facilitating IE in telematic courses APRDM provides several useful features that are not found in classroom implementations. (1) All learner responses are documented in time-stamped written form in the database. (2) The evolution of each learner's conceptual framework is available for educational research and analysis. (3) As persistent misconceptions are diagnosed, corrective measures may be applied in the HTML course materials. (4) The APRDM promotes self-paced mastery learning of concepts.

An important prerequisite for the use of APRDM is to have a minimal set of peer responses pre-loaded into the database. One option is to hire students to write down their naive responses and store them into the database. Another option is to have experts create a series of pseudo peer responses that include most common student misconceptions along with correct responses. The idea is to provide a number of peer responses for the student to critically review and analyze as they evaluate their own naive responses.

The course management team chose model parameters to control the peer interaction process. Software rules were then created to enforce these choices and notify the learner appropriately. This implementation first checked to see if the learner was logged in with a valid ID/password. Then a language option (Afrikaans, English or Tswana) had to be selected. A written response had to be entered in each text area. Naive responses had to be submitted sequentially for each question or problem in the module. Questions answered previously could be revisited at any time to refine a response, but skipping ahead was not permitted. Possible options not exercised in this pilot study are to; (1) encourage/force written peer review of the stored responses from other students, and (2) force students to revise their own naive response and/or interact with their peers in some way. These last two options arose from the observation that the naive responses in the database were often identical to the final responses. Some possible explanations are; (1) there is great confidence in one's personal conceptual framework, (2) a lack of openness to the thinking of others, (3) poor design of the HTML materials, or (4) a lack of plausible peer responses in the database.

The Pilot Project

A pilot study called the telematic teacher-training project (TTTP) was carried out at Potchefstroom University to study the feasibility and effectiveness of the APRDM. It used a module developed to coincide with the syllabus for the July contact (on-campus) session in the second year of SEDIBA. The telematic module (Tab.1), http://www.puk.ac.za/activelearning/, contained three units on basic electricity.

1. Electric Current (33)	**2. DC Circuits (40)**	**3. Application (35)**
A. Prerequisites (9)	A. Prerequisites (4)	A. Prerequisites (5)
B. Outcomes (4)	B. Outcomes (4)	B. Outcomes (7)
C. Background (3)	C. Introduction (2)	C. Electronic Parts Kit (4)
D. Circuit Building Blocks (3)	D. Schematic diagrams (2)	D. Resistors in Series and Parallel (2)
E. Current Basics (2)	E. Resistance, Voltage, Current, Power (3)	E. Cells in Series and Parallel (2)
F. Necessary Conditions (1)	F. Series and Parallel Circuits (4)	F. DC Circuit Analysis (2)
G. Precise Definition (1)	G. Ammeters and Voltmeters (1)	G. Energy and Power (3)
H. Exercises (6 + 4)	H. Exercises (16 + 4)	H. Exercises (3 + 7)

Table 1. The 3-unit module in basic electricity used in the TTTP pilot study. The number of responses required in each section of the module is enclosed by parentheses.

A representative group of twelve participants were selected from the cohort of 43 enrolled in the second year. A kit of electronic parts was used for the practical work required in unit three of the module. Pre- and post-testing made use of an instrument called DIRECT developed and tested at North Carolina State University. It was administered at the same times to both the pilot study and control group of the cohort. A locally developed attitude survey was used to assess student attitudes about the use of computers in education before and after the pilot study.

The pilot study took place in three phases (Tab. 2). The **first phase** began with the 13 July 1999 contact session at Potchefstroom University. It was divided into two 1-week intervals. During the periods scheduled for instruction in physics the twelve students involved in the pilot study reported to a campus computing facility and worked on the telematic module. The **second phase** began when these students returned home after the contact session. Those who didn't already have local Internet access were loaned computers and/or modems depending on their situations. They were also given Internet accounts, local access telephone numbers, and training in how to use the borrowed equipment. The **third phase** was a special one-day session on campus prior to the September 1999 contact sessions. It was used for debriefing, returning borrowed equipment, and continued work on the module. (Tab. 2) summarizes the progress of each TTTP student during the pilot study. The noteworthy features are:

1. Four students had extreme difficulty getting started in Phase 1a. Residual problems were discovered in the software, the computing equipment supporting the project crashed several times. Personnel overseeing the project lacked sufficient training to deal with these problems.
2. All students made rapid progress during Phase 1b. Corrective measures were taken in the course management area. Problems were identified and solved quickly. Students were given needed advice and feedback with little delay as questions arose.
3. Stagnation occurred in Phase 2. Students worked alone trying to use their own computers or computers loaned to them. Most found extreme difficulty in making connection to the web site from their homes in order to continue making progress on the module. Weekly telephone interviews were attempted to monitor progress and document problems. Most of the problems were due to inadequate computer literacy training. Students were unable to recognize and correct common problems associated with computer usage and in connecting to the Internet via a modem.
4. Five students who participated in Phase 3 again made significant progress through the module. It was also learned that the kit of electrical parts, which was to be used for practical lab work in unit 3, contained no bulbs, a key component in nearly every exercise. This had not been reported perhaps because the module failed to motivate individual work on the practical activities.

Student ID	*Phase 1a 17 July 99*	*Phase 1b 23 July 99*	*Phase 2 25 Sept 99*	*Phase 3 28 Sept 99*
15	1 - D - 3	2 - F - 4	2 - F - 4	2 - F - 4
16	1 - F - 1	2 - F - 4	2 - F - 4	2 - F - 4
17	1 - F - 1	2 - H - 12	2 - H - 16	3 - C - 3
18	1 - A - 2	2 - G - 1	2 - G - 1	3 - A - 3
19	1 - A - 2	2 - H - 1	2 - H - 6	2 - H - 6
20	-	1 - E - 2	1 - E - 2	1 - E - 2
21	1 - A - 1	1 - H - 6	1 - H - 6	2 - G - 1
22	1 - D - 2	2 - H - 11	2 - H - 11	2 - H - 11
24	1 - D - 3	2 - H - 10	2 - H - 10	2 - H - 12
25	1 - C - 3	2 - E - 1	2 - H - 2	3 - B - 4
26	1 - E - 2	2 - H - 14	3 - A - 5	3 - H - 1
27	1 - C - 3	2 - C - 1	2 - C - 1	2 - C - 1
% done =	12%	47%	49%	58%
Responses =	158	608	637	753

Table 2: Progress through the module at key points in the pilot study. The ending date for each phase is shown. Notation used = unit number - section - response number. Shaded cells indicate that no database entries were made during that time interval.

Findings

Assessment results using DIRECT are summarized in (Tab. 3). The TTTP group scored better on both the tests compared with the control group. Both groups showed modest learning gains during the pilot project with the control group outperforming the TTTP group. The correlation coefficients computed using question-by-question percent correct imply the two groups were similar while the disparity in pre-test average scores imply the two populations were different. The percentage of correct responses compares

favorably with studies in the USA, Canada and Germany, which found average percentages of 36% for high school (251 students) and 44% for university (441 students) after instruction (Vetter 1997).

	Pre-test	Post-test	t-test ⇔	<gain>
TTTP group	47.4%	53.1%	0.346	0.10
Control group	40.5%	50.0%	0.006	0.12
t-test ⇕	0.108	0.582		
Correlation	0.83	0.78		

Table 3: Average scores on DIRECT (shaded), t-test values, normalized learning gains, and correlation coefficients. T-test values measure the likelihood that the average scores could be from the same population. Correlation coefficients approach unity, as the average responses between the TTTP and control groups become proportional question-by-question. The normalized learning gains are typical of traditional instruction according to Hake (1997).

It is disappointing but not surprising that normalized learning gains for the TTTP group did not reach values expected for IE (Hake 1997). The TTTP group on average completed only 58% of the work on the module before taking the DIRECT post-test. One reason for this was that the computer literacy training received earlier in the SEDIBA program did not provide the skills needed for telematic learning. The attitude survey given at the beginning of the pilot study showed 70% of the TTTP group rating themselves as highly computer literate. In the same survey given at the end of the project the percentage had dropped to 33%, a far more realistic self-assessment.

It was generally assumed that low English language skills would have slowed reading, reduced comprehension and hindered the peer interaction process. That is why an option was given to write responses in their mother tongue. However, all responses were in English. Further the database shows no clear difference in the English writing skills among the slower students and the faster students. In addition, the attitude survey showed no reduction in confidence that their "English reading and writing skills are good." Although slower students produced far fewer entries in the database their final responses were revised from their naive responses in about 40% of the cases, i.e. they were beginning to use the learning cycle of (Fig. 2). The faster students seldom revised their naive responses since there were few, if any peer responses in the database for them to view. In addition, during phases 1 and 3 they were often able to confer orally in the computer lab before entering responses, which would tend to reduce the revision frequency of naive responses.

The control group did study and complete the same material using traditional instruction but faired very little better in terms of average normalized learning gains as assessed by DIRECT. The t-test values give support that the learning gains were significant for both groups even though the standard deviation was much larger for the smaller TTTP group. Average scores on regular course examinations in electricity that were given to both groups of students are shown in (Tab. 4).

	April 99	July 99	September 99	November 99
TTTP group	54.3	44.4	58.8	57.5
Control group	55.6	56.6	52.2	53.8

Table 4: Average scores for examinations on electricity administered around the time of the pilot study provide comparative information on the performance of the TTTP group and the control group.

Conclusions

1. The twelve learners selected for the TTTP project from the cohort were reasonably well matched to the control group based on assessment results (Tab. 3) and examination performance (Tab. 4).
2. Lack of pre-loaded peer responses in the database was an important constraint preventing full implementation and testing of the APRDM learning cycle (Fig.2) in this pilot study. Slower learners' use of the learning cycle verifies that APRDM does facilitate active learning.

3. Technical problems, programming errors, server crashes and module design errors were discovered and corrected during the pilot study. These all affected the ability of the students to work through the module at the rate originally expected.
4. A course examination was given at the end of the July 99 contact session when the TTTP group had completed just 47% of the telematic module. This may explain the lower average score of the pilot group compared with the control group (Fig. 4).
5. The pilot students lacked computer skills needed to progress rapidly through the module. The training they had already received in the SEDIBA program did not provide adequate preparation for these students. They needed a hands-on introduction to setting up and using a modem for connection to an Internet service provider and more practice using windows and a web browser.
6. Only four students were able to overcome technical obstacles in phase two of the project and make connection to the course Website from computing facilities near their homes. In many cases we believe this is due to very low bandwidth on their local telephone connections.
7. Non-technical issues also affected the study, especially during phase 2, with a nation-wide strike of government employees, including teachers.
8. The following improvements are recommended for future development of the model; (a) Provide forms for learners to contribute their own questions in context of the reading, (b) Design the peer interaction page to allow learners to comment on any peer response and send feedback to the author, (c) Integrate practical work into the learning activities from the beginning of the module, (d) Pose motivational scenarios with multiple solutions early in each section, (e) Carefully match stated prerequisites, outcomes, pre- and post-tests to the content.
9. There is reason to be optimistic about the value of this approach to telematic education. Much has been learned from the pilot study. There are reasons to believe that the learning gains expected from IE can yet be realized in a telematic learning environment using APRDM or a similar model. Further development work is planned.

With the rapid advance of communication technology and the improvement of services in SA, most of the technical problems experienced in this project should disappear in the near future. The growth of private PC ownership and Internet access will soon make this means of physics teacher development an option to be considered seriously by tertiary institutions in SA.

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Teaching "Computers & Society" - The Medium and The Message

Brendan Tangney, Bryn Holmes – Department of Computer Science
Ann FitzGibbon – Department of Education
Trinity College, University of Dublin, Dublin 2, Ireland.
E-Mail tangney@tcd.ie

Introduction

Of late there has been a concerted move within the computer science community to have courses on computers & ethics, or computers & society, given more prominence within the computer science curriculum. However as reported by Jewett (1996), and others, there are a number of significant challenges faced in teaching such courses. These include their inter-disciplinary nature, unsuitability for the traditional lecture format, large class sizes and less than total support for such courses from within the computer science community.

The research described in this paper is based upon experience with teaching one such course. Given the problematic nature of the course different strategies have been tried, over the years, to improve the quality of the course and these have met with some success, as outlined below. This success, however, begs the question as to what specific pedagogical forces are at work and whether or not the lessons learned can be generalized.

In order to explore what is actually occurring in the learning environment, significant events in the course have been recorded and analyzed. Specifically, video recordings were made of the preparation and final delivery of student's in-class presentations. New technologies for capturing classroom data, including digital video cameras, are making it easier to involve more of the research community in interpreting classroom data. The work reported here was done in co-operation by computer scientists and educationalists and images will be presented as part of the data in order to make explicit our assumptions of what we consider effective learning. The research presented here is part of a larger on-going analysis of the course.

Background

The education model in Ireland is similar to that of the UK. Entry to university is highly competitive and is based solely on the results of a national examination. This promotes a very exam-oriented approach to learning. Furthermore, the trend at third level has been towards specialized professional degrees with a strong emphasis on immediate relevance in the marketplace. Thus the prevailing educational climate is a long way from Newman's "Idea Of A University", as a place dedicated to liberal education, despite the fact that employers are now beginning to demand those very attributes that a liberal education instills.

The Computers & Society course discussed here is given as part of the first year of a four-year specialized computer science degree. The course objectives are to encourage students to take a broad look at the relationship between (information) technology and society and to expose them material, and methodologies, from outside their core discipline. The idea of the "Information Society" is critically analyzed. Giving the students experience of teamwork, improving their communication skills, and their ability to construct a reasoned argument are also key objectives. (For further details of the course see www.cs.tcd.ie/tangney/ComputersAndSociety.)

Within the author's institution the problems listed previously are further compounded upon by the fact that the subject has traditionally not been taken seriously by students, and in some cases fellow staff, who tend to regard it as a token subject. Furthermore it counts for a small component of the overall workload for the year, one contact hour per week, and was not examined by an end of year written examination. The class size is not small, 70 or so students, thus ruling out a tutorial or discussion type approach to teaching. Finally while there is an ever expanding literature in the area of Computers and Society the vast majority

of it, in English at least, is from a North American background and thus lacks a certain direct relevance to the immediate lives of the students.

The Teaching Strategy

During the first few years that this course was taught students did not engage with the subject matter, the quality of average student work was poor and attendance at lectures fell to 25% as the year progressed. In order to get the students to fully engage with the material presented in lectures, in the prescribed reading material, and in the overall learning process a number of different pedagogical and assessment techniques were used, some of which are based upon methods described in Schulze (1996).

In order to give the course stature within the student population an end of year written examination was introduced. This is far from being an ideal assessment technique but was crucial for the credibility of the course. A course web site contains not just the course description and links to on-line resources but also samples of selected pieces of work done by students each year. Thus the efforts of previous students are available as a reference point for current students. Inclusion of one's work on the web site also generates a certain amount of internal competition within the class.

During the year students engage in two different types of exercise, writing papers and giving presentations in class. The paper writing is a relatively straightforward. A major paper is submitted in each of the 3 terms and this is returned to the students with some comments. The papers are assessed based upon content, breath of reading in the area and depth of understanding of the material. Marks are also awarded for the coherency of the arguments presented and the proper use of bibliographies and citations. Sample papers are placed on the course web site. Further work needs to be done to improve this aspect of the course but this is outside the scope of this paper.

Group debates are the corner stones of the course. We believe that this is the activity which generates the best learning experiences and this is the aspect of the course that is the focus of this study. The class is divided into 4 groups, of 15-20 students each, and during the year each group must give a series of presentations in the form of in-class debates. The debates are organized on a league system with a prize for the overall winning group. Topics debated have included "IT the workers friend", "Technology is but an improved means to an unimproved end", and "The neutrality of information technology".

The debates are judged not by the course lecturer but by 3 other academic staff: one from the Computer Science department and two others from different areas in the university. This requires the students to pitch their presentations at a level which is not technology focused, which is not something that comes naturally to computer science students. The 3 adjudicators give very useful feedback to the students on what worked in their presentations and what areas need more improvement. In addition to the formal class presentation each group meets with the course lecture to give a dry-run of their presentation and this has greatly improved the quality of the final presentations.

To illustrate how this works in practice take the following example of a class presentation on the topic "IT - the worker's friend". Students research the topic on the web and in the process come to realise its advantages and disadvantages when compared to a library. They must work as a group, using e-mail to support the activity. The actual topic for debate is the relationship of IT to work and the students work extensively with IT in preparing the debate. The topic must be presented to non-IT specialists forcing them to frame their arguments for the lay person. The slide show used to support the presentation requires the students to structure their argument into coherent bullet points and all presentations are in turn published on the course web page turning the exercise into one of information production as well as consumption.

Assessment of group projects is always problematic, how does one prevent some students free-loading on the work of others? The solution adopted is to monitor the e-mail distribution list for each group. Students are awarded a mark based upon the overall performance of the group AND their own visible contribution to the preparation.

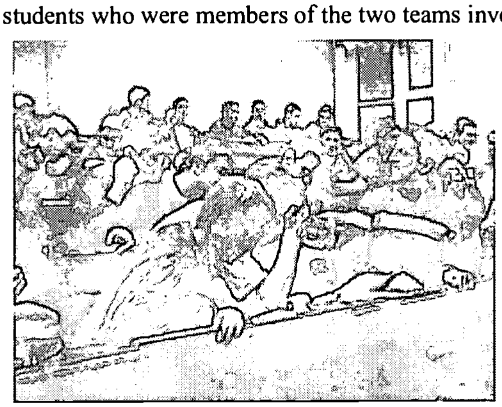
Results and Analysis

The approach just described appears to be paying dividends. Students are engaged with the course and it is seen as a subject to be taken seriously to the extent that the end of year examination has been dropped and the course is now evaluated purely by continuous assessment. The quality of the work produced by the average student in the class has improved. This is a reflection of the seriousness with which students now take the subject and that some of the techniques described above are working. Attendance at lectures is up to 75% or more.

The data analyzed here comes from videotaping two weeks of classroom debates as well as the pre-practice sessions. In order to reduce observer bias the recording procedure used was to first pan the classroom back and forth over a 10 second period. Then to the camera was focused on the front one-third of the class for a ten second period before moving on to the middle and back sections for similar periods. The process was repeated throughout the class. The presentations were held in one of the University's old lecture theatres and were well attended. The use of lightweight wireless laptop and data projector was somewhat incongruous in the setting and acted as a metaphor for the current debate on the role if IT in education.

The slide presentations, or successive bullet points, make students focus their arguments and leads to a hierarchical presentation of materials. In Mayer (1980) the effects of elaborated and hierarchical methods of organization of instruction on cognitive processing were compared. It demonstrated that students who had learning material presented in hierarchies were better able to elaborate and understand the deeper meaning of the information than the elaborative group. Mayer argues that cognitive skills would be supported by allowing learners the opportunities to chunk information into smaller, meaningful parts. The experience reported here, of groups breaking into sub-groups to prepare the bullet points for each speaker, would support that view. As the lecturer mentioned in the first practice session, "You need to focus your argument and make it sharper and doing slides would help you with that."

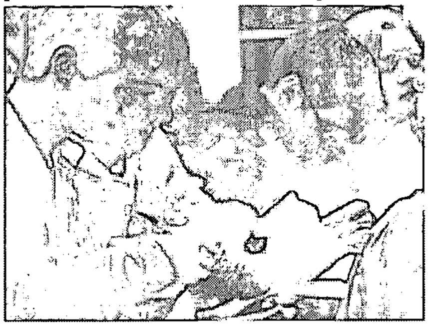
Analysis of the first set of debates shows strong differences in interaction and collaboration between students who were members of the two teams involved in the debate and those who were not. This is



captured in the accompanying still image which shows the higher levels of engagement and interaction of students in the front compared to the row of students who had presented the previous week and thus were sitting, quietly, in the back row. During the class students from the two presenting groups found plenty of opportunities to speak, e.g. when speakers rotated or when the judges left the room. Interaction among the students who are not presenting were limited to one or two instances. However, the audience was quick to react to presenter's jokes pointing to a clear interest in the debate but the lack of interaction and activity is probably an indication of a more passive role on the part of those not presenting. Although one would expect that students who were presenting would interact more than those who were not, the absolute lack of any sort of activity (from taking notes, to making comments to each other) was unexpected. This was even more noticeable when tapes were viewed several times and the key players from the previous debates were seen sitting quietly in the back. The initial findings point to an idea of a learned classroom role on the part of students, in this case different behaviors were considered acceptable by those who were the audience and those who were the participants.

A marked difference was noticed between the behavior of the groups even over the short period of observation. There was a considerable increase in group work and interactive behavior in the second presentation from the first one and this points to the rapid development of a collaborative learning strategy. In the first presentation recorded members of the same team as the presenters spent 3 minutes (out of a possible 51) interacting with each other. While in the second presentation, one week later, 18 minutes (out

of a possible 54) were spent carrying out some type of supportive collaborative activity, from passing notes to whispering together. In the in-class presentations the members of the teams opposing the presenters spent 10 minutes communicating during the first week compared with 26 minutes of group work exhibited by opposing members the second week. This included the passing of slips of paper from the group members to the student in charge of the rebuttal. The flurry of small sheets of paper may have grown out of the groups' expertise with using email. There was interaction in the green team (2nd week) between female and male students as well as between those of the same sexes. All other classroom interaction was between male students. This is partly due to the lower numbers of female students in the class and that in these presentations all the presenters were male. Although it could be argued that the interaction patterns are simply a factor of the personality of those involved the fact that even the most active students from the first week sat quietly in the back of the class in the second week points to a different force at work than simply the people who made up the group. Future presentations will be videoed as more research is needed here to explore this issue.



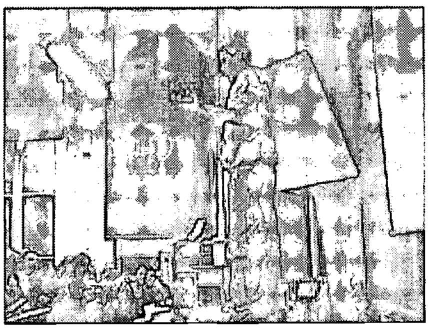
One of the key aspects of the course is to provide students with examples of good practice from their peers. A common comment from judges at the presentations is that they quality rises from presentation to presentation. This suggests that significant peer learning is taking place during presentations. Students who are yet to present are able learn from those they are watching, i.e. they take in the form of the presentation, as that is what would transfer over to their own future experience. It may be, therefore, that the way their peers present information is more important to their fellow students than the content. The role of the first presentations would, therefore, be one of the setting of a standard. The second groups both had a benchmark to try and best. This type of in-class learning would have implications for examining participation in a learning environment as a key area of delivery of information. Further research is needed and the effects of posting of exemplar essays to the course web page should also be explored.

The change in group processes were even more noticeable in the practice sessions than in the class presentations. In the first session, the lecturer spend 28 (out of a possible 42 minutes) coaching the students, giving them advice and asking questions. In the second working session the students initiated a great deal of the activity and during the first 25 minutes the lecture's total coaching time was 3 minutes (in total 18 minutes of a possible 60). The students who had arrived for the second working session had already met the previous day to practice the presentations together. Over half of the students present (as opposed to 5 key players /presenters in the previous week) contributed to the discussion as to what could be done to improve the presentations. Exchanges occurred between male and female members of the group in the 2nd working group (partly aided by the increase in numbers from 1 to 3). In the photograph you can see the 1st working group. Students are alert and interested but not working together and the nature of their exchanges were mostly one student interacting with the teacher as opposed to the 2nd group where the flow of information was multidirectional.

The first group spent more time listening to the lecturer coach them but the second seemed to provide some of the same sorts of critically supportive environment for their fellow students as the lecture did for the class as a whole. The lecturer exhibited a number of intellectual skills when working with the students and modeled them in his explorations of their arguments. He promoted coaching as a collaborative effort stopping to ask what students thought of the presentation and encouraging them to help each other. He cut short any comments that were not constructive or that were unnecessarily critical. Students were, therefore, given an environment in which they could begin to take over the role of the teacher – teaching each other, working together to construct knowledge. There lecturer would often ask the presenter to reword their

arguments and then provide scaffolding for the learner's intellectual growth by focusing on the development of key points and issues. The results were more reflective and refined articulation on the part of the students. This is in keeping with Vygotsky's theory that higher-level cognitive skills are formed as the result of social interaction. In his model, learning takes place between students and teachers when there is active intellectual interaction taking place. The students will in time take over and internalize these processes individually thus forming cognitive processes (Brandt, 1989).

As is often the case with using IT in the classroom there were occasional glitches. On one occasion this resulted in a group being forced present without their supporting slides. The lecturer introduced the group with the following remark. "Now we have a classic example of the effect of technology which is beyond anyone's control. The Red Team do not have their slides. That's fine and is not a problem. The slides are meant to structure the talk so let's see how we get on without them." The group then had to spontaneously adopt an alternative presentation strategy with one very creative student jumping, at one point, onto the lecture podium actually replacing the same physical space as that taken up by the slide he had prepared to support the point he was making.



The role of students in creating their own learning environments is of increasing interest in education. The use of computer-assisted learning environments (Chee, 1994; & Hilem & Futtersack, 1994) has been heralded as a way to provide a type of cognitive apprenticeship (Kurt & Miller, 1997). Promoting learner responsibility is seen as a key aspect of constructivist learning (Freedman, 1998). In this course, the structure of the course itself provides for the embedded situated cognition. Specifically the debates not only provide increased motivation and interesting content delivery but also a way for students to articulate their learning processes in aiding their peers improve presentations. This is in keeping with Mayer's (1980) work which explored the contributions of cognitive science to learning design in computer literacy and recommends that in order to promote the development of cognitive abilities, learners be provided with opportunities to restate information in his or her own words.

Conclusion

Obviously the course described here has benefited from the approach adopted and the research undertaken to date is beginning to shed light on the underlying reasons for this improvement. Key to the success of the research has been the use of digital video to record and analyze classroom behavior.

Orey and Nelson (1994) point out that the learning environment is key to the development of intellectual skills. The idea of situated cognition is supported by the creation of a cognitive apprenticeship where learners have a chance to become participants in a community of practice. This is very much the approach followed here. In terms of the information technology and society focus of the course all six attributes that Hancock (1997) points to as being characteristics of information age schooling are found in the learning environment of the course, namely interactivity, self-initiated learning, a change in the teacher's role, media and technology specialists as central participants, continuous evaluation, and a discussion-centered classroom environment.

Finally previous research on classroom performance of teachers points to how the foundations of their discipline became the foundations for restructuring of content knowledge for pedagogical purposes (Gudmundsdottir, 1987). Hence the sub-title of this paper – the medium and the message. The message of the course – issues to do with the "Information Age" – is embedded in the medium – information age schooling!

It is suggested here that the lessons being learned from this course can be generalized. Instructors can explore ways of going beyond the specific content of a course and allowing the course structure to provide a vehicle for transmitting important aspects of the discipline. Not only did designing delivery provide

structure for increased student learning it also helped to overcome many of the original difficulties of teaching the course.

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Learning Mathematics Through Image Processing: Constructing Cylindrical Anamorphoses

Steven Tanimoto, James King
University of Washington, Seattle

Richard Rice
Alias/Wavefront, Inc., Seattle, WA
United States

Abstract: Anamorphic images are distorted images that can be seen normally when viewed in special ways. A very popular form of anamorphosis in the 1700s and 1800s is a type of image that is intended to be viewed by placing a cylindrical mirror in the middle of it and observing the reflection. These images are fun to look at because without the mirror, an observer can make out just enough of the structure of the scene to be tantalized, and then the cylindrical mirror brings a visual resolution to the puzzle, answering the question "What is it supposed to really look like?" These kinds of images can be used today in compelling educational activities involving mathematics and computers. With the aid of special software for image processing in a mathematics context, students can construct their own anamorphic images while learning about image transformations, polar coordinates, ray tracing, digital image representation, and programming of computer operations on images.

Introduction

Anamorphic images are distorted pictures that look normal when viewed in special ways, such as reflected in cylindrical mirrors (see Leeman 1975). Anamorphic images have entertained people since the 1500s. It once required significant artistic skill and considerable patience to be able to produce an anamorphic image (see McLoughlin Bros. 1900). Today with a personal computer, some scanned images, and a few formulas, it is possible to produce good-quality anamorphic images in a few minutes. There are some educational benefits to students who study the various aspects of anamorphic images: students see a new connection between mathematics and art, they learn about computing transforms of images, they develop an appreciation for some subtle aspects of optics, and they increase their appreciation for the creative spirit of the renaissance.

This paper has two objectives: (1) to discuss some ways to introduce students to anamorphic images in the context of mathematics and computing, and (2) to present the geometrical relationships and the resulting formulas that permit the computation of anamorphic images.

The METIP Project

During the 1990s, the University of Washington ran a project entitled "Mathematics Experiences Through Image Processing" (METIP) with the objectives of producing special software and activities to explore the use of image processing in teaching and learning mathematics. One of the software tools produced by the project is a system called "Color XFORM" that permits users (and in particular, students in junior high school, high school, or college) to perform operations on digital images, where the operations are specified mathematically (rather than with simulated artists tools as is the case with most popular image-processing software). The Color XFORM program is sufficiently versatile that it can be used not only for common image enhancement operations but also to create special effects such as watermarked images, stereograms,

and anamorphic images. (For more information about the project, see Tanimoto 1995, 1998 or the the METIP project home page.)

NCTM standards and image transformations

A major thrust of the METIP project has been to provide new ideas to help teachers apply the curriculum and evaluation standards of the National Councial of Teachers of Mathematics (NCTM 1989). The project's software and activities have been developed to support learning by discovery, to foster connections between mathematics and the visual arts, to encourage construction using mathematical tools, and to promote communication about and using mathematics and visual representations. Another important aspect of the standards is their call for the incorporation of relevant new content into the curriculum. The mathematics of image representation and processing is an extremely important new topic for all citizens who will use images in the Internet. Knowledge about the economics of digital images, the trustworthiness of images as evidence and many other issues are connected with the essence of what digital images are, how they are represented, where they come from, and what techniques are available for altering them. The METIP project has therefore made an effort to provide activities that stimulate thinking about image representation and computer-based transformations of images.

Student Activities with Anamorphic Images

Anamorphic images offer students an opportunity to explore several mathematical ideas including polar coordinates, the geometry of ray-tracking, and the representation of geometric warps by pixel permutations. This mathematics ranges from middle-school level coordinate concepts through fairly advanced systems of equations, and it therefore has the depth to permit learning at a wide range of levels of expertise.

In order to exploit anamorphic images in mathematics education, it's important to take advantage of the motivational potential of the images. Therefore, a natural way to begin a unit on image transformation is by showing students lots of classical examples of cylindrical anamorphosis. Each image should first be viewed without the mirror in order to build anticipation. Then the mirror is used to resolve the puzzle.

After students have seen a variety of examples, they are ready to create their own anamorphic image using the old-fashioned method of drawing it while watching it reflected in a cylindrical mirror. The drawing process is facilitated for students new to anamorphic images by the use of specially lined paper having a polar coordinate grid on it.

After students have experienced the challenge of manually constructing anamorphic images, they have enough experience to appreciate computer-based methods for constructing them. We offer them two methods, one of which is simple and straightforward, but not physically as accurate an imaging method as the second method. The second method is based upon an accurate ray-tracing model of the process of viewing an anamorphic images, but its mathematics is more complicated, and applying the method requires the use of a general technique for applying arbitrary geometric transformations to digital images.

Geometric Relationships

We start our discussion of anamorphic images with an explanation of the geometry of the viewing arrangement. Then we derive expressions that permit us to determine how to map points from the distorted image to the corrected image and vice-versa.

Coordinate system and key points

We adopt a three-dimensional coordinate system with axes labeled by x, y, and z. We assume that the cylindrical mirror has a radius of 1 distance unit, and that it is positioned with the center of its base at the origin and oriented such that its central axis is the z axis of the coordinate system. These relationships can be seen in Fig. 1.

The viewer's eye point is assumed to lie in the x-z plane at a distance of r from the origin along the x axis and at a height of h. Thus the eye point is $E = (r, 0, h)$.

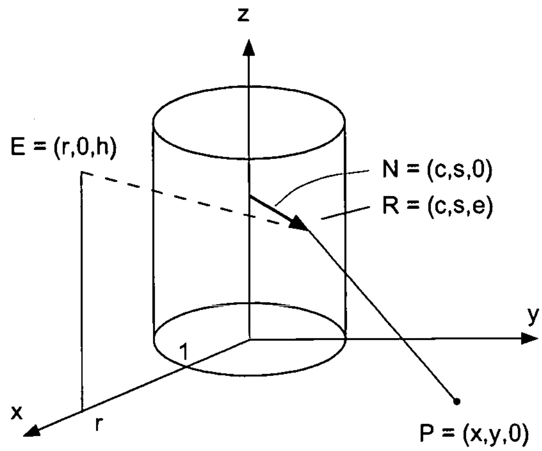

Figure 1: Geometric relationships with viewer, cylindrical mirror, and point in an anamorphic image.

The anamorphic image is presumed to lie in the x-y plane. A designated point $P = (x, y, 0)$ of that image is assumed to have a visible point R of reflection on the cylinder, when viewed from E. The point R can be described with the coordinates (c, s, e) where $c = \cos\theta$ and $s = \sin\theta$ for some angle θ. This is because the relection point lies on the cylinder, which has radius 1. The value e is the height on the cylinder of the reflection point.

At the point of reflection, we denote the normal vector to the surface of the mirror by the symbol N. We have $N = (c, s, 0)$, since N is equivalent to the projection of R onto the plane $z = 0$.

Vector relationships for reflection in a mirror

Let us momentarily study the relationship between two vectors A and B, where A can be considered the vector of incidence of an incoming light ray to a reflecting mirror and B can be considered the vector for the reflected ray. We assume that A and B both point away from the reflection point.

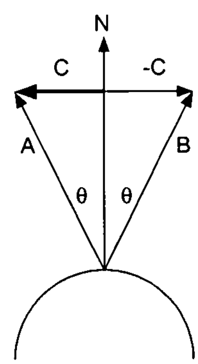

Figure 2: Vector relationships for reflection in any mirror.

As can be seen in the Figure 2, the vector A can be expressed as a sum of two vectors of smaller magnitude: a vector along the normal N to the reflecting surface and the vector C which is perpendicular to the normal. The vector along the normal is the projection of A onto N, which is given by the dot product of A with N multiplied by N. Thus, we have $A = (A \cdot N)N + C$. In the same way, B can be expressed as $B = (A \cdot N)N - C$.

Now if we solve the equation for C and substitute it for C in this, we get an expression for B independent of C: $B = (A \cdot N)N - [A - (A \cdot N)N)]$, or even simpler, $B = 2(A \cdot N)N - A$.

From a point on the cylinder to a point on the image

Let us now apply the relationship between incident and reflected rays to the particular case of the cylindrical mirror. Let us take as our incident vector A the vector from eye point E to reflection point R. (The physics of which ray is incident and which is reflected does not really matter here, since the mathematical relationship for reflection is symmetrical.) Thus, we substitute $E-R$ for A and obtain $B = 2((E-R)\cdot N)N - (E-R)$.

The point P in the anamorphic image lies on the line that passes through R in the direction B. This line can be expressed as the locus of points of the form, $R+tB$. The point in the image lies at the intersection of this line with the plane $X \cdot K = 0$, where $K = (0,0,1)$.

At P we have $(R+tB)\cdot K = 0$, or $t = \frac{-R\cdot K}{B\cdot K}$. Thus $P = R - \frac{R\cdot K}{B\cdot K}B$. Since $R\cdot K = e$, we have $B\cdot K = 2(E-R)\cdot NN\cdot K - (E-R)\cdot K = e-h$. Thus $P = R + \frac{e}{h-e}(2(E-R)\cdot NN - E + R)$. Since $R\cdot N = 1$, we have

$$\begin{aligned} P &= R + \frac{e}{h-e}(2(E\cdot N - 1)N - E + R) \\ &= R + \frac{e}{h-e}(2(rc-1)N - E + R) \\ &= (c,s,e) + \frac{e}{h-e}(2(rc-1)(c,s,0) - (r,0,h) + (c,s,e)) \\ &= (c,s,e) + \frac{e}{h-e}(2rc^2 - r - c, s(2rc-1), 0) \end{aligned}$$

Now let $w = \frac{e}{h-e}$. Then,

$$\begin{aligned} x &= c + w(2rc^2 - r - c) \\ y &= s + ws(2rc-1) \end{aligned}$$

Eliminate w and we have $\frac{x-c}{2rc^2-r-c} = w = \frac{y-s}{s(2rc-1)}$, and $(x-c)s(2rc-1) = (y-s)(2rc^2-r-c)$, together with:

$$\begin{aligned} s(2rc-1)x + (r+c-2rc^2)y &= \\ &= cs(2rc-1) - 2rc^2s + rs + sc \\ &= 2rc^2s - cs - 2rc^2s + rs + sc \\ &= rs \end{aligned}$$

Now we solve the above for s: $s[(2rc-1)x - r] = (2rc^2 - r - c)y$. Equivalently, $s = \frac{(2rc^2-r-c)y}{(2rc-1)x-r} = \frac{a}{b}$. Now we use $c^2 + s^2 = 1$ to obtain a relationship among a, b, and c:

$$\begin{aligned} c^2 + s^2 &= 1 \\ c^2 + \left(\frac{a}{b}\right)^2 &= 1 \\ b^2c^2 + a^2 &= b^2 \\ b^2(c^2-1) + a^2 &= 0 \end{aligned}$$

Replacing a and b by their values, we get: $((2rc-1)x - r)^2(c^2-1) + (2rc^2 - r - c)^2y^2 = 0$. Now we expand in powers of c:

$$4r^2(x^2+y^2)c^4$$

$$
\begin{aligned}
-4r(x^2+y^2+rx)c^3 & \\
+((x+r)^2+y^2-4r^2(x^2+y^2))c^2 & \\
+2r(2x(x+r)+y^2)c & \\
+r^2y^2-(x+r)^2 & \\
& = 0
\end{aligned}
$$

This fourth-order polynomial equation can be numerically solved for c at each (x, y) pixel location. Alternative derivations are possible; depending upon the pedagogical needs, versions without dot products or with cross products can be presented (see Rice et al 2000).

Practical considerations

The method above has good and bad aspects. What's good about it is that it gives us a means to accurately obtain c and thus the angle (or longitude) of the reflection point on the cylinder for a given (x, y) point in the anamorphic image. From this, we can then obtain the height or latitude of this reflection point and then establish what pixel in an original scanned image to use in creating the anamorphic image.

The method has its downsides, too. Numerically solving the fourth-order polynomial is a lot of computation to do for each pixel. In order to avoid doing this every time one makes an anamorphic image, this mapping could be computed once in advance for every pixel of a certain sized image and then reused. However, if one is going to do that, then there is a more practical way to obtain the mapping, which is to use a forward mapping computation with resolution that adapts to fill the holes that would otherwise result.

Another disadvantage of this direct-mapping method is that the anamorphic image that we make with this method will look good only from the particular viewpoint used. Consequently, another approach will be more attractive if we want an anamorphic image that can be viewed in the mirror from any direction with reasonable results.

The Full 360-degree Method

In order to produce cylinder anamorphoses that look reasonably good from any angle around the cylinder, we can use the following approach. We begin by adjusting the scale of the original scanned image so that it can be wrapped around the cylinder and have its left and right edges meet. Next, we project the image points on the cylinder down to the anamorphic image plane using rays that begin on the axis of the cylinder and that make a certain fixed angle (e.g., 45 degrees) with the axis while passing through the image points.

Figure 3 shows the relationship between the source image and anamorphic (destination) image for the full 360-degree method. The source image has x values going from 0 to $x_{\mathrm{sm}} - 1$, and y values going from 0 to $y_{\mathrm{sm}} - 1$. Here sm stands for source maximum. The destination image is assumed to be square and has pixels with x and y coordinates ranging from 0 to $x_{\mathrm{dm}} - 1 = y_{\mathrm{dm}} - 1$. Here dm stands for destination maximum. The center of the destination image is (x_c, y_c), where $x_c = y_c = x_{\mathrm{sm}}/2 - 1$. The radius of the empty region of the anamorphic image (where the cylindrical mirror will sit) is ρ, measured in pixel widths.

We can now give an expression for the values of the pixels in the anamorphic image.

$$f_d(x, y) = f_s(c_x \mathrm{angle}(y - y_c, x - x_c), c_y[\sqrt{(y - y_c)^2 + (x - x_c)^2} - \rho])$$

where

$$\mathrm{angle}(dy, dx) = \begin{array}{l} \pi + \arctan(dy/dx) \text{ if } dx \neq 0 \\ \pi + \mathrm{signum}(dy) \cdot \frac{\pi}{2} \text{ if } dx = 0 \end{array}$$

and c_x and c_y are scaling factors given by

$$
\begin{aligned}
c_x &= x_{\mathrm{sm}}/2\pi \\
c_y &= y_{\mathrm{sm}}/y_c - \rho
\end{aligned}
$$

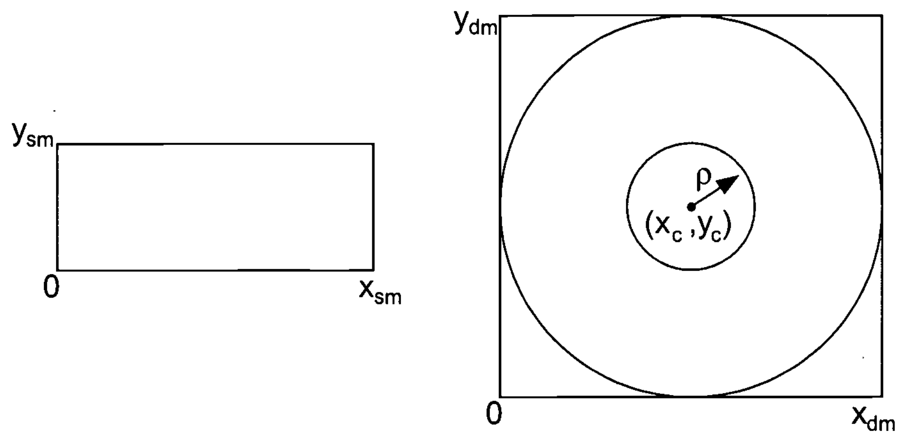

Figure 3: Source and destination (anamorphic) image formats for the full 360-degree method of creating cylinder anamorphoses.

Results and open questions

Our project has succeeded in producing materials that enable students and teachers to explore anamorphic images with the help of computers. Further work is needed to assess the relative impact this type of activity has on students' actual learning, not only of image processing concepts themselves but of transfer effects to the learning of the mathematical subject matter in the traditional curriculum.

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Teaching of "Spreadsheets- design and use" by Learning Activity Package

Daniela Touparova (Doureva)
Department of Computer Science
South West University "N. Rilski"
Bulgaria
ddureva@avala.bg

Abstract: The focus of this paper is application of Learning Activity Package (LAP) and the Web- based variant of LAP in teaching "Spreadsheets- design and use".
In the Section 1 the background of education concerning Information Technology (IT) and Computer Science(CS) in Bulgarian secondary school is described.
Section two deals with the architecture of LAP. More precisely the types of problem solving tasks and their components are proposed and discussed.
Section 3 concerns the analysis of the experimental study of using LAP for module "Spreadsheets- design and use.". The study has been carried out with 184 students from Language School and Vocational School in Business and Agriculture.
In Section 4 one point of view for Web- based presenting of LAP are given.
Also some ideas for future research of application of Web- based LAP in teaching different IT and CS modules at the Bulgarian Secondary Schools are discussed.

Introduction and Background of the Education in Information Technology (IT) and Informatics (Computer Science) in Bulgaria.

Information technologies influence the social and economic development in Bulgaria as well. If IT should be coming into everyday life, an adequate training is to be ensured as early as at secondary school level.

At the present moment a wide range of software and hardware supply is used in Bulgarian schools. Unfortunately, there still are upper-secondary schools which are only equipped with 8-bit computers in a minimal configuration of 48 KB RAM, with no floppy-disk drives. Other schools use 8-bit computers with floppy-disk drives and RAM upgraded to 64 KB. The greater majority of schools use 16-bit Bulgarian Pravetz-16 computers which are IBM PC/XT compatible. Selected schools are provided with IBM compatible computers with 80286, 80386, 80486 or Pentium processors or with APPLE MACKINTOSH computers. The hardware diversity in schools is inevitably linked to a diversity in software.

Most schools have only one small computer laboratory, which hinders to a grate extent teachers' attempts to integrate Informatics and IT into other subjects.

There are three ways of teaching Informatics (Computer Science) in Bulgarian schools:

- as a compulsory subject in the Secondary Comprehensive School.
- as an extra or optional subject in the Secondary Comprehensive School and Secondary Technical Schools. Informatics is studied in the 9th - 12th form of the former and in the 1st - 3rd form of the latter; the workload is 72 lecture hours per year.
- as a subject of specialization.

Since 1994/5 academic year a subject named *Technologies* has been introduced in the curriculum for the 9th and 10th form of the Secondary Comprehensive School. One of the sub-disciplines of *"Technologies"* is *"Information Technologies"*.

The tuition in IT varies depending on the type of school. In comprehensive schools IT is studied as a compulsory subject 2 hours per week.

The curriculum consists from several modules, which the teachers could choice depending of used hardware, software and student's interests.

In some comprehensive schools informatics is introduced earlier as an extra or optional subject. Not all students choose to study Informatics earlier. The problem arises for the teacher to organize the teaching process in a way which will ensure the motivation of each student.

In the background of quickly changes of information technologies the students should be able to use different software documentation to master new abilities and knowledge for solving a great variety of real tasks. The students should be prepared for their future career. Still in the schools they should obtain abilities for self-learning and be ready for lifelong learning. In teaching software applications LAP could help to be achieved these important educational goals and could ensure a differentiated approach to the teaching of informatics in conditions of distinguished entrance level of the students.

The LAP for Teaching "Spreadsheets- Design and Use."

The LAP is described in (Callahan&Clark, 1988) like a tool for independent, individual study. It consist instruction, references, exercises, problems, self- correcting materials, and all the other information that a student needs to carry out a unit of work in his own.

The LAP for teaching "Spreadsheets- design and use." is divided in 7 chapters and is composed from:

•instructions;

•exercises;;

•system of problems;

•self- correcting materials.

Each chapter begin with outline of outcomes and end with summary for learned basic terms and ideas.

The instructions are similar to the instructions in software user's guides. In this way the students will improve their reading abilities for self learning and using of software documentation.

The exercises are directed to the replication and assimilation of the instructions and the problem solving.

The system of problem solving take a central place in development of LAP "Spreadsheets- design and use.". Through them the students master the basic components and operations in software environment. They should be related with solving of real everyday problems. The tasks should improve student's motivation.

In the LAP for teaching IT and in particular for teaching spreadsheets could be classified next types of tasks:

•*operational tasks*- they are related to the learning of software environment Example: files operations-Save, Create New File, Open, edit and format of data and spreadsheet's structure.

•*conceptual tasks*- that are the tasks for learning and assimilation of basic ideas and principles for information processing. Example: design of spreadsheet; data manipulations through different operators and application of formulas and functions, choosing of suitable graphics for data presentation, etc.

•*fundamental practical problem solving*- in their background the elements of the software environment, basic concepts, working principles and processing of used information. Each task is composed of several task-components. The concept "task- component" is defined for mathematical tasks in (Ganchev, 1971). The task - component could be operational or conceptual. The fundamental problem solving could be formulated in beginning of the module and should be solved in several consecutive topics or chapters. Examples are given in Fig. 1. The most of that tasks are consisted with Bulgarian school practice.

•*supplementary practical problem solving*- it is aimed to the assimilation of knowledge and abilities, formed by fundamental practical problem solving. This type of problem solving includes some of task-components, composing a fundamental problem solving.

•*course project problem solving*- it is directed to the elaboration from team of several students. The solving of this task requires not only basic knowledge and abilities. The students should show original approach.

The structures of the fundamental and supplementary problems solving are given on the Fig. 2.

The proposed system of tasks and problem solving responses to the followed requirements:

•the problems are based on their practical useful and are selected according to the frequency of their application, they demonstrate the special features of the used software;

•most of the problems motivate the introduction of the new knowledge and abilities;

•the system reflect the principle of "accessibility"- the problems are arranged with gradually growing of difficulty and complexity, there is ensured a continuity between the problems.

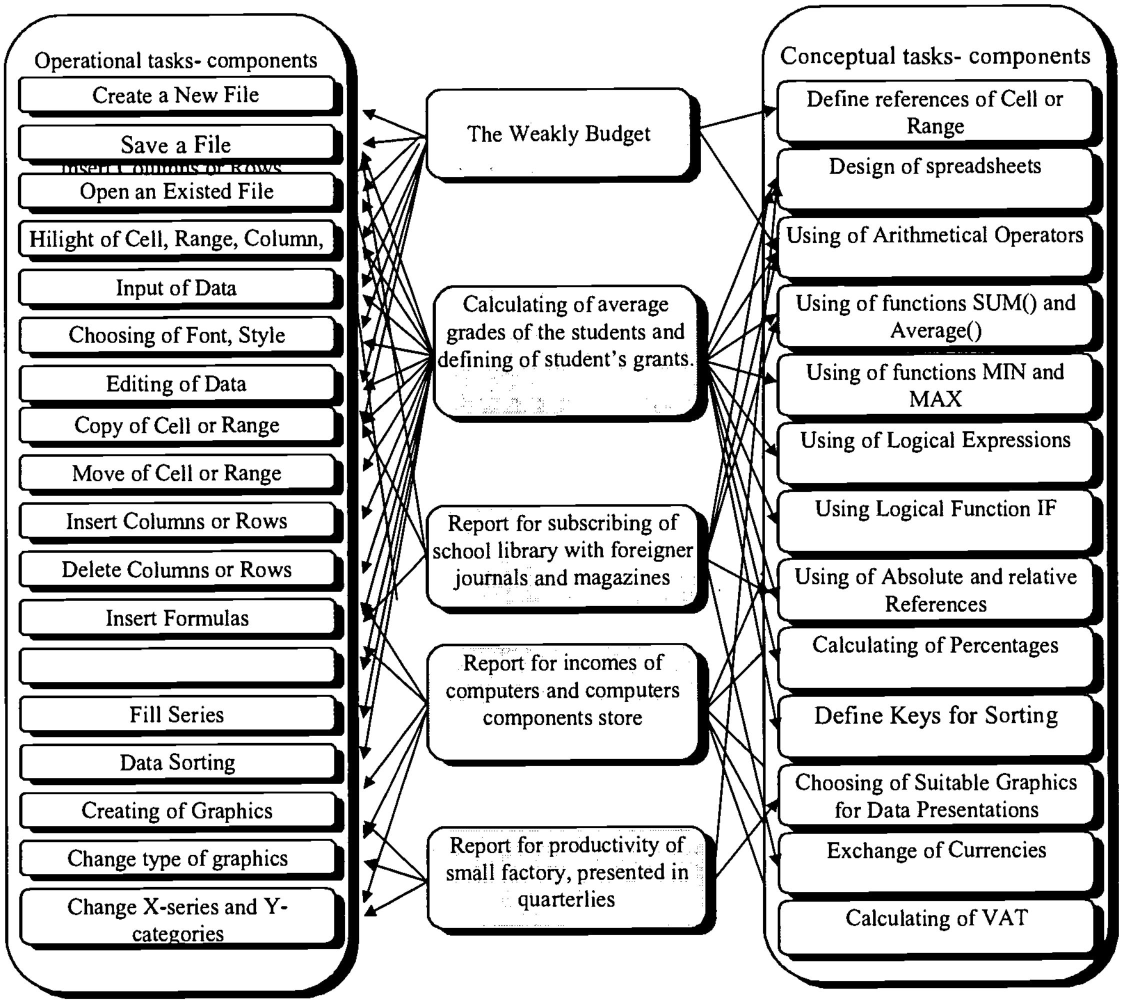

Figure 1. The schema of the system of used task and fundamental problem solving,

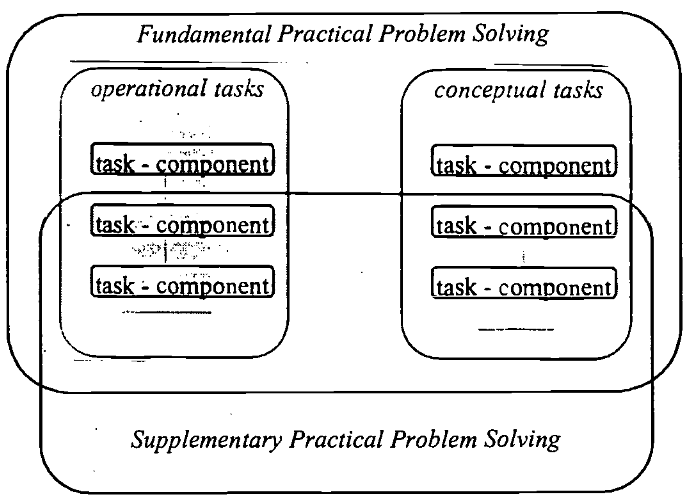

Figure 2. The structures of the problems solving .

The presented system of problems provide high efficiency of educational process.

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The self- correcting materials are included in each topic of the package. There are used criterion-referenced tests. The "cut- off" of each test is determined by expert evaluation.

One Experimental Study of Using LAP for Teaching "Spreadsheets- Design and Use."

The experimental study was carried out in 1996/1997 and 1997/1998 academic years. In the experiment participated 184 students from 10th. and 11th. forms from Language School and Vocational School in Business and Agriculture. The students was divided in 3 experimental groups (EG)- EG1 included all students from 10th. form at the Language School, EG2 covered the students from 11th. form at the Language School and EG3 included the students from 11th form at the Vocational School in Business and Agriculture. The students from EG1 and EG3 had learned only the module "Operational Systems- Windows 3.*" before they started to learn module Spreadsheets- design and use" by LAP. In EG2 had been learned modules "Operational Systems- Windows 3.*", "Word- processing" and some of topics from the module "Spreadsheets-design and use" by conventional methods of teaching where the teachers had taken a central place in process of education. Therefore the EG2 was used also like a control group for comparison of student's achievements. The students from EG2 used whole LAP but in more short period.

The proposed LAP was used in each of the groups for self- learning. The teacher was an adviser and helped the students to solve the questions and troubles in working with LAP. The tests that had been included in the LAP was used for self- assessment, but in each moment the teacher had a possibility to require the copy of a test for feedback receiving. The teachers assessed the student's achievements by tests and solving of different operational and conceptual tasks and problems.

At the end of the study a questionnaire with the students was hold. The Fig. 3. represents student's answers for some of the questions.

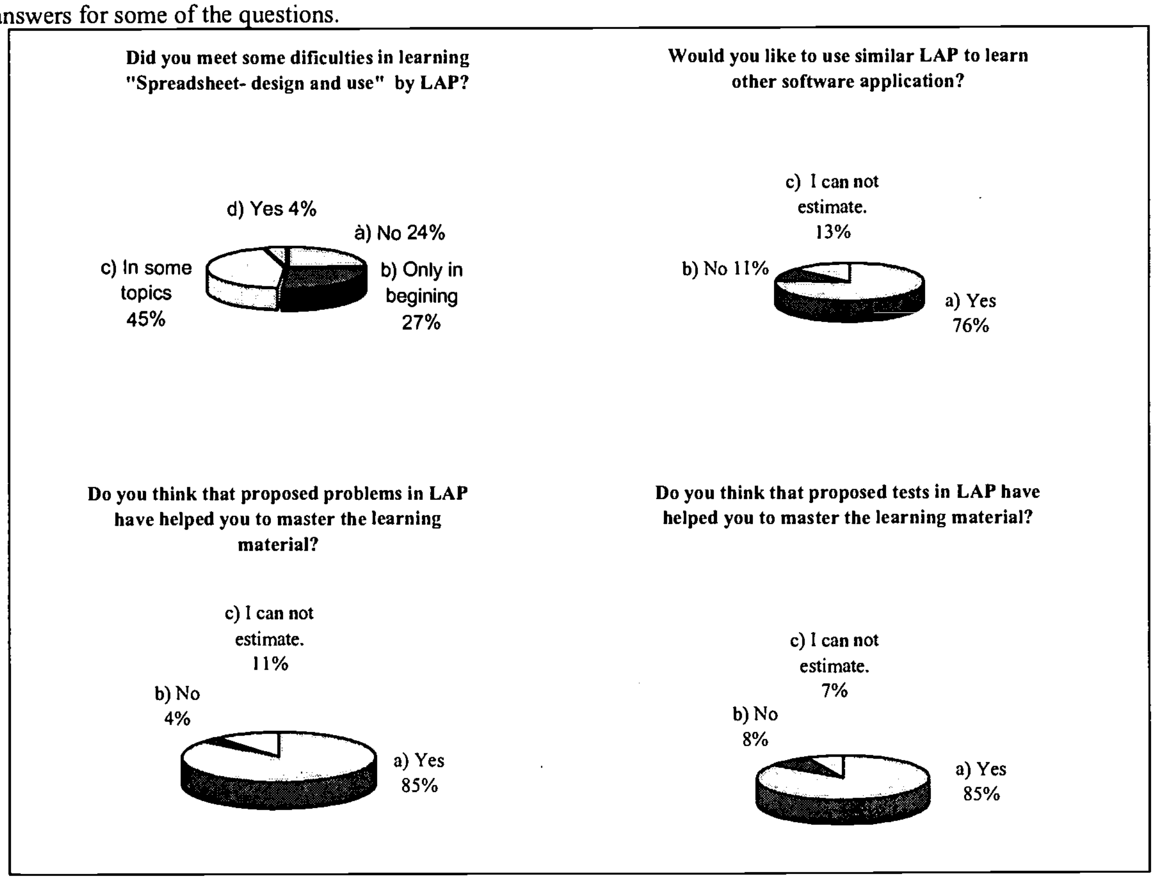

Figure 3. Graphics of student's answers.

Also the students define like most difficult the topics "Absolute and relative references" and "Using of logical function IF". Due to more conceptual problems they have needed for more explanations by teachers. In mastering of software environment they have not met difficulties.

The results of the experimental study in EG2 showed that there is a significant difference between the knowledge and abilities achieved before using of LAP and after than. Around 95% of the students achieved better scores in learning of "Spreadsheet- design and use" by proposed LAP. For other 5 % there was no change in the achieved scores.

One Point of View for Web- Based Presentation of LAP.

The components of LAP, showed above could be presented successful in Web- based environment using virtual learning environments (VLE), HyperText Markup Language (HTML) etc. For development of Web- based variant of LAP "Spreadsheets- design and use" is chosen a HTML technology because:

- for design of the materials could be used free of charge software - for example Netscape Composer 4.0 or Front Page Express;
- for reading of the materials the learner could use free browsers;.
- there are not high requirements for used hardware;
- the LAP could be used even without Internet connection in all time because it could be delivered through CD or downloaded from the server;
- using Java Applets, JavaScript etc. for development of LAP could be included assessment and self-assessment tools.
- The HTML technology has several disadvantages (Wimmer 1997):
- In some cases the learner could 'lose" in hypertext space and "forget were come he from";
- Often the learner could be cognitive overburden with a lot of concepts, attractive animation graphics or others multimedia effects.

To be avoided the negative effects of HTML a window structure of Web- based variant of the LAP "Spreadsheets- design and use" is in 3 frame-organized (Touparov&Doureva, 1999) and is presented in Fig. 4.

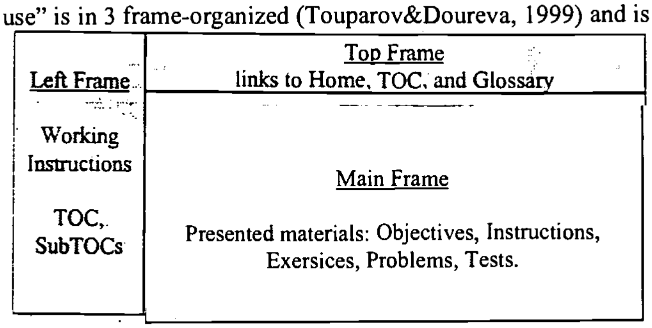

Figure 4. A Window structure of Web- based variant of the LAP "Spreadsheets- design and use"

Top Frame and Left Frame are used for navigation through course materials:

•*Top Frame* is operated for Main menu that provides direct links to Table of Contents (list of all Chapters), SubTOCs of every chapter and Glossary of terms used in LAP.

•*Left Frame* is used to present working instructions, Table of Contents (TOC) and SubTOCs of every chapter.

•*Main Frame* is used to present course materials - objectives, text, examples, exercises, self- assessment tests, etc.

External Web- based resources are opened in new browser window.

Link structure of the LAP is presented in Fig. 5. It is developed with respect to non-linear structure of Web- based materials and provide several starting point and flexible route through the package. Key features of the structure are:

•One-step switching between chapters;

•Direct access to the Glossary of terms;

•Two- way choice for displaying module's parts - direct from subTOC or "Previous - Next" from current part;

•In the top of the each chapter are described the learning objectives.

•The exercises are a part of the units in the chapters;

•The self- assessment tests are presented in submit forms developed by JavaScript. That allows the students to use learning material even without Internet connection

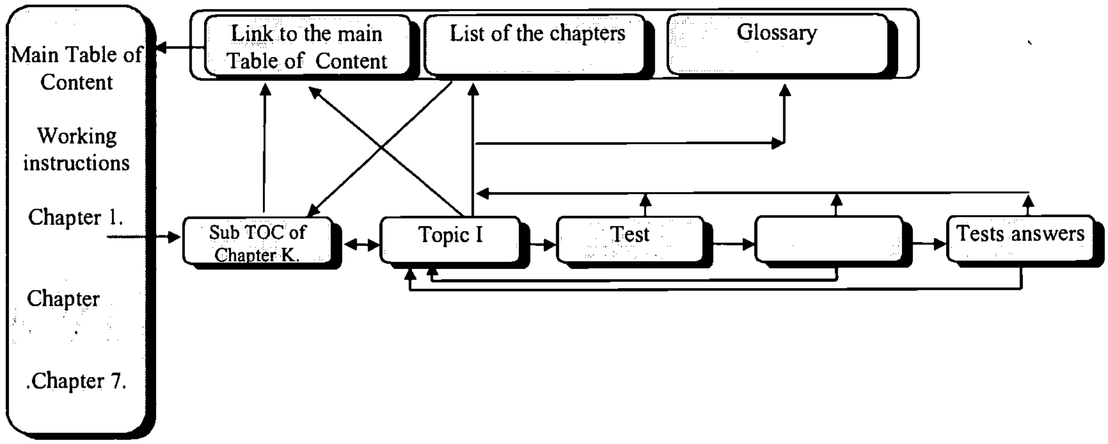

Figure 5. The link structure of the Web- based LAP.

Conclusions

The considered study for teaching “Spreadsheets- Design and Use” by LAP indicates that this approach increases the efficiency of the educational process when the LAP consists well balanced system of problem solving and self- assessment tests. Presentation of new knowledge in manner similar to the instructions in User’s Guides help the students to master reading abilities This way of teaching of software applications in IT and Informatics courses will allow to prepare students for their future career and to create abilities for self- learning and lifelong learning. In the background of quickly changes of information technologies the students should be able to use different software documentation to master new abilities and knowledge for solving a great variety of real tasks.

Recently there is a growing trend toward using for the development of web- based learning environments. The future studies will be directed to the use of web- based LAPs in teaching different software environments and applications. The discussed way of LAP’s presentation in World Wide Web using HTML and JavaScript allows the learning materials to be used only at one local computer event without Internet/Intranet connection. The approach has low costs and is suitable for the schools from countries in transition where the financial support for software and hardware is too limited.

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THE EFFECT OF ADVISEMENT & MODE OF INSTRUCTION ON TRANSFER, ADVISOR USE, AND ATTITUDE TOWARD MATHEMATICS USING A COMPUTER-BASED SIMULATION GAME

Richard Van Eck
Instructional Design & Technology
University of Memphis
United States
rvaneck@memphis.edu

Abstract: This study examined the use of a computer-based mathematics simulation game with differing forms of advisement on transfer of mathematics skills, and attitude toward instruction. A game was developed using the principles of anchored instruction and piloted on middle school students in a gulf coast city. The independent variables were context of advisement and mode of instruction. The dependent variables were performance on an authentic transfer task and attitude towards mathematics. Preliminary analysis of the data indicate that the game was more effective than the computerized word problems. Analysis of gender, competition, and other variables are ongoing.

Introduction

The primary purpose of this study was to determine if a computer-based instructional mathematics game can promote transfer and improve attitude toward mathematics and the game by including built-in advisement, situating the transfer opportunities and advisement in a meaningful, authentic context, and allowing for learner control of advisement. A secondary purpose was to examine ways to increase advice selection and effectiveness. The expectations were:

- Participants who use advisement more often than others would have higher accuracy scores (transfer of mathematics skills).
- Participants who use advisement more often than others would have higher attitude toward mathematics scores.
- Participants in the competition conditions would have higher learning efficiency scores than participants in the noncompetitive conditions EXCEPT when participants in the competition conditions have a negative attitude toward mathematics.
- Participants in the competition conditions would use advisement more often than participants in the noncompetitive conditions.
- Participants in the competition conditions would have higher attitude toward mathematics and attitude toward the computer game scores than those in the noncompetitive conditions EXCEPT when participants in the competition conditions are unsuccessful.

One criticism frequently leveled at our educational institutions is that students are unprepared for the "real world." They may do well on standardized tests and other "book learning," but when they are faced with solving problems outside school, they are unable to

transfer or map their knowledge to real situations (Thurman, 1993, Brown, 1989, Simon & Hayes, 1976). This may be especially true for abstract domains like mathematics, where students regularly complain that since they'll "never need to know this stuff," why should they learn it? The failure of transfer of learning is perhaps what has led many to call for an emphasis on critical thinking skills and problem solving in schools. Unfortunately, this is easier to call for than to implement. One way to address this issue is the use of anchored instruction.

In this theory, "knowing" and "doing" are not separate concepts, as is often assumed in formal instruction. Learning should be "situated" in authentic contexts, and it is inextricably entwined with the social contexts in which the knowledge is embedded. There are many teaching practices or approaches that are consistent with situated cognition.

Practices like anchored instruction may promote transfer because the situation and the learning are one and the same (Choi & Hannafin, 1995). Anchored instruction activities in traditional classrooms can be expensive or impractical to develop and implement on a large scale, at least in public schools (Thurman, 1993). Increases in computing power and programming ease, however, present another way in which computerized instruction can be effective. Computers can create microworlds (Rieber, 1996): concrete representations of real-world situations using graphics, text, audio, sound, and video, which can be used to design anchored instruction (Harley, 1993). These representations can be combined with instructional events to create anchored instruction scenarios. With slight changes in variables and minor programming changes, one anchored instructional environment can provide multiple practice opportunities while still allowing the teacher to work individually with students who are having difficulty beyond the scope of the CBI.

Like anchored instruction, instructional games present an excellent opportunity for problem-solving skills and transfer of prior learning by accommodating anchored instruction principles. Games are (if well designed) motivating and entertaining (e.g., Malone, 1981). According to Dempsey et al. (1997), "computer games have been employed effectively in all areas of traditional schooling—from preschool . . . through higher education . . . and continuing education of the elderly." While, in theory, properly designed games should function similarly to anchored instruction, no research on this could be found.

Another way that research has shown to be effective in promoting transfer is simply prompting users to consider prior knowledge (Brown, 1989). One way to do this is through the use of coaches or advisors who prompt the learner to consider prior knowledge. A review of the literature indicates that such advisors seem not to have been used to promote transfer, nor have they been examined in instructional simulation games.

The Study

The target population for this study was middle school-aged children in grades 6 through 8, with a range in age from 11 years to 14 years old. This population was available at several local middle schools, one with relatively low Stanford scores (n=100), one with average or above Stanford scores (n=120), and one with exceptional Stanford scores (n=80).

The content of the lesson was delivered via a computer-based instructional simulation game and was developed using the NCTM 2000 mathematics curriculum standards which will form the basis of the VNTM (Voluntary National Test of Mathematics). Problems based on these goals and standards were developed and integrated into an instructional simulation game in which

participants play a community volunteer working to help fix up houses for people (similar to Habitat for Humanity). The players' goal was to complete a work estimate for materials such as paint, trim, and wallpaper

This game made extensive use of graphics, sound, video, and interactivity. Participants enter a room in a computer-generated house and navigate around in it by clicking in the direction they want to go. They are able to use a variety of tools in the game, such as a tape measure, pencil, and calculator. Participants use these tools to learn about the environment (how long/high a wall is, for instance) and solve a series of problems, including how much paint to buy for the walls, how much wallpaper border to put around the room at ceiling height, and how large an air conditioning unit to purchase for the volume of the room. They recorded their observations in a work estimate plan. Players were also able to access advisement at any time. Participants in a control group were given word problems identical to those in the computer game in the form of a computer tutorial to minimize any differences or resentment due to medium.

Advisement was available to all participants except controls in the game. Some received video-based advisement in which a man and woman discuss the problem, solution process, and relevant formula. This type of advisement has a high contextual relevance to the storyline of the game itself. Other participants received only text-based advisement in the form of the formula alone, which is considered to have low contextual relevance to the game.

The role of competition was also examined. Participants were either in a competitive environment or a noncompetitive environment. In the competitive environment, participants were given a time limit (complete your work estimate by the end of the day) and told they would be competing against a computer character. They were asked to indicate the level of competitor they want, either below average, average, or above average. The goal was to solve the problem faster and more accurately than their competitor. In the noncompetitive environment, participants had no opponent to compete against for time or accuracy, but they were encouraged to work quickly and accurately.

In order to collect data for use as covariates and for post hoc examinations, a demographic survey was developed to collect data on age, sex, ethnic background, computer experience, mathematics experience, game playing behavior, hours spent on schoolwork, etc.

A pretest was developed based on existing mathematics textbook word problems for grades 5 and 6. This pretest was used to assess incoming mathematics skills. The problems were taken with as little modification as possible, and designed to resemble word problems as participants are likely to encounter them in the classroom. These grade levels were chosen because they are below the level of the participants, and thus should have been mastered in earlier grades. This instrument was content validated by the teachers at the participants' schools and by a professor who teaches K-12 teachers at the University of South Alabama.

A 64-question, five-item, Likert-type mathematics beliefs scale was developed by James P. Van Haneghan and Daniel Hickey in 1993. This scale is composed of 13 different mathematics beliefs scales, with Cronbach alphas ranging from .44 to .91, with four falling below .70. This instrument was used to measure mathematics attitude.

Because the first game functions as an instructional module on transfer of math skills (via the advisors), transfer of mathematics skills was assessed via a second computer-based instructional simulation game (posttest) identical in structure and general content but differing in the setting. Whereas the game context for learning about transferring previous knowledge to a new situation consisted of a room in a house, transfer was assessed by a game set in an old movie

theater. For instance, instead of calculating the amount of paint needed for the walls, participants calculate the amount of material to buy to replace the movie curtain, the number of chairs to buy for the given dimensions and subtracting for walkways and chair spacing requirements, and the amount of carpet to buy for the floor. Instead of wallpaper border, they determine how much velvet cord to purchase to surround the lobby. Instead of an air conditioning unit, players determine how strong a ventilation unit was needed to draw air out of the theater (still based on volume). The skills and formula required are identical to the earlier game, but the context and amounts varied. No advisement was available, nor was there any element of competition present in the game. Transfer, as indicated earlier, was measured by accuracy in solving the problems.

Findings

Data have been collected and are currently being analyzed. Preliminary data indicate that certain aspects of attitude toward mathematics were changed by the instructional gaming experience. Participants in all treatment conditions seem to have performed better than those in the control conditions (word problems only). Analysis of competition and the interactions of the independent variables have not yet been completed. These, and several post-hoc analyses on gender differences, intrinsic/extrinsic motivation, and others are currently underway.

Conclusions

Preliminary results indicate that the use of a computer game may promote transfer of mathematics skills and increased attitude toward mathematics in some students. If so, the use of a game may be an inexpensive alternative to "true" situated learning. The use of an instructional game may also promote student motivation, which aside from any performance gains may justify the use of a computer game for mathematics. Many participants indicated that they wanted to play the game a second time, and asked when they would get a copy of the game. Because the participants had access to the game for only one day for 45 minutes, it is not possible to assess what benefits are possible through continued exposure to this instructional format. The roles that competition, gender, and advisement play in performance, transfer, and attitude remains to be seen, and will be reported as the data are analyzed.

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Web-Based Implementation of the Little Man Computer

Joaquin Vila, Ph.D.
Applied Computer Science, Illinois State University, USA
e-mail: javila@ilstu.edu

Barbara Beccue, Ph.D.
Applied Computer Science, Illinois State University, USA
e-mail: bbeccue@ilstu.edu

Abstract: This paper describes the implementation of a well-known paradigm to depict the architecture and operations of a computer. The model, originally introduced by Dr. Stuart Madnick at MIT, is called the Little Man Computer (LMC). This simplistic metaphor is an effective method to introduce students to the workings of a computer. The LMC uses familiar objects and actions to represent computer components and operations. The "Little Man" visibly interprets and performs all the assigned tasks that are equivalent to the fetch and execute cycles in a traditional CPU. The LMC model uses a small instruction set that lets students write simple programs in code which resembles that of low-level languages. The LMC simulation was implemented in Java and operates in two modes, edit and execute. This application has proven to be very useful for teaching the Von Neumann architecture.

Introduction

Computer architecture deals with the structure and operation of computers. Even though the capability of computers changes very rapidly, the underlying concepts of computer architecture have remained relatively unchanged over the last 50 years. Most digital computers still use the traditional von Neumann architecture. Within this architecture, the concepts of a stored program, equivalence and interchangeability of program code and data, nature of a basic instruction set, way in which instructions are formatted and addressing of data are presented. A stored program refers to the fact that programs are stored and executed from memory in a sequential fashion. Inherent in this idea is the fact that programs and data must exist in memory in order to be accessible to the CPU. The second concept deals with the idea that without a given context there is no way to distinguish data from code in memory. Only within a specific context, of use and time, can the contents of memory be identified as data or code. The third concept is that of a set of simple instructions that can be combined to create programs. The instructions are comprised of an operation code and zero or more address fields. The last concept deals with the use of addressing modes to store and retrieve data.

In order to convey the concepts of von Neuman architecture, Dr. Stuart Madnick at MIT (Englander, 1996) created a simplified model of computer architecture to demonstrate the way that a real computer works. The model that Madnick created is called the Little Man Computer (LMC) and was first introduced in 1965. This simplistic yet cogent metaphor is an effective method to introduce students to the workings of a computer.

The LMC, a simplistic model of a computer, uses familiar objects and actions of a mailroom to represent computer components and operations. Mailboxes represent memory, a calculator represents the Arithmetic Logic Unit (ALU), a digit counter represents the program counter register, and an in/out basket represents the input/output devices. The "Little Man" inside the mailroom visibly interprets and performs all the assigned tasks that are equivalent to the fetch and execute cycles in a traditional CPU.

The LMC model uses nine different types of instructions to execute any given task (program). The instructions are described in Table 1. Using this short instruction set, students are able to write simple programs that resemble code written in machine/assembly language.

Instruction	Type	Mnemonics	Description
1	LOAD	LDA	LMC reads the three digit number located in the mailbox address specified in the instruction and punches that number into the calculator.
2	STORE	STA	LMC reads the number in the calculator and writes that number in the mailbox whose address was specified in the instruction. The number in the calculator is unchanged.
3	ADD	ADD	LMC reads the three-digit number located in the mailbox address specified in the instruction and adds it to the number already in the calculator.
4	SUBTRACT	SUB	LMC reads the three-digit number located in the mailbox address specified in the instruction and subtracts it to the number already in the calculator.
5	INPUT	IN	LMC reads the top most number from the in basket and punches it into the calculator. The number in no longer in the basket.
6	OUTPUT	OUT	LMC reads the number in the calculator and writes it down into the out basket. The number in the calculator remains unchanged.
7	HALT	HLT	LMC stops. (The address portion of the instruction is ignored.)
8	SKIP (on condition)	SKN (skip if negative) SKZ (skip if zero) SKP (skip if positive or zero)	LMC reads the number in the calculator. Depending on the value of the number the LMC may increment the location counter an extra time. The two address digits of the instruction will be used to test a condition as follows: Address — Conditions 00 — Skip if result in calculator is negative 01 — Skip if result in calculator is zero 02 — Skip if result in calculator is greater or equal to zero
9	JUMP	JMP	LMC changes the location counter to the location shown in the two address digits of the instruction.

Table 1: LMC Instruction Set

Web-Based Implementation of the Little Man Computer

This paper describes the implementation of this well-known paradigm, LMC, to depict the architecture and operations of a computer. A model of the Little Man Computer was implemented as a web-based application. The LMC simulation was implemented in Java. It recreates the mailroom and all of its components in an interactive fashion. The LMC simulation operates in two modes, edit and execute. The edit mode allows students to input and update programs written in LMC code. The execute mode interprets the programs by animating the "little man" to enact the fetch and execute cycles of each instruction. Students have access to this web-based application and are expected to use it to complete certain class assignments as well as to learn about the von Neuman architecture.

Figure 1 shows the interface view of the mailroom and the program source code window in the web-based LMC application. This interface allows the user to either execute or edit the source program. If the user wishes to execute the program, s/he has the option of visualizing the uninterrupted execution of the program depicting the fetch and execute cycle in slow motion. The user also has the option of controlling the pace of the execution of the program by stepping through the fetch and execute cycle on request by the selection of either the "Step Into" or

"Step Over" controls. The "Step Into" control shows the fetch and execute phases of the cycle separately so that each instruction is broken into a fetch step and an execute step. The "Step Over" control combines the fetch and execute cycle into a single visual step in the visualization sequence.

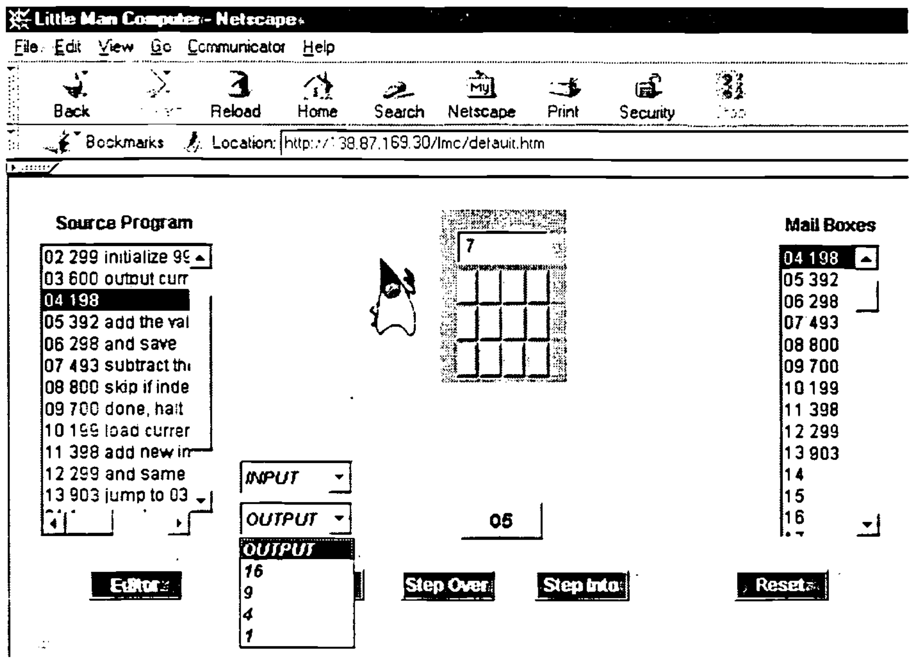

Figure 1: Interface View of the Web-Based LMC Application

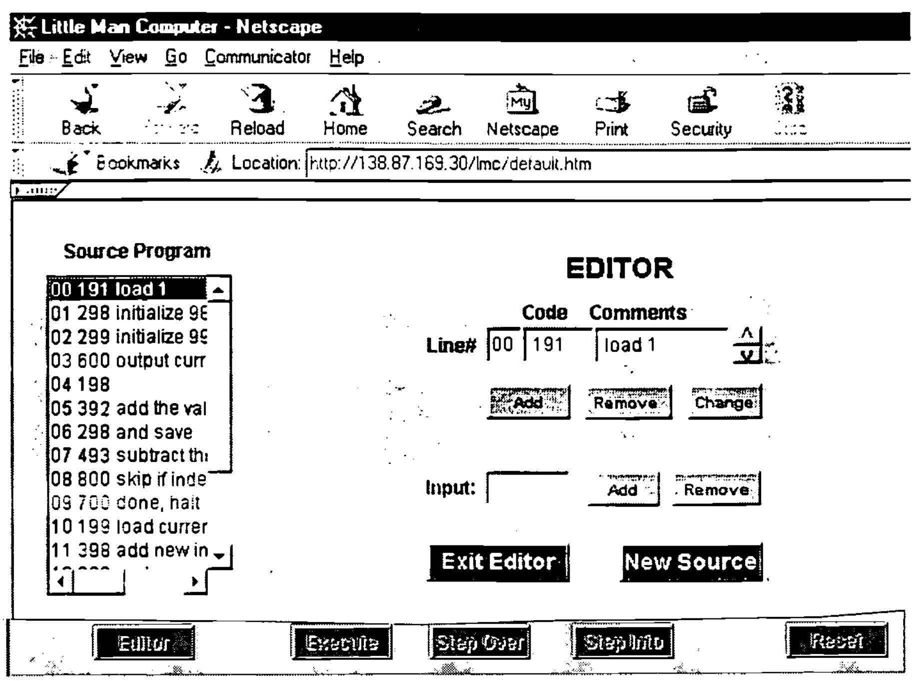

Figure 2: Interface View of the LMC Editor

Figure 2 shows the LMC editor that enables the user to create and edit a LMC source program. In this view, the user can input one line of code at a time. The code line includes three fields: the first field is for the program line number (the address or mailbox number where the instruction will be kept), the second field is the actual instruction, and the third field is an optional comment field. The user can edit any existing instruction by selecting the line of code in the source program window and causing it to be loaded into the editor.

LMC Instruction Set

LMC emulates a one address machine supporting a small group of instructions that exemplifies the most basic instructions found in low level languages. The length of the instruction is three digits. The first digit represents the operation code and the two right most digits represent the address to be used as part of the instruction. The Table 1 lists the instruction set supported by LMC.

A Simple Program

The simple program in Table 2 reads and adds two numbers and places the result in the output basket. This program exemplifies the simplicity of LMC and touches on the stored program concept that instructions are executed sequentially.

Mailbox	Code	Instruction Description
00	500	Input first number
01	233	Store data in address 33
02	500	Input second number
03	333	Add first number to calculator
04	600	Output result
05	700	Halt
33		Data

Table 2: A Simple LMC Program

The SKIP (on condition) and JUMP instructions allows for non-sequential processing of instructions. These instructions are used to perform branches and loops. For example, consider the following C while loop:

```
while ( number ==0 )  task;
another_task;
```

This loop can be implemented as shown in Table 3 using LMC's SKIP and JUMP instructions.

Mailbox	Code	Mnemonic	Instruction Description
20	180	LDA 80	LOAD number (80 is assuemd to contain number)
21	801	SKZ	Skip if the number is zero
22	960	JMP 50	Exit loop; jump to another_task
23	.		
24	.		Body of the loop (where task is located)
	.		
48	.		End of Task
49	920	JMP 20	Loop to test condition again
50			another_task
...			
80	0		number

Table 3: A Loop Implementation Using LMC

The following example is a solution to a typical assignment given to students (see Table 4). This particular exercise and its solution come from a textbook by Irv Englander (Englander, 1996). The program prints out the sums of the odd values from 1 to 39. The output will consist of 1, 1+3, 1+3+5, 1+3+5+7 ... no input is required. This series outputs the squares of consecutive integers ranging from 1 to 20.

Address	**Code**	**Mnemonic**	**Instruction Description**
00	191	LDA 91	Load 1
01	298	STA 98	Initialize 98 with the index value 1
02	299	STA 99	Initialize 99 with the sum value 1
03	600	OUT	Output current sum
04	198	LDA 98	
05	392	ADD 92	Add the value 2 to index
06	298	STA 98	/and save
07	493	SUB 93	Subtract the value 39
08	800	SKN	Skip if index <39
09	700	HLT	Done, halt.
10	199	LDA 99	Load current sum
11	398	ADD 98	Add new index
12	299	STA 99	/and save new sum
13	903	JMP 3	Jump to 03 to continue
....			
....			
91	001		The value 1
92	002		The value 2
93	039		The value 39
...			
...			
98			Data
99			Data – current sum

Table 4: Square of Consecutive Integers Implementation Using LMC

Conclusion

This web-based implementation of the Little Man Computer is being used as a teaching/learning aid for a sophomore level course on hardware and software concepts. This application has been available for student and faculty use for a year. During that time, it has proven to be very useful and beneficial in overcoming some of the difficulties that students have in understanding concepts central to the von Neumann architecture, including:

1. Understanding the difference between the address location and the contents of that address.
2. Realizing that the data being used or referenced by an instruction is not part of the instruction but is stored someplace else in memory and must be obtained as a separate step.
3. Understanding that data input or output goes directly to a special I/O area and must be saved or stored elsewhere in memory for later use. Otherwise, the next execution of an input instruction with overlay the previous data with the new input data.

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Knowledge Retention Following Problem-Solving Versus Information Gathering

Jeanne Weidner and Michael Ranney
Graduate School of Education
University of California, Berkeley
United States
jweidner@socrates.berkeley.edu and ranney@soe.berkeley.edu

Abstract: This study investigated the retention of concepts and knowledge organizations six months after an initial phase during which subject pairs used computer technology to support two divergent instructional goals: (a) the solving of a clinical problem versus (b) gathering factual information to answer direct questions. After the intervention, the information gathering activity yielded significantly higher performance on the outcome measures (e.g., gain scores, post-tests and PFNET correlations) compared to the problem solving activity. However, this advantage disappeared upon delayed testing six months later, as the information gathering context yielded significant declines on all measures, while there were no such declines regarding the problem solving context. In addition, heterogenous academic pairs and homogenous gender pairs exhibited superior performance on initial testing, a finding that persisted to some degree upon delayed testing.

Introduction

Many of the cognitive science applications for instructional practice have emphasized ways to make classroom science learning a more active process. One salient approach has been problem based learning (PBL), which generally begins with a problem, and requires students to acquire concepts and facts that will ultimately assist in solving it. Two advantages credited to this method have been (a) a greater retention of knowledge and (b) an increased ability to apply it (Eisenstaedt, Barry, & Glanz, 1990; Norman & Schmidt, 1992; Albanese & Mitchell, 1993). Support for these claims may lie in current cognitive theory which would seem to suggest that more durable cognitive structures are developed during PBL instruction. While rather non-contextualized learning has a greater tendency to develop inert knowledge that is stored in memory without any indication of how it will be used, problem-based learning develops knowledge that must be used to solve a specific problem and is thought to be incorporated into cognitive structures that may be well-modeled as production systems (Anderson, 1987). By applying knowledge in an active manner, the learner is thought to develop production systems in which the knowledge becomes encoded into more robust and longer-lasting frameworks. For example, it is possible that problem solving affects the way that knowledge is organized and accessed, giving rise to cognitive structures that account for some of the benefits often attributed to PBL. If problem solving results in different knowledge organizations than those emerging from other activities (such as responding to questions or gathering information), then these differences should be able to be captured and compared by measures such as semantic networks.

We chose Pathfinder Networks (PFNETs; Schvaneveldt, 1990) as one of our outcome measures because they have been shown to discriminate among the knowledge organizations of subjects who use information for divergent purposes. Each network representation (PFNET) yields a two-dimensional "concept map" of a subject's knowledge organization, based on his/her subjective rating of the relatedness of pairs of terms (as in Figure 1). For example, Durso, Rea, and Dayton (1994) used Pathfinder Associative Networks to measure the knowledge organizations of subjects solving an insight problem, relative to those who were given the information as a story, rather than as a problem to solve. They reported that people who solved an insight problem had a significantly different knowledge organization, as measured by PFNETS, than did those who (a) did not solve it, or (b) were presented with the information in a non-problem format. In this study, we selected pairs of terms related to cranial nerves and utilized Pathfinder Networks to determine whether or not problem-solving yields different knowledge organizations when compared to query-driven information gathering. Other researchers have found that students' performances in a course correspond well with the correlation of their Pathfinder Networks with Pathfinder Networks generated by their instructor (Goldsmith & Johnson, 1990).

Initial Phase of the Study

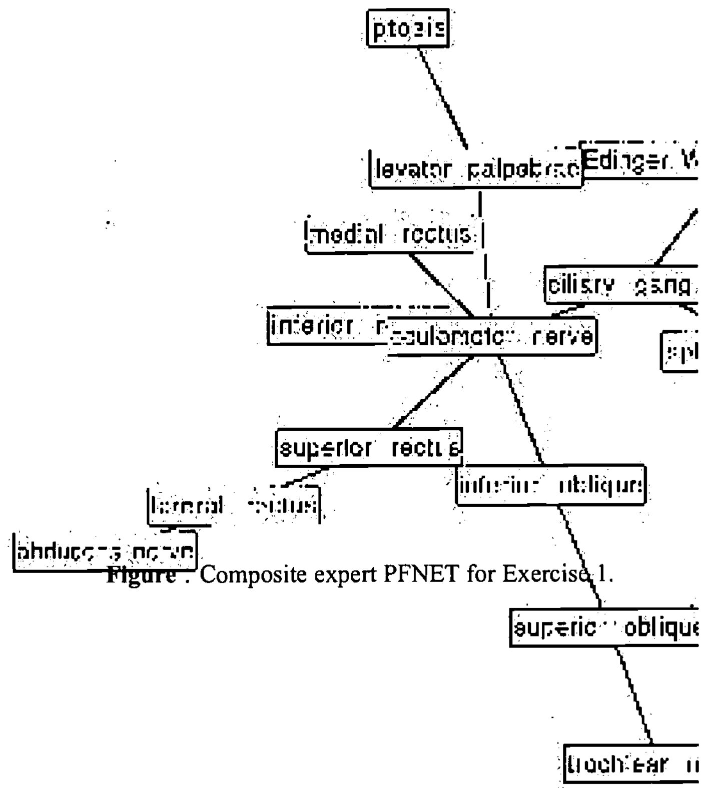

Figure . Composite expert PFNET for Exercise 1.

As reported previously (Weidner, Ranney & Diamond, 1999), we studied the ways in which pairs of students used the representationally rich multimedia program *BrainStorm: An Interactive Neuroanatomy Atlas* (Coppa & Tancred, 1995) under two contexts – while solving a clinical problem due to cranial nerve dysfunction and while gathering information in order to respond to direct questions about these cranial nerves. For example, the problem solving (PS) context presented the symptoms of a patient suffering from a lesion of the oculomotor nerve, whereas the information gathering (IG) context would ask a question such as "What is the function of the oculomotor nerve?" Each pair of subjects completed two exercises, one in the PS context and one in the IG context. The study was counterbalanced such that the subset of subjects who were assigned a PS context for the first exercise received the IG context for the second, and vice versa. A total of 22 students (13 graduates and 9 undergraduates; 11 males and 11 females) participated in the study.

Assessments completed individually by each subject included a (20- or 23-point) pre-test prior to each exercise, and a 50-point post-test after the exercise (which included the corresponding pre-test items). By comparing the pre-test score to the performance on those corresponding items from the post-test, a *gain score* was calculated for each subject. Subjects' scores on the additional, non-corresponding, items on the post-test (the *supplementary post-test*) were also analyzed as an outcome measure. In addition, the subjects were given a list of 15 terms from each exercise, which was used to generate Pathfinder Networks (PFNETs) after the completion of each

exercise. Five experts in the domain also used the same 15 terms/exercise to generate PFNETs in order to determine whether these networks would differentially correlate with subjects' PFNETS as a function of context. A composite of the experts' PFNETs was used for comparison with each subject PFNET yielding a correlation (*PFNET correlation)*.

Findings from the initial phase revealed that, relative to the mean from the problem-solving (PS) context, the information gathering (IG) context yielded marginally higher gain scores (IG = 23.4% vs. PS = 15.5%; t = 1.866, p = 0.08) and its PFNETS were marginally more highly correlated with the experts' (r (IG) = .574 vs. r (PS) = .513; t = 1.960, p = .06). In addition, since the IG context resulted in higher mean scores for all outcome measures across both exercises, non-parametric tests revealed a significantly higher performance overall for the IG context across these outcome measures (Wilcoxon Signed Ranks Test: Z = 2.201, p < .05). An additional significant measure of the superior performance under the information gathering context is evidenced by the fact that a greater number of the experts' PFNETs correlated more highly with PFNETs resulting from the IG instructional context, relative to those from the PS context (Wilcoxon Signed Ranks Test: Z = 2.201, p <.05).

With regard to the effects of pair membership on performance, significant findings from this initial phase showed that undergraduates working in academically heterogenous pairs (i.e., with graduate students), compared to their peers who worked in homogenous pairs (i.e., undergraduates with undergraduates), scored higher on two of the outcome measures (with gain score means of 30% vs. 14%; $F_{(1,17)}$= 4.74, p < .05, and PFNET correlations of .610 vs. .371; $F_{(1,17)}$ = 16.07, p < .01). Graduate students seemed to also benefit from working in a mixed academic pair, as indicated by their marginally higher performance on PFNET correlations (.692 vs. .582; $F_{(1,25)}$ = 3.54, p = .07). Non-parametric tests comparing means of all measures indicated that both undergraduate and graduate students performed better in mixed academic pairs than their counterparts in homogenous pairs (Wilcoxon Signed Ranks Test: Z = 2.201, p <.05; cf.,White and Frederiksen, 1998, on the mutual benefit of heterogenous ability pairings in younger subjects).

Further results from this initial phase revealed differences based on gender pairings. Non-parametric tests comparing means of all measures indicated that both males and females performed better in same-gender pairs than their counterparts who were in mixed gender pairs (Wilcoxon Signed Ranks Test: Z = 2.201, p < .05; cf., Underwood, Jindal & Underwood, 1994). Additionally, males who were paired with males rather than females yielded significantly higher gain scores by analysis of variance (26% vs. 15%; $F_{(1, 21)}$ = 5.01, p < .05).

Delayed Phase of Study

Subjects who completed the initial phase of the study were contacted by email or telephone to participate in a follow-up phase, and were paid for their participation. All 22 subjects who participated in the initial phase were contacted, with only one declining to participate. The delayed phase was designed to compare subjects' performance on the outcome measures (e.g., gain score, supplementary post-test, and PFNETs) six months after the completion of the original exercises. The overall declines between initial and delayed scores for each context, and the difference in absolute decay between contexts were also of interest.

Context	Measure	Initial Post-Test	Delayed Post-Test	Difference	t	p value
Information Gathering	Gain Score (from Pre-test)	0.239	0.157	-0.083	-3.523	0.002
	Supplementary Post-Test Score	0.586	0.525	-0.061	-2.172	0.042
	PFNET correlation	0.583	0.454	-0.130	-3.061	0.002
Problem Solving	Gain Score (from Pre-test)	0.165	0.111	-0.054	-1.565	0.133
	Supplementary Post-Test Score	0.573	0.544	-0.029	-1.385	0.181

	PFNET correlation	0.510	0.485	-0.025	-0.816	0.424

Table 1: Paired t-tests of the differences between delayed and initial outcome measures for both IG and PS contexts.

Findings from this phase showed that, in contrast to the results from the initial post-test, analyses of variance for the delayed post-test revealed no significant or marginal differences whatsoever between the two contexts (i.e., across gain scores, supplementary post-tests, or PFNET correlations). Further, the initially significant non-parametric difference between the two contexts' performance-yields on the various independent measures was absent during the delayed testing. As expected, both contexts yielded an overall decline for all measures from initial post-test scores to delayed post-test scores. However, paired t-tests indicated that while these declines were significant for the IG context on all measures (gain scores: 23.9% to 15.7%; supplementary post-tests: 58.6% to 52.5% ; PFNET correlations: .583 to .454; all *p's* < .05), the PS context showed no significant or marginal declines from initial to delayed post-test scores (gain scores: 16.5% to 11.1%; supplementary post-tests: 57.3% to 54.4%; PFNET correlations: .510 to .485; all *n.s.;* see Table 1). (Slight differences in means between these initial post-test scores and those previously reported are because one subject did not participate in the delayed phase). Further, the information gathering context yielded a significantly larger PFNET correlation decay, compared to that yielded by the PS context (IG = .13; PS = .03; $F_{(1,40)} = 5.002, p < .05$).

A significant finding that actually suggests superior performance under the problem solving context upon delayed testing is that a greater number of the expert PFNETs correlated more highly with the PFNETs yielded by the PS context than the PFNETs arising from the IG context (Wilcoxon Signed Ranks Test: $Z = 2.090$, $p < .05$). This is essentially directly opposite to the finding after the initial post-test.

Further findings from the delayed post-test with regard to the effects of pair membership showed that, as in the initial post-test, undergraduates who were paired with graduate students performed significantly better on the ultimate gain score than those in undergraduate-undergraduate pairings (27% vs. 10%; $p < .01$; see Table 2). Indeed, graduate students also performed significantly better on this (delayed) gain score when paired with undergraduates rather than graduate students (18.8% vs. 9.1%; $p = .05$) – and in further contrast to those paired with fellow graduate students, showed no significant decline in scores upon delayed testing. As in the initial phase, non-parametric tests comparing means of all measures indicated that both undergraduate and graduate students performed better in mixed academic pairs than their respective peers in homogenous pairs (Wilcoxon Signed Ranks Test: $Z = 2.201$, $p < .05$).

	Measure	Homogenous Academic Pairs	Mixed Academic Pairs	F	p value
Undergraduates	Gain-Score (from Pre-Test)	0.103	0.273	9.218	.009
	Supplementary Post-Test Score	0.495	0.499	.003	.954
	PFNET Correlation	0.377	0.454	.750	.401
Graduates	Gain-Score (from Pre-test)	0.091	0.188	4.276	.050
	Supplementary Post-Test Score	0.535	0.631	2.277	.144
	PFNET Correlation	0.499	0.544	.357	.556

Table 2: ANOVA of subjects' delayed performance based on academic pair membership.

Gender pairings yielded results similar to those from the initial phase of the study. Non-parametric tests once again revealed that both males and females from same-gender pairs performed better (when tested individually) when one compares all outcomes. Analysis of variance also revealed that males performed significantly better on delayed gain scores when their learning took place in same-gender, rather than mixed-gender, pairs (19.0% vs. 9.4%; $p < .05$; see Table 3).

To assess near transfer in the delayed phase of the study, subjects were given two new problems to solve that were similar to the clinical problems in the problem-solving context of the initial phase. No context-based difference for either exercise could be demonstrated by either analysis of variance or paired sample t-tests between subjects' performances based on the context in which the material was originally learned (means: PS = 69.3% v. IG = 67.2%, n.s.). However, a significant correlation was observed between subjects' performance on the two problem cases ($r = .592, p = .005$).

	Measure	Homogenous Gender Pairs	Mixed Gender Pairs	F	p value
Females	Gain-Score (from Pre-Test)	0.142	0.098	.580	.456
	Supplementary Post-Test Score	0.545	0.533	.038	.848
	PFNET Correlation	0.567	0.494	1.619	.220
Males	Gain-Score (from Pre-Test)	0.190	0.094	4.435	.048
	Supplementary Post-Test Score	0.544	0.512	.276	.605
	PFNET Correlation	0.440	0.384	.496	.489

Table 3: ANOVA of subjects' delayed performance based on gender pair membership.

Discussion

This study appears to support earlier research indicating that problem solving, although contributing less to learning in the short term, has the benefit of considerable retention after a period of time. Advantages exhibited due to the information gathering context in the short term disappeared on subsequent testing six months later. These findings, which appear to favor the problem-solving context for concept retention, seem particularly impressive given that the study was conducted as part of a regular college course. After subjects were introduced to the concepts via the experimental contexts, they encountered them again in lectures, laboratory procedures, examination review sessions and (presumably) individual study. All of these variables would be expected to introduce noise and mute the contexts' effects on an individual's retention of the concepts. The demonstration of a difference on overall retention, after the introduction of so many modulating factors, underscores the importance of the conditions under which subjects first encounter new material.

If we extrapolate the delayed post-test data to even longer delays, these results serve to (a) support the claims by advocates of PBL regarding its characteristic of increased retention, and (b) indicate that PFNET correlations may be more sensitive indicators of retention than conventional objective post-tests. Both the fact that PFNET decay from the IG context was greater than that from the PS context, and that the expert PFNET correlations were higher for those from the delayed PS context, than from the IG context, support the use of this assessment as a learning outcome.

The claim that problem-solving as a method of instruction leads to a greater ability to apply concepts for future problems did not find much support in this study. However, this effect may be more difficult to demonstrate when subjects are exposed to only one example of a clinical problem, rather than several, as is commonly practiced in problem-based learning. Furthermore, it is conceivable that the additional instructional exposure to the concepts introduced in the experiment may have led to a greater ability to apply these concepts in later encounters with clinical problems. These possibilities represent an area for further study, of course.

In summary, it appears that information gathering contributed to greater initial learning as assessed by this study's outcome measures. Further, it appears that problem-solving leads to somewhat greater retention of what was initially learned. It must be pointed out, though, that although there was less decay in the PS context performance, it still never achieved even marginally significant superiority over the delayed performance of the IG context, so

further research is necessary to determine if the information gathering context's measures would continue to decline at a higher rate than those yielded by the problem solving context. Finally, advantages for paired subject performance based on academic heterogeneity and gender homogeneity were stable over both post-testing and delayed post-testing.

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Improving Instruction and Reducing Costs With a Web-based Learning Environment

Beverly Park Woolf, David M. Hart
Computer Science Department
{bev, dhart}@cs.umass.edu

Roberta Day, Beatrice Botch, William Vining
Department of Chemistry
{rday, bbotch, vining}@chem.umass.edu
University of Massachusetts
Amherst, MA 01003

Abstract: An electronic learning environment manages homework assignments for more than 3,000 students in large enrollment courses at the University of Massachusetts at Amherst. Originally developed to fulfill a critical need in the Chemistry Department, the system has been so successful that it has been expanded to other departments and supports new, interactive forms of learning over the World Wide Web. Careful and thorough evaluation has been an integral part of the system's development, which has now been adopted by ten departments and seven other institutions. We report here on the costs and benefits of using the basic system and on significant increases in student performance.

1. Enhanced Undergraduate Teaching

Costs in higher education place tremendous pressure on institutions. Faculty lines are difficult to acquire and budgets for TA resources are often reduced. These pressures are acute in teaching "service" courses such as general chemistry and physics required for majors in many other departments. For example, the two-course general chemistry sequence offered by our Chemistry Department serves 1400 students from 35 departments. The challenge was to develop an effective system that supported increased student study time and reduced the need for more instructor resources.

The Chemistry Department embraced this challenge almost 15 years ago when it switched from a recitation-based model to the exclusive use of electronic homework as a means of encouraging students to work with the material on a regular basis outside of class. Working closely with the Computer Science department, the Chemistry Department replaced its original system with OWL (Online Web-based Learning) a modern web-based homework system complete with enhanced authoring tools (Hart et al., 1999a). Current goals are to:

1) Expand the use of OWL in other large service courses. This effort started with the Physics Department in the Fall of 1997 and has since expanded to over ten departments, such as Geosciences, Biochemistry, Nutrition, Education, Foreign Languages and Mathematics. We will use Physics as a case study in this paper because we have carefully documented both the costs/benefits to the department in adopting OWL, and because we have seen impressive learning outcomes associated with OWL use over four semesters.

2) Turn OWL into a true online learning environment. By leveraging the university's investment in the creation of OWL, we have acquired significant grant funding to expand OWL's capabilities, creating and deploying online learning activities that are more sophisticated than anything available to date. We have carefully evaluated the impact of these new activities in the large-enrollment general chemistry courses (1400 students/semester) and are beginning to see impressive results, reported below. The simulation and intelligent tutoring systems record and respond to large numbers of students with very low overhead for course instructors.

Of significance is the size of the testbed: 1400 regular users in Chemistry, 1000 in Physics and 600 in Geosciences. Such sample sizes give us greater confidence that we can identify real impacts on learning resulting from OWL use.

The "traditional" system of recitation sections and weekly quizzes was extremely labor intensive -- 72 faculty contact hours each week was spent in Chemistry, plus an even greater amount of TA time spent on grading. Eliminating recitation sections saved significant faculty resources (critically, at a time when large numbers of faculty were retiring) and produced a pedagogically superior model.

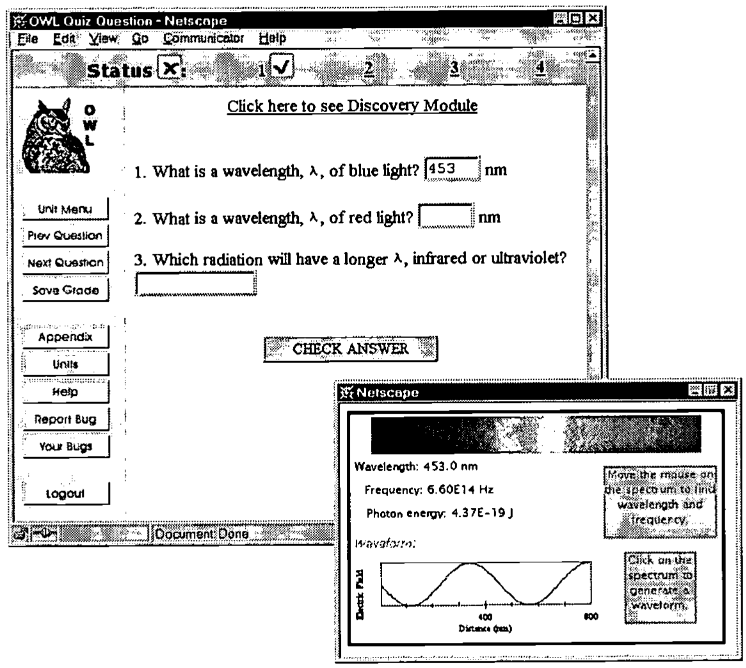

Figure 1: Discovery Exercise Modules in OWL

OWL provides a platform-independent delivery system available anytime from anywhere. In a typical semester over 50,000 quizzes are taken, with more than 5000 in one day during peak usage periods. 75% or more of these quizzes are taken outside the Chemistry Department's Resource Center (i.e. in students' rooms or other labs on campus).

2. Evaluation Studies

Third-party evaluation of student performance was incorporated from the outset. Qualitative feedback in chemistry from a survey of 330 students (Figure 2) shows that students believe OWL helps them learn the material covered in class and in particular, that the direct feedback is very helpful. These results come from a sixteen-question survey administered as part of the course evaluation or in conjunction with the final exam. Typical questions include "OWL helped me to learn the material covered in class" and "OWL feedback helps me learn from my mistakes."

Wider campus distribution is a primary goal of OWL and new departments want to see evidence that OWL saves resources and is an effective pedagogical tool. We have worked with experts in cost modeling and educational psychology[1], and are preparing a cost/benefit analysis of OWL use in four departments over two years. We studied cost savings and student performance gains in the Physics Department.[2] Student exam scores improved while using OWL (see Figure 3). The professor taught Physics I without the use of OWL in 1997 and then with OWL in subsequent years. He taught all of the students himself, using the same curriculum and covering the same material in as close a fashion as he could across semesters, given the questions and topics brought up by the students.

1 Professor Michael Royer of the University's Psychology Department.

2 Collaborators in the Physics Department include the Associate Department Head Professor Arthur Swift and the co-director of the Scientific Reasoning Research Institute (SRRI) Professor Jose Mestre. SRRI studies Physics education from K-16.

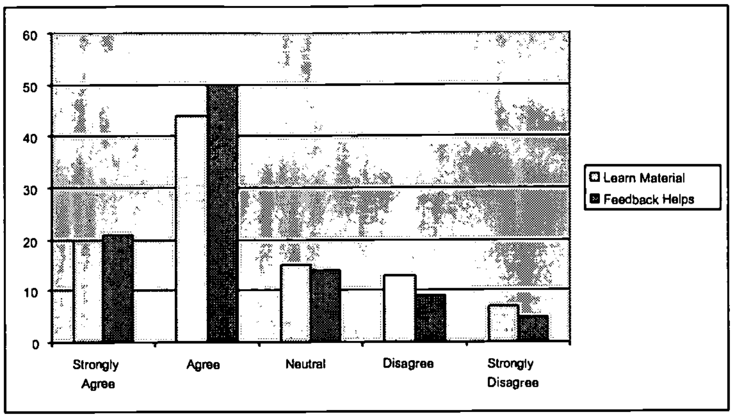

Figure 2: OWL Survey with 330 students

Institutional data tells us the control group is comparable to the treatment group, even though they are one and two years apart. The improvement can not be attributed to different Scholastic Aptitude Test scores nor to weaker students dropping the course. These factors were measured in all three years and no significant differences were found. The average score increased in most semesters in which OWL was used. All of the differences are significant except forExam 1 in the second OWL semester and Exam 3 in the first OWL semester.

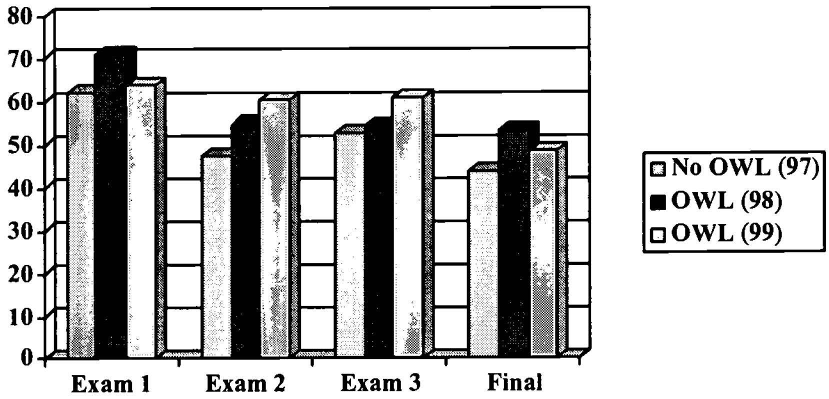

Figure 3: Exam Score Averages in Physics I
(one semester without using OWL and two with OWL)

Overall, the semesters with OWL had a substantial advantage in test scores when compared to those without. Since the only major difference between the content of the semesters was the presence of OWL, this finding is very promising. The benefit conveyed by the use of OWL seems to be consistent over time.

In general, the standard deviation from the mean test score decreased on each test (see Figure 4). It was different across the semesters, with the OWL semester generally having the same or lower variance in test scores. This indicates that OWL is helping to raise the test scores of those who otherwise would have done worse, thereby tightening the distribution.

The weakest students seem to benefit most from OWL use (see Figure 5). When the students in the physics classes were divided into quartiles based upon their exam performance (Quartile 1 contains the weakest students and Quartile 4 the strongest), a clear pattern emerged in which the OWL advantage (the amount by which the average test score in the OWL semester was greater than that of the non-OWL semester) was greatest for the weakest students (first and second quartiles) and least for the strongest students (fourth quartile). This pattern was consistent for both semesters during which OWL was used.

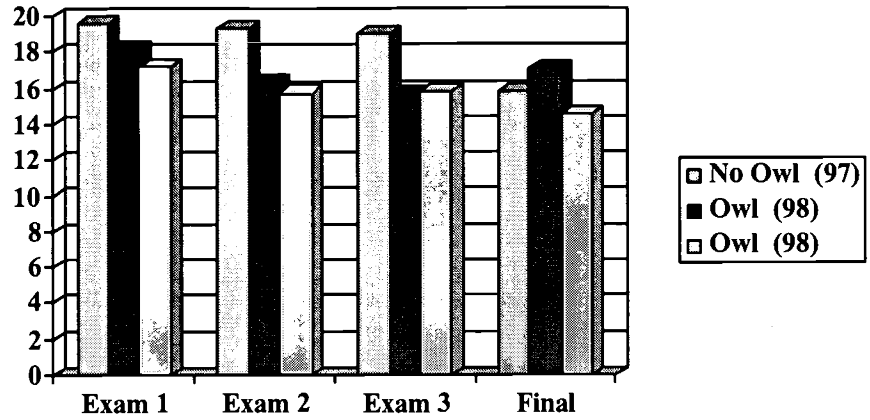

Figure 4: Standard Deviations of Exam Scores in Physics I

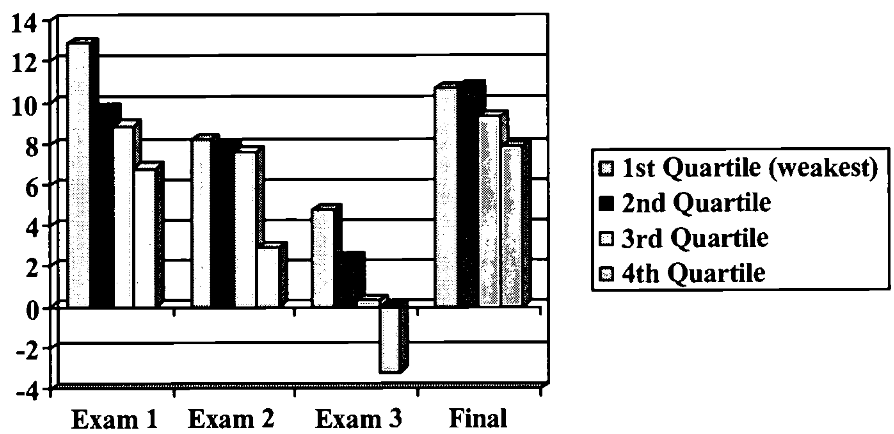

Figure 5: Advantage on Exam Scores Due to OWL is Greatest for Low Ability Students

3. Effective Implementation of the Homework System

OWL contains large databases of questions authored by faculty from many departments. In addition to the electronic questions and feedback, Chemistry faculty have developed Guided Discovery Exercises. Basic OWL provides electronic homework for students, posts assignments, grades them automatically, and stores the results. Students can repeat assignments until they master them by passing a required threshold. Feedback provided by the question author instructs the student when wrong answers are given. This feedback cycle is one of the primary benefits of OWL. Course management and authoring tools allow the instructor to manage the course and track student progress. There are currently over 3500 students in ten departments using OWL each semester.

OWL has been extended from an online quizzing system to an interactive learning environment through incorporation of resources such as Guided Discovery Exercises and intelligent tutoring – all web-based. OWL's open architecture allows the incorporation of these new resources by treating them as additional quizzes or homework assignments. Guided Discovery Exercises allow students to interact with a multimedia simulation or

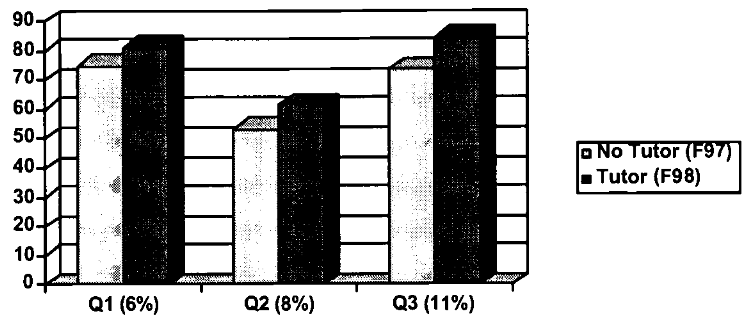

Figure 6: Stoichiometry Tutor -- Percent Correct Responses for 776 and 438 students, respectively

visualization activity, using leading questions to guide them to the "discovery" of basic laws and concepts such as gas laws or electromagnetic radiation. These exercises allow students to interact with a multimedia simulation or visualization activity such as that shown (in Figure 1) using leading questions to guide students to the "discovery" of basic laws and concepts such as gas laws or electromagnetic radiation. Prof. William Vining of the Chemistry Department has created the library of 65 such exercises, collectively called Chemland (see http://soulcatcher.chem.umass.edu/web/projects.html), though these exercises only run standalone on a PC. Forty of these exercises have been ported to Java to run on the Web under OWL's control. These are integrated into OWL (see http://owl.chem.umass.edu/Chemland/chemland.html). For each of the ported Chemland exercises a set of guiding OWL questions effectively simulates the guidance provided when a skilled instructor uses that Chemland exercise in the classroom.

Intelligent tutors tailor their instructional strategies to the needs of the individual student, varying the pace of instruction and presenting problems in such a way as to challenge the student at the appropriate level. Students are required to interact with the instructional material to demonstrate facility with it. OWL is being extended to incorporate more than a dozen intelligent tutors. A Stoichiometry Tutor presents each student with problems that start with basics and gradually increase in difficulty, varying this increase according to the perceived ability of each student (Eliot, 1999). 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").

The Stoichiometry Tutor underwent large-scale evaluation during the Fall 1998 semester. Results, which were very positive, are reported in (Hart et al., 1999) (see Figure 6). Tested with 859 students, the tutor produced impressive improvements with students scoring 6-11% better than those not using the tutor. 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 a control group of students from the previous fall who did not use the tutor.

Qualitative evaluation measured students' reactions. 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.

A Lewis Structures Tutor has been developed and evaluated with over 600 students (see Figure 7). Lewis Structures is a systematic method for drawing molecules in two dimensions and 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. The Lewis Structures Tutor runs as a Java program and uses Java server-side technology to manage each student's session. The chart above shows that the 350 students in the sections who were assigned to use the tutor responded correctly to the exam questions about Lewis Structures significantly more often than the 295 students in the sections who didn't use the tutor.

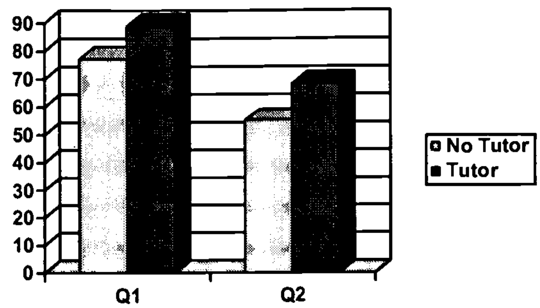

Figure 7: Lewis Structures Tutor --Percent correct responses for 600 Students

4. Cost Savings

Physics began using OWL with two courses and quickly moved to seven. If we consider its use in Physics up through five courses (900 students), we can analyze the cost savings realized by the department (and by extension the University) for this use. The costs for OWL courses, including set up and maintenance, authoring new courses, cost of a TA, and administration, totals around $25,000/semester. The savings come from the number of recitation sections dropped, which total 74 over these three semesters. This results in savings of instructor time roughly equivalent to a full instructor each semester (Physics' average faculty salary is $83,000/year and fringe benefits put this number over $100,000/year) and in savings of TA time for grading of $20,000/semester. There is also a savings in space as classrooms used for recitation sections are returned to the University pool for reallocation (the computer lab.

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Making Sense of Science: The University of Iowa Science Information Literacy Initiative

Karen Zimmerman
University Libraries
University of Iowa
United States
karen-zimmerman@uiowa.edu

Barbara I. Dewey
University Libraries
University of Iowa
United States
barbara-dewey@uiowa.edu

Abstract The University Libraries is in the process of developing a new initiative in partnership with faculty to integrate acquisition of information literacy skills into the fabric of the undergraduate science and technology curriculum. Called the University of Iowa Science Information Literacy Initiative, the project's primary goal is to ensure that UI undergraduate science and technology majors develop effective information seeking and analysis skills in science and technology for use during their academic and professional careers.

Why Science Information Literacy?

The ability to locate, critically analyze, organize and apply scientific information is an important skill for University of Iowa science and technology graduates. On a daily basis students preparing for professional and academic careers in science and technology will need, to correctly locate, evaluate, and apply science information from the constantly growing and rapidly changing universe of print, electronic, multimedia, and web-based sources.

Advancing information literacy in the sciences and technology is of major importance at the highest levels of national policy. Albert Henderson writes that "an ideal vision of science requires goals and strategies to deal directly with the growth of new information. "Information Age" science policy fails to do this. By ignoring the study of science communications, it fosters a policy vacuum on information."[1] Although the more general concept of "science literacy" has been recognized as a concern and challenge in the U.S., particularly since the post-Sputnik era, proponents have focused primarily on recruiting students into the sciences and heightening the public's understanding of science issues rather than on addressing effective scientific information seeking.[2] Academic libraries have not developed comprehensive science-based literacy programs although many science librarians have been successful in promoting certain information seeking skills such as specific database manipulation and web searching. For example, a widely cited *College & Research Libraries* article reviewing the advances of information literacy efforts by librarians made no mention of specific applications in science or technology.[3] The University of Iowa Science Information Literacy Initiative seeks to address this void for the campus and as a potential model for other institutions.

The University of Iowa Information Literacy Initiative (UIII)

The University of Iowa Libraries is considered a leader in library user education and was cited recently in a major research library journal as one of six institutions demonstrating the best practices and models for information literacy in the United States.[4] The Science Information Literacy Initiative is an outgrowth of the University of Iowa Information Literacy Initiative (UIII), an emerging program developed in cooperation with the College of Liberal Arts to integrate key information literacy components directly into courses in a discipline-based, customized way.[5] These information literacy initiatives constitute a major advance in the Libraries' user education program which emphasizes collaborative work with faculty, creative application of information technology and teaching methods, and aggressive efforts to make information resources in all formats understandable and accessible. Iowa's strong reputation is based on its success in integrating library instruction in the university's curriculum through a variety of innovative methods. For example, *Library Explorer*, a web-based library instruction program is used by Rhetoric faculty to provide the basics of library use and search strategies for new students.[6] In 1998-99 librarians conducted 318 in-class library instruction sessions supporting a wide variety of subject areas reaching over 5,000 undergraduate students.

The TWIST (Teaching with Innovative Style and Technology) project, funded by the Roy J. Carver Charitable Trust, has created a model program for training librarians and faculty to integrate networked information technology into the teaching and learning process.[7] For example, during the fall semester 1999 over 64 faculty are partnered with 16 librarians in 83 courses to develop new web-based methods of instruction and information delivery. TWIST also provides classes and self-paced tutorials for faculty in a variety of departments on applying new learning technologies and linking course content to information resources. TWIST's impact is most accurately captured by an English professor who said that "for me and my department, TWIST has made a profound, transformative, and enduring difference." The TWIST program was one of three finalists for the prestigious University of Iowa 1998 President's Award for Technology Innovation. Faculty enthusiasm for TWIST is an important ingredient for willingness to participate in the information literacy initiatives.

Launching of UIII was based on several opportune factors including the appointment of a new Dean of the College of Liberal Arts who was supportive, the fact that the College curriculum was beginning to include more active learning and problem-solving models, the University of Iowa Office of the Provost's new strategic plan is emphasizing "comprehensive writing excellence" and "revitalizing the University Libraries" as priority initiatives, and heightened faculty interest based on the programs noted above.[8]

The Roy J. Carver Charitable Trust

A major factor in the development of the Science Information Literacy initiative was the interest and subsequent funding of the project by the Roy J. Carver Charitable Trust. The Carver Trust had funded the successful Information Arcade, the Information Commons, TWIST, and a new Biological Sciences Library, a total of $2.13million in awards. Senior library staff developed a prospectus and presentation for Carver and were then encouraged to submit a formal grant proposal. Funding of $270,000 was recently received for the two-year project. Funding supports a coordinator, an instructional designer, and two graduate assistants.

Scaling Information Literacy

Both the UIII and the Science Information Literacy Initiative are based on the University of Iowa Libraries' philosophy that integrated curriculum-based user education in the most effective and scaleable approach for developing students' portfolio of information literacy skills. The University of Iowa's student population is large consisting of about 20,000 undergraduates and 8,000 graduate students. Currently the Libraries reach only about half of the undergraduates through some type of user education program and only in a scattered way. An important outgrowth of the information literacy programs will be development of alternative methods for faculty to incorporate into their courses for each component including web-based methods, in class presentations, use of existing library web tutorials, and other means since librarians are not numerous enough to appear in every introductory class at a university of Iowa's size.

Student Learning Objectives

Development of relevant student learning objectives in partnership with faculty is an essential part of the Science Information Literacy Initiative. Below are examples of objectives likely to be included in the program:

- Identify problems that require solutions based on scientific information
- Identify appropriate scientific information sources and execute effective search strategies
- Interpret and analyze search results
- Critically evaluate scientific information retrieved
- Organize, synthesize, and apply scientific information
- Understand the structure of the information environment and the process by which scholarly and other information in the science and technology fields are produced and disseminated
- Understand the ethical issues related to access and use of scientific information.

Flexibility will be the hallmark of the Science Information Literacy Initiative because individual fields in science and technology are structured differently. For example, Physics students require the use of digital "pre-prints" or articles found on the web that have not yet been published while Astronomy students require the ability to locate photographs. Experimental psychology students must be able to locate appropriate research articles in the literature of psychology as well as in bioscience and medical indexes. Mechanical engineering students must locate all relevant design and safety standards for a particular product using a wide variety of print and electronic sources for industry and governmental regulations. Chemistry students need to be able to plan and execute experiments based on chemical research literature such as searching for chemical and physical properties of substances. Faculty and librarians will select the most appropriate "assignment" delivery and evaluation methods to meet the learning objectives determined to be most critical.

Methodology and Project Evaluation

Science Information Literacy project staff and science librarians are working directly with select faculty in each science discipline to customize curriculum components which meet the student learning objectives. Faculty and librarians will test these curriculum components in actual courses and may present them as web-based instruction, in-class instruction or some other format depending on course requirements, needs, and structure. Evaluation of the project will be accomplished using appropriate tools to measure students' acquisition of the learning objectives. Information literacy components deemed successful on the basis of student outcomes will be developed into an easily adaptable program for widespread use throughout the science and technology curriculum.

Initial Projects

Building on information literacy components already underway seemed the best way to begin structuring components of the Science Information Literacy Initiative for fall semester 1999. Starting out slowly also allowed the librarians to plan on expansion and incorporation of project components over the duration of the grant period.

One example project initiated in the fall semester exemplifies a simple expansion of a learning assignment already in place for a course in the Science Education division of the School of Education. For several semesters students in the course "Methods of Elementary School Science" had been given an assignment to browse the web to locate science education resources that would be useful in their future K-12 teaching. In this assignment, each student would locate several useful web sites, making a one-page annotated bibliography of four web sites to share with fellow classmates. Students were given URLs for two educational sites and were to find others using a search engine of their choice. They were also given a list of several common search engines.

The librarian liaison for the School of Education met with the faculty member responsible for the assignment and offered to provide a summary of criteria for the students to use when choosing web sites for their bibliographies. It was actually rather surprising to the librarian that the assignment had been given to students

without any discussion of evaluation of web sites. The fact that the faculty member had not considered the students' need for guidance was an indication that there is a need for a literacy program. Once the concept was suggested, the faculty member agreed that this would be a helpful addition to the assignment and could be implemented without any major restructuring of the course.

After discussion with the faculty member, the librarian and the project coordinator developed a simple web page that could be added to the course web page or handed out as a printed guide. The page included a very brief summary of questions to consider when reviewing a web page, a short description of using the domain address as an evaluative tool and some sample course-related web sites to practice on.

One value of this simple add-on to an existing course assignment was that it provided a very non-threatening way to begin discussing information literacy skills with the faculty member. He could easily see that with little effort on his part, his assignment would be made more useful for the students. There was no time taken from an already full course schedule.

From the viewpoint of the librarian, this initial assignment can become the basis for a more extensive plan to gradually expand the information literacy component of the course. For instance, with enough prior planning with the faculty member, she could meet with the class and go over the criteria for evaluating information for the course and broaden the scope of the assignment to include other literacy components.

A second focus during the initial semester of the Science Information Literacy Initiative was to build upon work already being done in the School of Engineering. One basic learning outcome for engineering students is the ability to gather and critically evaluate and synthesize print and electronic information.

Engineers designing a product in industry must not only be able to find all the relevant technical design information but must also be able to search the patent and standards literature. Students in the senior level mechanical engineering design class were given an assignment in which they selected a product and then searched for all relevant design and safety standards that apply to that product. The students were to write a report and deliver a class presentation on the standardization issues involved with the product. To complete the assignment, students had to be able to successfully search a variety of print and electronic sources for industry, national, international and government standards and regulations that apply.

Students in Engineering I were given a "Writing, Information Acquisition and Assessment" assignment in which they were to write a report on a device, invention or engineering topic of their choice. The goal of the assignment was to help the student learn more about an area of engineering that interests them, to use print and electronic resources in the library or on the internet, and to improve writing skills. Among requirements for the paper was the following statement: "You must document the report with at least 6 references, at least 3 of which must be technical references obtained from the engineering library or engineering journals. At least 2 of your references should come from information that you obtained on the internet."

To enhance the information literacy component of the assignment, a second part of the assignment required the students to select the best web resource used in Part I and explain why the web site was a good site. The engineering librarian developed a handout based on Esther Grassian's *Thinking Critically About World Wide Web Resources*[9] for the students to use in completing this part of the assignment and met with the class to discuss resources and evaluating information.

Again, this addition to an existing assignment was a very simple way to begin building on an already developed collaborative process between the engineering librarian and a faculty member without causing a major restructuring of a course. Over the two year grant period, continued collaboration will gradually incorporate other assignments into the engineering curriculum that will increase the information literacy skills of students in the University of Iowa's engineering program.

Building an Interface to Scientific Information Resources

Besides enhancing course assignments, the University of Iowa plans to develop an easier interface for beginning level students in the sciences who need to access various science information databases. This part of the project is currently in the initial development stage, but will include examination of various basic science databases to determine how beginners might best choose which database to use in response to particular needs.

One full time instructional technologist has been hired to assist in developing this interface as well as any other instructional materials for the librarian-faculty partners to use in creating assignments. Two half-time graduate assistants will also work on development of learning materials.

Conclusion

Prior project development such as UIII and TWIST has taught project librarians that gradually integrating new initiatives into the existing framework is sometimes a slower process than we might like, but patience developing the collaborative process often pays off in the final outcome. We have at this point laid the groundwork for successful implementation of our project goals and hope to report on our further progress at a later date.

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The Effects of Technology on an Undergraduate Mathematics Department

Leigh Ann Myers
Department of Mathematics
Northwestern State University of Louisiana
USA
myers@nsula.edu

Stan Chadick
Department of Mathematics
Northwestern State University of Louisiana
USA
chadick@nsula.edu

Abstract:
Technology in hand-held form is changing the manner in which we teach mathematics. The first and most important question is whether to require every student to have a graphing calculator. An immediate effect is the classroom itself with calculators in the hands of all students and an overhead for the instructor. The positive effect on the faculty, curriculum, and pre-calculus sequence makes the change to mathematics with technology worthwhile. We look forward to future developments in technology and their impact on mathematics.

Hand-held or Desktop Technology, The Question

Over a period of time a mathematics program and a faculty might get stuck in a rut of doing the same thing again and again. Maybe the traditional is the best, but what circumstances are needed to force the question, "Is there a better way of doing this?" In the early 90's a new generation of technology for doing mathematics was born. There were computers with mathematics software and hand-held graphing calculators that could perform complicated mathematical algorithms in just seconds.

We begin to experiment with using these two technologies in pre-calculus courses in 1992. One class used the computer lab with each student purchasing the mathematics software program named DERIVE, and the other class used hand-held calculators with each student purchasing a TI-85 graphing calculator. Both technologies led to some problems, but it was evident that something about the classes and the learning that was taking place in them was different. Because of the results of this experiment, we decided to require every student in our school to have one of these new technologies.

We decided to require all students who would not take calculus to have a graphing calculator. The deciding factor was the development of the TI-82 and other graphers that permitted representations beginning with data. A limited number of computers available for almost two thousand students each semester made using computers nearly impossible for these students, while the portability and availability of the hand-held calculator made it feasible for every student on campus. These factors made the graphing calculator the technology of choice for the majority of our students.

We decided to require those students who would take calculus to have a computer algebra system (CAS). Computer algebra systems were available at that time through several software packages, such as Mathematica, Maple, and DERIVE. The relatively inexpensive computer algebra system of the DERIVE package made it the technology of choice for mathematics and science majors during the first two years of our experiment. Then, Texas Instrument produced the TI-92 calculator with CAS that included the features of DERIVE along with the benefits of the graphing calculator. The portability of the hand-held technology that make it available in the classroom and wherever the student happens to be makes the TI-92 the technology of choice for mathematics majors.

The effect of the decision to require this CAS technology of all mathematics majors was widespread. The decision impacted the classroom, the faculty, the curriculum, and teaching methods. It was soon obvious that each of these things had to change. We could no longer teach our courses in the manner we once taught them. The technology made the traditional questions trivial and allowed us to explore concepts in much more depth.

The Effect on the Classroom

The teaching setting in the classroom changed. Each mathematics teacher uses a cart with an overhead projector and a viewscreen to display the screen of the calculator or CAS used in the class. The audiovisual screen off to the side of the board has become as much a part of the classroom setting as the chalkboard. Students are required to bring the technology to class and work the problem situations with the instructor. The techniques of using the calculator are taught as needed to solve the problems. So, it is essential that the teaching-learning process became hands-on, with students regularly participating in the process rather than listening as the instructor demonstrates or lectures. In this manner, the calculator creates a teaching environment recommended by national teacher organizations. No longer is learning of college mathematics a passive process. The process of learning mathematics has become participatory with teacher and students working together on most of the problem situations. There are synergistic effects to working problem situations during class using graphing technology. Students are working with their neighbors on tasks without being asked to do so. The atmosphere of the class changes with more noise, but the noise is one person working with another on significant problems raised in this setting.

Effects on the Faculty

The change to requiring graphing calculators and CAS had an immediate effect on the teaching faculty. They were faced with a dilemma. Either they began to spend time with the technology, learning to teach in a new way and answer questions about solving problems with the calculator, or they had fewer and fewer courses that they could teach. Only a couple of faculty members resisted for a time, but then they had to join the program or retire. The rejuvenation of the faculty was a pleasant outcome of the decision to introduce technology into all the mathematics classes. Professors who had not discussed teaching methods and curriculum for some time were overheard discussing the proper ways of using this new technology in teaching mathematics. Every topic in every class has come under inspection as a result of teaching with technology. The question heard from faculty again and again was "should we still be teaching this topic or should we be teaching it differently?" Even when we answered this question satisfactorily, that was not the end of the discussion. We know that similar questions must be asked repeatedly and that we must be open to the opinions of others. Research is clear in indicating that improvement of the faculty depends heavily on interacting with colleagues about the best methods of teaching and what topics should be taught.

Effects on the Curriculum

Before the decision to require graphing calculators and computer algebra systems, the mathematics curriculum was static and so were the methods we used to teach. We have found that good use of hand-held technology has permitted an in-depth understand of important mathematical concepts. We have always advocated that courses in mathematics should teach students mathematical concepts and problem solving. However, we had never been able to deal with the abstract notions, proofs and in-depth problem solving we had advocated. Our reasons have always been that we cannot teach those things until students understand how to perform certain algorithmic techniques. It is estimated that before hand-held technology about 85% of the mathematics curriculum consisted of paper and pencil computation. This process involves a very low order thinking skill. These paper and pencil processes are so tedious that they took the bulk of the work and, therefore, became important because we spent more time on them. The technology has freed us from paper and pencil techniques that hampered our march to mathematical

understanding and has allowed us to explore more interesting mathematical concepts, even in our lower level courses.

The Effect on the Precalculus Courses

The use of hand-held technology in college algebra permitted us to teach a new type of course. Before the change to hand-held technology, we taught college algebra, college trigonometry, and pre-calculus courses with many topics that appeared to be unrelated. The goal of the college algebra course appeared to be the teaching of paper and pencil techniques to solve linear and quadratic equations. Solving equations is a worthwhile endeavor, but the techniques involved used most of the available time and prevented an overall understanding of the applications of algebra. The variable "x" represented an unknown to be found and the algorithmic procedures to find "x" did not give motivate student interest in the course. The only purpose for the course seemed to be a hurdle for the students to vault. Now, the variables "x" and "y" represent change. College algebra takes on new meaning. It has become a course describes the changes happening about us using mathematical models. Quite often in a real world setting, two things are changing and the change of one is dependent on the change of the other. For example, there are multitudes of interesting phenomena that are changing dependent on the change in time. As time goes by everything from the paint on the wall to the population of the world is changing. Students recognize that these are important ideas. We have created courses that permit them to study these changes with mathematical models and predict the future. They no longer ask about the value of the course. The course speaks for itself.

The Future of Hand-held Technology

As we study the history of hand-held technology, we see a graphing calculator that has developed into a computer algebra system. We believe the technology will continue to evolve. Current calculators are small enough to fit into a student's backpack, but are not computers. The technology is primarily based on a small fixed set of capabilities. We see in the future every student carrying a computer that is small but has all the capabilities of computer algebra systems as well as spreadsheet and word processing capabilities. It will have a color monitor and its graphing capabilities will be awesome. Best of all, it will be easy to upgrade as new software is developed. The textbooks for our courses will be on disk, with demonstrations of graphing technology that students can replicate. The text and the CAS will be interactive and students will bring the computer to class. The CAS capabilities will be useful in science and businesses classes, and will be used in English and other classes for word-processing, spreadsheet tools, and other features. Hand-held technology will eventually hear the voices in the classroom and write the notes. This technology must be put together at a cost that is reasonable to the student. In our opinion, the teaching and learning of mathematics is inextricably tied to technology. Based on the response from our students, they will not allow us to return to only paper and pencil techniques.

POSTER / DEMO PAPERS

STRATEGIES FOR DEVELOPING A PRECALCULUS COURSE WITH WEB BASED ACTIVITIES

Jean Bevis, Georgia State University, USA; Margo Alexander, Georgia State University, USA; Draga Vidakovic, Georgia State University, USA

In the precalculus course under development, students have the option of accessing interactive web based materials in lieu of attending lectures. They also have the option of taking daily quizzes in class or over the web. When students complete their daily work, it keeps them involved in the course material in a regular and beneficial manner. When students do not complete their daily work, the easy accessibility of options, helps students to accept responsibility for their decisions. We also report on a successful strategy for the rapid development of this Web-based course.

A MODULARIZED COMPETENCY-BASED SCIENCE /MATH CURRICULUM FOR ASSOCIATE DEGREES IN INFORMATION TECHNOLOGY

Douglas Brown, NorthWest Center for Emerging Technologies / Bellevue Community College, USA; Arthur Goss, Bellevue Community College, USA

This session will present the Science & Math for Information Technology (SMIT) core curriculum developed through the NorthWest Center for Emerging Technologies at Bellevue Community College (Washington) and a selection of representative hands-on activities. Designed to provide an efficient and flexible tool for strengthening the analytical component of IT programs by infusing appropriate science and math learning experiences, it has several distinguishing features: Competency-based and linked to the nationally recognized, industry-based NWCET IT Skill Standards, Individual units can be incorporated into existing IT courses or combined into stand-alone courses, Curricular goal is not topical coverage but for students to "learn how to learn science" and acquire a foundation for broadly applicable science/math-based analytical techniques, and Organized around team projects with a real world structure and format. They are inquiry-based but require a concrete deliverable outcome.

DIGITAL PHOTOGRAPHY FOR MATH AND SCIENCE

Catherine Cavanaugh, Ph.D., University of South Florida, USA; Terence Cavanaugh, Ph.D., University of South Florida, USA

Digital cameras have many advantages over film cameras for math and science education, and add a multimedia dimension to learning. Today's digital cameras offer a variety of features, and are as easy to use as film cameras without the expense of film processing. Digital images are available more rapidly than film images, allow unlimited low-cost duplication, and can be controlled and manipulated easily. Using a digital camera, students make personal meaning of documents, presentations, and electronic communications such as email and web pages. Math and science teaching and assessment are enhanced through electronic field trips, demonstrations and portfolios. Digital cameras enable students to visualize the mathematical and natural worlds in unique ways. Many cameras have panorama and limited audio/video capabilities. Most offer live or recorded video output, and can be used with special lenses, including microscopes and telescopes.

MATH AT MIDNIGHT: TEACHING AND LEARNING IMPLICATIONS

Faith Chao, Golden Gate University, US; Jim Davis, Golden Gate University, US; Peg McPartland, Golden Gate University, US; TJ Tabara, Golden Gate University, US

In this presentation we will discuss some of our course explorations that utilize the asynchronous features of the Internet together with its graphic capabilities to build web-based math courses at Golden Gate University. We will focus on the internet technology that gives students the flexibility to participate in classes at any time of the day and any day of the week and how this flexibility affects their expectations of the course. We will also discuss course design features and teaching strategies in order to motivate students to achieve understanding at a deep level for the varied learning styles of this new medium. The techniques utilized in a variety of math courses will be discussed along with student comments and our findings of learning outcomes.

USING MAPLE V (GRAPHICS AND PROGRAMMING) FOR CALCULUS TEACHING

Mingxiang Chen, North Carolina Agricultural and Technical State University, U.S.A.

Maple V is an elaborate Computer Algebra Systems (CAS). We use Maple as a tool in teaching Calculus. We give students brief tutorial on Maple commands and syntax. We use Maple to plot graphs of library functions and user-defined functions, of one variable and two variables, implicit functions, and parametric equations. This part of activities helps students become familiar with curves and surfaces in two-dimensional and three-dimensional spaces, and with polar, cylindrical and spherical coordinate systems. We use Maple programming language to write procedures such as Trapezoidal Approximation and Simpson's Rule in numerical integrations. We combine programming and plotting to demonstrate intrinsic points such as relationship between a function's monotone and convex properties and the sign of its derivatives, graphs of a function and its inverse function, Taylor Approximations, and dynamics of a family of functions with parameters.

REALISM AND CREDIBILITY IN A SIMULATION-BASED LEARNING ENVIRONMENT: THE VIRTUAL PHYSICS LABORATORY (VPLAB)

Marc Couture, Télé-université, Canada; Alexandre Francis, Université de Montréal, Canada

Realism and effectiveness of computer simulation-based learning or training environments have been examined in several studies. It was shown that under certain conditions, simulations can be as efficient as real experiments, and that increased realism may result in gains in 'practical appreciation'. However, few have investigated the relationship between realism and credibility, or between credibility and effectiveness. The VPLab is a simulation-based learning environment featuring many characteristics and constraints normally associated with real experiments. These include uncertainty in measurement, random fluctuation of parameters, and limitations in user control over the simulation. We believe that our approach, which distinguishes the VPLab from most existing simulation-based laboratories, greatly increases its credibility. It also makes possible the teaching of laboratory skills not usually associated with simulation.

EFFECTS ON ATTITUDES TOWARD COMPUTER PROGRAMMING OF USING JAVA VERSUS C++ TO TEACH INTRODUCTORY PROGRAMMING TO NON-COMPUTER SCIENCE MAJORS

Fred Croop, College Misericordia, USA

Several non-Computer Science disciplines may require students to take computer programming courses. Examples include Information Systems, Educational Technology, Engineering, and Business Management. These curricula typically are designed to provide the enrollees with exposure to the application of computer programming, development of problem-solving skills, and possibly the background in a language that can be used for further study in research, analysis, or data structure design. Some non-Computer Science majors fear, and/or do poorly in programming. Other students find programming interesting and non-threatening. For all students there is a possibility that their attitudes toward computer programming will change during and as a result of their introductory course(s) in the subject. Two languages used to teach object-oriented programming are Java and C++. This poster demonstration summaries self-expressed attitudes toward computer programming of a small group of students who have studied both Java and C++.

INVESTIGATING FAMILIES OF QUARTIC POLYNOMIALS VIA A COMPUTER ALGEBRA SYSTEM

Tilak de Alwis, Southeastern Louisiana University, USA

Consider the one parameter family of quartic polynomials given by f(x)=(x-a)(x-t)^2*(x-b) where a and b are distinct real constants, and t is a real parameter. Let A(a,0), B(b,0) and C(t,0) be its x-intercepts, and D(0,abt^2) be its y-intercept. Suppose that the normal lines to the graph of f at the points A and B meet at R, and the tangent lines to the graph at those points meet at S. As the parameter t changes, the graph of f changes. However, the points A and B remain fixed while all other points C, D, R and S change. This paper discusses some geometric properties such as centroids, circumcenters, orthocenters, and locus problems of the variable triangles ABR, ABS etc.

AN AUTHORING TOOL FOR HINT GENERATION

Rachel DiPaolo, The University of Memphis, USA; Holly White, The University of Memphis, USA; Arthur Graesser, The University of Memphis, USA

Hinting is important during the learning process, because it facilitates the active construction of knowledge. Constructive activities lead the student to an integrated and prolonged involvement with the material. Hints encourage the student to generate information and enhance memory for the learned information. Hinting increases student control during the learning process. We propose an authoring tool for hint generation that is based on conceptual graph structures. Conceptual graph structures have been used in the study of text comprehension (Graesser & Clark, 1985). These knowledge structures are made up of different types of nodes, which are interconnected by different types of arcs. Our hint generation model makes use of the information embodied in the relationship between the arcs and the nodes of these structures. This model is currently being implemented in computer based tutoring and has potential applications in related areas, such as web-based training.

COMPUTER VISUALIZATION IN THE MATHEMATICS CLASSROOM

Erzsebet Forczek, Albert Szent-Györgyi Medical University, Hungary; Janos Karsai, Albert Szent-Györgyi Medical University, Hungary

This paper reviews of the education in mathematics at the University of Szeged. Mathematics is a fundamental course for Pharmacy students. The main topics are basic concepts and properties of functions of one or several variables, limit, derivative and 1D differential equations. All the topics are illustrated with practical examples. The abstract concepts are somewhat difficult for the student to understand consequently, we emphasize the geometrical meaning and this is the point where we apply computers, so visual images are important aids in making matematics understood, because visualization is essential for understanding. The 3D scenes, the animation and the possibility of students interactivity are real advantages of the computer.

CONCEPTUAL LEARNING OF PHYSICS - SCIENCE

Ivan Gerlic, University of Maribor, Slovenia

One of the main objectives of physics is to lead students to an undestanding of basic concepts which can serve as basis for an explanation or prediction of natural and technical processes. Mathematical methods play a decisive role while pursuing this goal since an explanation or prediction is only reliable if the underlying law can be formulated in mathematical terms. Therefore mathematics is an essential part of physics teaching; however, it causes at the same time severe learning difficulties, well-known and especially important for physics teaching. To understand an unknown piece of knowledge, the use of an abstract tool has first to be acquired and then this tool has to be applied to the yet unknown part of reality. With modern computers and their advanced possibilities to animated graphics it is now possible to model and visualise a major part of classical physics by using rather simple numerical methods. All needed calculations can be left to the computer. Only after a qualitative understanding has been reached, the advantage of abstract mathematical methods can be demonstrated and corresponding learning goals can be acquired.

CONSTRUCTING PHYSICS UNDERSTANDING: SIMULATION SOFTWARE FOR EXPLORING PHYSICS

Fred Goldberg, San Diego State University, USA

The Constructing Physics Understanding Project is a National Science Foundation supported project (Grant No. ESI-9454341) aimed at creating laboratory and computer-based materials to support a learning environment where students take primary responsibility for developing valid and robust knowledge in physics. As part of this project we have developed 20 pedagogically-oriented computer simulations, covering several topical areas in physics: light and color, static electricity and magnetism, force and motion, current electricity, waves and sound, and the small particle model of matter. The simulations are written as Java applets to run under Internet Explorer on individual computers (not over the Web). Students use the simulators to explore phenomena, both qualitatively and quantitatively, and they can receive both phenomenological and model-based feedback. The simulations can be used to complement all types of physics courses, but were especially designed to be

integrated into the CPU curriculum, where they are used to complement and extend hands-on laboratory activities.

THE CONSTRUCTING PHYSICS UNDERSTANDING PROJECT: INTEGRATING COMPUTER SIMULATORS, HANDS-ON EXPERIMENTS AND GROUP DISCUSSIONS TO PROMOTE MEANINGFUL LEARNING IN PHYSICS

Fred Goldberg, San Diego State University, USA; Valerie Otero, San Diego State University, USA; Andy Johnson, Black Hills State University, USA

The Constructing Physics Understanding Project is a National Science Foundation supported project (Grant No. ESI-9454341) aimed at creating laboratory and computer-based materials to support a learning environment where students take primary responsibility for developing valid and robust knowledge in physics. The CPU project has developed a student-centered pedagogy, carefully sequenced sets of activities in several different topical areas of physical science, and a set of pedagogically-designed computer simulators. Rather than depending on the instructor as the source of knowledge, in the CPU classroom students develop, test and modify their own ideas through experimentation and discussion with their peers. The materials have been used successfully with secondary school physics and physical science students, and with prospective and practicing elementary teachers (through workshops and University courses).

THE INFLUENCE OF INSTRUCTIONAL VIDEO MATERIALS ON STUDENT ACQUISITION OF BIOLOGICAL CONCEPTS

Moses Gostev, Teachers College of Columbia University, USA; O. Roger Anderson, Teachers College of Columbia University, USA

Students' cognitive preferences in using scientific information were analyzed using a paper and pencil inventory. We found strong and weak cognitive components. Strong components ("questioning-preference") predicted higher academic performance ($p = 0.03$, d.f.=19) compared to the remaining "weaker" components (more knowledge-based), which were not readily discriminable from one another. Moreover, "questioning"-type students, compared to the "weaker"- component group, achieved better test scores on higher-level cognitive skills (e.g., application and analysis) ($p < 0.02$, d.f.=18), but not with basic knowledge, indicating their greater capacity with increasing cognitive demands in learning. Furthermore, use of a video that served as a theme or guiding framework for instruction significantly increased achievement compared to a control group taught in a more conventional way ($p = 0.04$, d.f.=16). These results suggest that use of thematic-centered video segments, and due attention to strengthening higher order cognitive preferences, in other instructional settings such as computer-based learning may enhance achievement.

EDUCATION AND THE INTERNET OPPORTUNITY

Jennifer Degnan, SmarterKids.com , USA; Beth Standring, SmarterKids.com, USA

SmarterKids.com, is the number one educational store on the Internet that is dedicated to providing quality services and products to help parents instill a love of learning in their children. Smarterkids.com is unique for several reasons including the site's assessment and personalization options. Our Learning Style Survey allows parents and teachers to quickly and easily assess how a child learns best and find appropriate educational tools best suited to that child's individual style. Our MySmarterKids feature enables parents to develop distinct learning profiles for a child to ensure personalized product recommendations based on the child's individual learning needs, goals, and styles. Additionally, partnerships with Lightspan.com and National Computer Systems Inc. allow us to better bridge the gap between home and school. Together, we combine award-winning content and up to date statewide standards and assessment information with a unique educational shopping experience.

DEMOS WITH POSITIVE IMPACT: A RESOURCE FOR MATHEMATICS INSTRUCTORS

David R. Hill, Temple University, USA; Lila F. Roberts, Georgia Southern University, USA

In any form of instruction the instructor plays an important role as facilitator of learning. Demonstrations to accompany ideas and concepts are a requirement for effective instruction. Experienced instructors have private toolboxes of demos, conceptual approaches, or physical gadgets they use to encourage students to tune-in to mathematics. This rich, but largely unharvested source of tried-and-tested ideas forms the basis for Demos with Positive Impact, a project that will develop a web-based database of instructional demos and connect this resource to university mathematics instructors. This project takes advantage of the knowledge and experience of colleagues across the country and presents these valuable resources to the mathematics community in an attractive, user-friendly format. Demos with Positive Impact is a resource for instructors who are looking for ideas or demonstrations adaptable for various teaching styles and learning environments.

WEB-BASED WRITING AND PEER REVIEWING IN CHEMISTRY EDUCATION

Christie Jester, University of Texas at Austin, USA

Research has been done showing the usefulness of writing in learning academic subject material. In college programs, numerous techniques, such as summary writing and peer reviewing have been adopted. In the sciences, however, large class sizes often preclude students from having frequent writing opportunities. We solved this problem by creating a semi-automated web-based peer-editing program. Our goals were to help students learn chemistry concepts by writing about them and to prepare students for future careers by developing their writing skills. A peer-reviewing process and assessment rubric was devised to allow upper-level chemistry students to read, critique, and grade their classmates' papers. Results of the rubric were stored to a database and were available to the writer through an on-line search. The course was served using a Macintosh and the inexpensive software FileMaker Pro 4.0 and Claris Home Page 3.0.

DEVELOPMENT OF MULTIMEDIA LEARNING MODULES IN CHEMISTRY USING AUTHORWARE 5.0

Christie Jester, University of Texas at Austin, USA; Joanne Williams, University of Texas at Austin, USA

Valence Shell Electron Pair Repulsion and Valence Bond Theories pose great difficulties for chemistry students. Using Authorware, we developed a user-friendly computer tutorial with multiple interactions and animations, an interactive glossary, periodic table, and practice problems and quizzes with personalized feedback. Students will use hyperlinks to move throughout the tutorial at their own pace, will be able to revisit sections of interest for extra help, and look up key words in the glossary. Three-dimensional molecular models and movie clips help students visualize molecular structure and hybridized orbitals. To encourage active participation and practice, students will be given short segments of text accompanied by a graphic, followed by several practice problems. End-of-chapter review questions will be similar in scope and form to those that students encounter on course exams.

INTEGRATING SPACE SCIENCE RESEARCH INTO AN INTERACTIVE WEB-BASED CURRICULUM: IMPLEMENTATION AND EVALUATION

Rita K. Karl, Lunar and Planetary Institute, USA; Leslie C. Hunt, University of Houston Clear Lake, USA

This poster illustrates two prototype web-based instructional modules created for the Lunar and Planetary Institute's Mars Millennium web site and CD-ROM project to support the National Aeronautic and Space Administration's Jet Propulsion Laboratory.

DISCOVERY CHEMISTRY USING STATISTICS AND MINITAB

Patrick Keller, Castleton State College, USA; Abbess Rajia, Castleton State College, USA

Students entering general chemistry courses are weak in fundamental math skills and knowledge of statistics even though they have been exposed to basic concepts in statistics through their preparatory math courses. There is a difficulty in transferring knowledge of statistics to science courses and this is found throughout the K-16 curriculum. The problem is that students lack statistical knowledge in the context of applications in sciences. Discovery Chemistry Using Statistics and Minitab overcomes these difficulties through its integrated and inquiry based laboratory approach. Most importantly, the course shows how statistics is a fundamental part of the process of acquiring knowledge in chemistry. The discovery approach includes an inquiry based laboratory designed to stimulate students to think creatively about analyzing and modeling data that they generate through experimentation. This laboratory environment helps immerse the student in a learning process that is rich in technology, data analysis and fundamental explorations in statistics and chemistry . Students are presented with a series of laboratory experiences in which they are asked to design experiments, collect, analyze and model data to solve problems while working in small collaborative groups. Each student generates data sets from his/her experiment and these data sets are pooled together to form a data base that is used for class discussion and to explain concepts in statistics. This integrated approach stimulates interest in statistics and encourages students to take the risk to ask questions and get engaged in a discussion. This teaching approach moves statistics from a pure methods approach to one which is founded in applications.

THE DEVELOPMENT OF AN INDEX TO MEASURE SENSE OF LEARNING COMMUNITY IN COMPUTER SCIENCE

Robert Lucking, Old Dominion University, USA; Fred Rovai, Old Dominion University, USA; Dean Cristol, Old Dominion University, USA; Katherine King, Old Dominion University, USA

The purposes of this study were to develop, refine, and field test the Sense of Learning Community Index (SLCI), and to determine its validity and reliability for use with college students in traditional and distance education environments. The 40-item SLCI measures sense of learning community within a group of learners. The SLCI was field tested with university students in traditional and synchronous distance education courses. Data were collected from 135 students. Instrument reliability is very high (Cronbach's coefficient alpha = .97). The SLCI also exhibits high content validity covering the domains of collaborative learning, teamwork, shared goals, and active creation of knowledge and meaning. No evidence of differences in sense of learning community was found between traditional and distance learning courses and between content areas. However, differences were found between groups taught by different instructors. It was concluded that the SLCI is an effective measure of sense of learning community.

PROJECT LINKS: INTERACTIVE WEB-BASED MODULES FOR TEACHING MATHEMATICS AND ITS APPLICATIONS

Kenneth S. Manning, Ph.D., Rensselaer Polytechnic Institute, USA

Project Links at Rensselaer is a cooperative effort to develop materials linking mathematical topics with their applications in engineering and science. The product of this effort is a set of interactive, web-based learning modules that rely on hypertext, animations, and interactive Java applets. We employ interactive web-based modules in the studio classroom environment, pioneered at Rensselaer, to engage students in guided learning. The intent is to provide students with an experience unavailable in traditional lecture or textbook lessons. These modules are designed for use in more than one course, with a topic-qualified instructor and assistant available in the classroom during use. They are not intended as self-paced learning modules, nor as text replacements, but are to supplement existing courses with a degree of interactivity and universality not available before the advent of the World Wide Web. There are currently 47 modules in development. All modules will be available for examination.

DEVELOPING PRAIRIE TO MOUNTAIN EXPLORER: A GIS AND REMOTE SENSING DATA SET FOR THE FIFTH-TWELFTH GRADE CLASSROOM

Patricia McClurg, University of Wyoming, USA; Alan Buss, University of Wyoming, USA

Results of a three-year collaborative investigation into what constitutes viable GIS data sets for use with fifth through twelfth grade students will be reported and the product Prairie to Mountain Explorer (PTME) will be demonstrated. This collaboration involved teachers, teacher educators and scientists participating in a NASA funded five-state consortium (Upper Midwest Aerospace Consortium-UMAC). PTME is a spatial data base which provides a rich context for student investigations using the Internet, Geographical Information Systems (GIS), Global Positioning Systems (GPS), and Calculator Based Laboratories with sensing instrumentation (CBL). PTME contains selected base-line data sets at regional and county scales (ranging from 1:2,000,000 to 1:100,000), and a user's guide with meta-data for over 300 themes. Results from extensive pilot testing coupled with input from agriculture/natural resource researchers contributed to this powerful educational resource. UMAC maintains a web-site to support PTME and to provide a growing resource of classroom tested lesson plans (nasc.uwyo.edu/edparc).

MODELLING THREE-DIMENSIONAL SURFACES ON A SPREADSHEET

Abas Md Said, Universiti Teknologi Petronas, Malaysia; Mohd Yunus Nayan, Universiti Teknologi Petronas, Malaysia

This paper describes how three-dimensional surfaces can be drawn using an electronic spreadsheet. This program is useful and an inexpensive way for both teachers and students to visualize 3D surfaces from almost any angle and interval. This when blend and together with theory will be a promising approach for them to get a firmer understanding of the subject.

QUANTITATIVE COURSES IN DISTANCE LEARNING

Antoni Meseguer-Artola, Universitat Oberta de Catalunya, Spain

In distance learning through Internet, where the Universitat Oberta de Catalunya (UOC) is one of the pioneers in the world, the particular type of students attending the courses and the difficulties in the transmission of mathematical texts create the necessity of developing new strategies which facilitate the learning–training process. These strategies are based on the development of ad-hoc learning guides that establish a particular link between self-directed learning and directed learning. We focus our study on a particular type of courses: quantitative courses, i.e., courses that use mathematical language for its development or courses where mathematical concepts are the aim of study. The design of appropriate learning guides for quantitative courses and their classification are the main objectives of this paper. In this sense, from different educative experiences in low, medium and high level courses in mathematics, this work proposes different items that a learning guide has to contain and it also gives a classification criteria of such these guides.

DISCOVERING XYALGEBRA: INTELLIGENT INTERACTIVE INTERNET INSTRUCTION

John Miller, The City College of CUNY, USA

Passive activities such as watching presentations, listening to explanations of general principles and watching experts solve sample problems are helpful, but peripheral, to the mathematical learning process. For students the indispensable step is solving problems for themselves. Yet most commercial mathematics software still concentrates on presentations and sample problems, while sending students off line to do practice problems on paper without interactive support. Answers are either multiple choice or limited to a single simplified final step. Early Internet courses are even less interactive. In contrast, students using xyAlgebra can enter each step of each problem solution. They enjoy intelligent support at every step as xyAlgebra's suggested solution strategy changes in response to their steps in simplifying expressions, solving equations and even in setting up and solving verbal problems. The next version of xyAlgebra will support instruction over the Internet, yet the entire package can be downloaded without cost at math0.sci.ccny.cuny.edu/xyalgebra.

SCIENCE EDUCATION IN ALTERNATIVE PROGRAMS: BUILDING BRIDGES WITH TECHNOLOGY

Barbara Moore, The University of South Florida, USA

Science educators, using technology, can build bridges across the digital divide by helping alternative education students graduate and break the cycle of poverty. Alternative students often miss various segments of content. The results are poor grades and low scores on standardized tests. These students need resources for self-paced acquisition of knowledge, comprehension, and application levels of missing content. They also need resources for individualized drill and practice, as well as stimulation of higher level thinking skills. The Digital Bridge, URL http://typhoon.coedu.usf.edu/~bmoore/bridge.htm, is an on-line learning resource designed to address individual differences in student learning style and ability. The site offers short, self-paced units of content. It features objectives, key terms, tutorials of several types, links to related information, flashcards, and timed quizzes. The Digital Bridge helps students learn and allows teachers to focus on individual students or community-based class projects.

MINING THE INTERNET: INTEGRATING REAL-WORLD DATA AND INTERACTIVITY IN THE ONLINE CLASSROOM

Gerald "Jerry" Nelson, Casper College, USA; Susan Nelson, Casper College, USA

The internet does three things extremely well that can promote interactivity in the online classroom: communications, immediacy of data, and the internet's ability to archive data sets. These three taken together can produce opportunities for true interactivity between students and scientific theory and mathematics.

THE APPLICATION OF MAPLE V IN LEARNING ACTIVITIES FOR COURSES IN TRANSPORT PHENOMENA

Araceli Reyes, Instituto Tecnologico Autónomo de Mexico, MEXICO; Bernardo Hernández-Morales, Universidad Nacional Autónoma de México, MEXICO

Courses on Transport Phenomena (Fluid Flow, Heat Transfer and Mass Transfer) are taught at the junior level in the engineering curricula. These courses require the use of mathematical-oriented skills, in particular the application of methods for solving differential equations, in the context of an applied problem. To aid in the learning process, we are developing a series of activities based on the Maple V R4 software package — a language for symbolic mathe-matical calculation. Each activity is based on a Maple V R4 worksheet, accompanied by a handout. The worksheet must be completed by the students as an extra-class activity. The handout is divided in two parts: i) a brief descrip-tion of the problem, where the objective of the exercise is clearly defined; and ii) instructions on how to complete the worksheet, followed by questions that can only be answered after the worksheet has been successfully com-pleted.

FLEXIBLE GENERATION OF ANIMATIONS USING ANIMAL

Guido Roessling, University of Siegen, Germany; Bernd Freisleben, University of Siegen, Germany

ANIMAL is a tool for generating animations suitable for integration in lectures. Animations can be generated by visual editing using drag and drop, scripting using the built-in scripting language and generation by function calls in the ANIMAL API. ANIMAL offers the primitives point, polyline / polygon, text, arc and list element. All elements are adaptable to subtypes such as square, ellipse or circle segment. Animations consist of separate steps containing an arbitrary number of effects each. Current effects include show/hide, move, rotate and change color and can be given both offset and duration, measured in milliseconds or internal time units. Both scripting and API support inclusion of source/pseudo code with indentation, element and code highlighting, arrays including index pointers and relative object placement. Automating animation generation is easily accomplished. The resulting animation files seldom exceed 10kB. ANIMAL is implemented in Java and available at http://www.informatik.uni-siegen.de/~inf/Software/Animal/.

MATHEMATICS, ARTS, AND NEW MEDIA : SOME INTERESTING INTERCONNECTIONS

Nicoletta Sala, Academy of Arch. - University of Italian Switzerland, Switzerland

Imagination and creativity are among the qualities of a good mathematician. The academic mathematics course has become, for many students, a highly structured sequence of definitions, theorems, and proofs that lead only to additional definitions, theorems, and proofs. This work describes an educational approach, in two different undergraduate course (first and fourth year), where some mathematical concepts are presented with their artistic connections (e.g., the polyhedra, the golden section, the fractal geometry, and so forth), using also the new educational tools (e.g., hypertext, hypermedia, virtual reality). I refer of my experience at the Academy of Architecture of Mendrisio, University of Italian Switzerland where I have researched the interconnections between Mathematics, Arts and Architecture using the new media and I have observed that they can help: to reach good cognitive goals, to increase the students' attention, and to do more interactive the learning process.

HYPERTEXTS AND HYPERMEDIA TO PRESENT THE INTERCONNECTIONS BETWEEN MATHEMATICS AND ARTS

Nicoletta Sala, Academy of arch- University of Italian Switzerland, Switzerland

The computer plays a central role in educational environment, for this reason I describe an educational approach where some mathematical concepts are presented with their artistic connections, using also the hypermedia, and the Web. For example, to explain the platonic solids and the polyhedra I have used some hypertexts and hypermedia (on CD-ROM and online) and I have also researched in the Internet some interesting Applet Java. At the Internet address: http:// home.a-city.de/ walter.fendt/mathengl/platonengl.htm there is an Applet Java which contains an animation where we can choose and rotate the platonic solids (changing the rotation angle). To present the polyhedral components and the tessellation in the M.C. Escher's paintings I have proposed to my students the CD-ROM Escher Interactive (for Windows) which contains an audio/ visual life of M. C. Escher and videos of the artist at work . To introduce the basic concepts of the fractal geometry I have created a hypertext using HTML language. It is available at the Internet address: http: // www. arch.unisi.ch / fractals/fract1e.htm inside of my hypertext there is a page dedicated to the fractal architecture with the building's self-similarity (e.g., an Indian fractal temple, the fractal floor of the church of Anagni, Italy).

ZELIG: STATISTICS FOR ALL

Teresa Sancho, Universitat Oberta de Catalunya, Catalunya; Antoni Meseguer, Universitat Oberta de Catalunya, Catalunya; Francesc Vallverdu, Universitat Oberta de Catalunya, Catalunya; Eloi Batlle, Universitat Oberta de Catalunya

This work presents a web-format framework for teaching and learning Statistics in the Universitat Oberta de Catalunya (UOC). UOC is an Open University with a virtual campus where both students and teachers interact, breaking time and distance constraints. The learning and teaching process is evolving with the information and communication technologies. These technologies facilitate the interaction between the student and the material through the resolution of exercises and the experimentation with simulated cases. Statistics is a transversal subject or tool used, at different levels and skills, in most of Higher School studies. In this sense, we propose a digital and navigable didactic framework that integrates the basic elements of the self-learning process and adapts the learning material to the student, according to his personal profile (career, previous knowledge, skills, behavior, etc). A tailor-made and oriented evolution implies an intelligent tracking of the student's actions. In this respect, we might say that this kind of activity allows either the student to learn significantly or the teacher to keep the process under control.

REALIZING AN IDEA/ COMPUTER-AIDED INSTRUCTION AND LEARNING

W. Udo Schroeder, Univ. Rochester, USA

An Interactive Distributed Educational Application (IDEA) has been realized for an undergraduate physical-chemistry course at the University of Rochester. It supports the educational goals of generating a more intuitive, yet realistic, understanding of complex, abstract physical theory by the students and helping them develop numeracy and important skills in actively simulating physical processes. Interactive Study/Lecture Notes (ISLN), containing an electronic text, hyper-linked to

explanations, tutorials, "hot" data plots, simulations, and quizzes, represents the core of the IDEA. They are embedded in a Web-based course frame, together with course annunciator and communicator segments. ISLNs and course frame have been produced with MS-Word TM and MathcadTM software and can be viewed with freely available browsers. This widely used software makes the tasks achievable for both students and instructor. The IDEA course system has been accessible via the University's local network but may serve as a more general model of an effective self-paced, distance-learning environment.

USING GRAPHING SOFTWARE, COMPUTERS AND EKG'S TO HELP STUDENTS LEARN ABOUT THE BEHAVIOR OF THE HEART

Leonard Simons, Elmira College, USA; Jerry Przybylski, Elmira College, USA

Reading the output of an EKG is often confusing for students in beginning biology courses. A variety of distances, ratios and slopes need to be read from the graph to obtain the pertinent information for describing the behavior of the heart. However, many students in these classes do not have a good background in graphical analysis. We propose that doing some mathematical work in a biology course before encountering circulation lab activities will greatly aid in the students' understanding of the material. The students first generate some very simple graphs. They see how various distances, slopes and ratios obtained from the graphs describe different quantitative behaviors. The students work through a small set of increasingly complicated periodic graphs leading to a graph that looks like the output of an EKG. Then, when running the actual EKG's, the students can concentrate on the biological concepts rather than learning new mathematics.

I.MO.PHY. A NET-COURSE SUPPORTING THE INTRODUCTION TO MODELING IN PHYSICS EDUCATION AT HIGH SCHOOL LEVEL

Rosa Maria Sperandeo-Mineo, University of Palermo, Italy

IMOPHY (Introduction to MOdeling in PHYsics-education) is a teacher training Course delivered on the Web. It consists of various Net-Seminars (on line seminars using on-line discussion groups) concerning different physics topics. Each Net-Seminar is tailored to train teachers in transforming their teaching by promoting a constructivistic teaching practice and computer-enhanced instructional approaches that enable students to learn about the process of modeling physical phenomena. The Net-Course approach involves a construction of the physics content structure that has to be taught not mainly, or even solely, oriented to physics issues but also including educational issues and pupils' conceptions. These two issues, students spontaneous models and statements of the scientific knowledge, are therefore accepted to be of the same relevance and treated as resources for physics education. The Net-Seminar about thermal interaction between bodies will be described and the pedagogical tools prepared (experiments using Microcomputer Based Laboratory and software) will be analyzed.

A NAVIGABLE BOOK TO LEARN DISCRETE MATHEMATICS

Francesc Vallverdu, Universitat Oberta de Catalunya, Catalunya; Teresa Sancho, Universitat Oberta de Catalunya, Catalunya

This work will discuss on a course material in web-format for teaching and learning Discrete Mathematics, a subject that is offered at the Computer Science School of the Universitat Oberta de Catalunya (UOC). UOC is an Open University with a virtual campus where both students and teachers interact, breaking time and distance constraints. The learning and teaching process is evolving with the new information technologies. The teacher-student relationship is changing, even more in distance education. The interactivity between the student and the material can be done through the resolution of exercises and the experimentation with simulated cases. The simple exercises are usually Java Applets embedded in the same html page where the exercise evolves, in a xml framework. Depending on the student's behavior and skills, different paths are presented in order to optimize the learning process. The more the student knows, the more difficult questions are. A tailor-made and oriented evolution implies an intelligent tracking of the student's actions. In this respect, we might say that this kind of activity allows either the student to learn significantly or the teacher to keep the process under control.

COMPUTER-BASED INTERACTIVE MATH COURSES - THE GUAM EXPERIENCE

Yu-mei Wang, College of Education, University of Guam, U.S.A; Carl Swanson, College of Arts and Science, University of Guam, U.S.A

The island of Guam is a U.S. unincorporated territory in the Western Pacific Rim. Guam is the largest and most heavily inhabited of the Marianas Islands with a population of 146,000. With 85% to 90% of college students forced to take remedial math, clearly, students in this region are mathematically challenged. To counter this problem, the Guam Community College introduced interactive multimedia computer-based learning system into their math courses. This study presents a survey result regarding students' attitudes towards interactive computer based math course. The sample for the study was the students enrolled in computer-based math courses at the level of ranging from Basic Math to Precalculus. Data collection spanned two semesters in 1999. Sixty-nine students participated in the study. Data analysis shows that students were overwhelmingly positive towards computer-based interactive math courses and interactive multimedia learning system.

EXPERIENCES IN TEACHING AN ASYNCHRONOUS WEB-ENABLED COURSE TO A DIVERSE STUDENT

Chris Wild, Old Dominion University, USA

This paper describes a transition course in the C++ programming language aimed at transfer students and students with associate's degrees who wish to obtain an undergraduate or graduate degree in Computer Science. Because of the diversity of background of students entering the university, an adaptive web-enabled presentation of material was chosen. The instructor defines a course of study that links educational objectives to course material stored in a database and indexed by subject matter, media type, difficulty level and background. A given subject area may be covered by several explanations each appealing to a different level of prior experience, preferred mode of delivery, background and previous retrievals in the data base. Experience to date has shown there is a need to support a diverse student population. Of the 19 students taking this course, only 1 or 2 could be considered "traditional" students.

AUTHOR INDEX

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