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ABSTRACT

The work described in this paper is part of a larger project, called InterQuest, which is dedicated to establishing effective models and methods for teaching using Internet technology, especially the World Wide Web. Features of two InterQuest projects, CalculusQuest and QuestWriter, are discussed. CalculusQuest is a first-term differential calculus course based entirely on the Web. It was developed around a set of performance objectives and in accordance with the principle that technology should serve pedagogy. QuestWriter is an environment for administrating and authoring general Web-based courses. QuestWriter includes tools for creating classes and setting up student authentication. It can record, evaluate, and react to the results of on- and off-line activities. It enables instructors to author and administrate question-based activities (for example, savable quizzes with feedback) and communication activities (pedagogically driven guided student exchanges). This paper focuses on those aspects of CalculusQuest and QuestWriter that use Web technology for specific pedagogic purposes. (Author/DLS)

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Abstract: This work is part of a larger project, called *InterQuest*, which is dedicated to establishing effective models and methods for teaching using Internet technology, especially the World Wide Web. Here we discuss features of two InterQuest projects, *CalculusQuest* and *QuestWriter*.

CalculusQuest is a first-term differential Calculus course based entirely on the Web. It was developed around a set of performance objectives and in accordance with the principle that technology should serve pedagogy.

QuestWriter is an environment for administrating and authoring general Web-based courses. QuestWriter includes tools for creating classes and setting up student authentication. It can record, evaluate, and react to the results of on- and off-line activities. It enables instructors to author and administrate *question-based activities* (for example, savable quizzes with feedback) and *communication activities*(pedagogically driven guided student exchanges).

We concentrate on describing those aspects of CalculusQuest and QuestWriter which uses Web technology for specific pedagogic purposes.

Introduction

In the Fall of 1995 at Oregon State University, only 250 of about 500 students initially enrolled in first term Calculus passed the course with a "C" or better [Brumley]. This is typical nationally [Steen 88]. In response to this problem Bogley and Robson joined forces with Dorbolo, who in 1993 had pioneered pedagogic uses of the Internet and Web to address problems with an introductory philosophy course, and Sechrest, who had been providing technological support and vision for Dorbolo's project in conjunction with the educationally oriented Shared Computing Environment which is part of the Network for Engineering and Research in Oregon (NERO).

One result of this collaboration is an ongoing project for the Oregon State System of Higher Education. The goals are to develop a Web-based first term Calculus course, to provide an infrastructure for offering such courses, and to demonstrate a model for teaching Web-based courses across educational sectors. CalculusQuest and QuestWriter are the concrete realizations of this project. They are a team effort which has come to involve content experts, programmers, graphic artists, and an instructional designer.

A beta version of CaclulusQuest will be offered in the Fall of 1996 at Oregon State University, Linn Benton Community College, and to high school students in Eugene, Oregon. It will use many of the tools from

QuestWriter, which will be available for platform-specific beta testing this Winter. An extensive program to assess the efficacy ofCalculusQuest is in place.

This report is limited to pedagogic applications of technology for which we believe either the pedagogy or the use of technology is new. The details of design methodology, mathematics education issues, the problem of communicating mathematics via the Web, and the architecture of QuestWriter will be addressed elsewhere. The InterQuest [IQ 96] and CalculusQuest [CQ 96] home pages serve as current references.

CalculusQuest

CalculusQuest is broken into 10 *stages*. Each stage has three main areas: a *Lesson* area, a *Practice* area, and an area called *Onward and Upward*. Content is delivered in the Lesson area. The Practice area is the equivalent of homework and labs. Quizzes with feedback are the mainstay of the Practice areas, but some Practice activities are more imaginative. "Onward and Upward" contains activities used to assess progress and comprehension.

We will discuss two aspects of CalculusQuest: (1) How we implement extensive interactivity which engages the student and merges the skills-based and process-based aspects of Calculus and (2) how we use the Web to cater to diverse learning styles and academic backgrounds. Much of the substantial attention paid to Calculus teaching during this last decade [Tucker and Leitzel 1995] [UME Trends 1995] has been focused on these goals.

Interactivity and Engaging the Student

From the very start we engage the student with short, interactive stories. In the first such story the student inputs guesses of the exact height of a fictional character named Andron. Andron gives one of two honest replies: "I am taller than that" or "I am not taller than that". The student discovers that it is possible to estimate Andron's height to any degree of accuracy, but not to pin it down exactly.

The majority of content is presented in a Shaum's outline style. Following accepted principles of Web design [Lynch 96] we have kept pages short and restricted to a single concept. Over half of our pages contain in-line interactive exercises which require thoughtful input. These force students to stop and think about the material and give them the opportunity to assess understanding. Hints and explanations are accessible through separate buttons on the page. These are displayed in pop-up windows. Pop-up windows permit the inclusion of optional information without increasing the length pages or adding another level of links.

In-line interactivity and pop-up windows are programmed client-side using *Javascript* [Javascript 96] [Danesh 96], a proprietary language built into Netscape Navigator versions 2.0 and higher. Microsoft Internet Explorer also implements Javascript but without pop-up windows. A significant use of Javascript is to present the student with "black box" functions for which values can be obtained by entering a number and pressing a button. Numerous activities emphasizing exploratory decisions are centered around black box functions. These activities are unique to the Web and rely heavily on the client-side technology for instantaneous feedback.

Other forms of interactivity are implemented server-side using QuestWriter. QuestWriter generates URL's which are linked from CalculusQuest pages. Examples include self-assessment quizzes and *communications activities*. All exercises in our Practice area give feedback (either through client-side or server-side technology) and can be repeated. Server-side "quizzes" have the added feature that they can be saved for future reference, see the section [Question-based Activities].

Communications activities are interactive exercises which exploit the communications capabilities of the Internet and Web. The most complex communication activities are structured peer-peer exchanges. These are facilitated by our server. For more details see the section [Communications Activities]. A simplistic communication activity is a logout page which demands of the student a short assessment of the learning session. More traditional communication activities include the use of Hypernews, bulletin boards, and chat rooms to foster discussions of Lesson content and Practice area exercises (allowed and encouraged). In their totality communications activities force students to communicate mathematics on a regular basis.

Addressing Diverse Learners

The mathematical community wants texts which are "lean and lively" [Douglas 86]. Client disciplines want texts which impart a large set of "indispensable" skills. Educators insist that we address all learning styles, and administrators demand that we bring along students with diverse mathematical backgrounds. These standards are impossible to meet in a printed text, but the non-linear nature of the Web offers new potential. CalculusQuest strives to meet all of these standards.

Each CaclulusQuest Lesson has a central core of pages accessible from a special page called the Lesson *Hub*. CaclulusQuest is an outcomes-based course designed around a list of performance objectives and criteria, see [CQ 96]. The core pages cover all performance objectives for the Lesson. Diverse interests are addressed by *enrichment pages*, unobtrusively linked and visually distinguished from core pages. These add historical context and present a deeper mathematical point of view. In future versions, students will be able to choose application areas of interest and see pages tailored to this choice.

The inclusion of background material is addressed through a separate *Field Guide to Functions*. The Field Guide offers review of all basic functions used in Calculus. Another project at our university is building pre-Calculus modules which will be linked and coordinated with CalculusQuest. These separate entities, together with their interactive self-assessment opportunities, give students the resources *and responsibility* to recognize and remedy deficiencies.

The organization of CalculusQuest Stages permits students to work through the material in any order. We go so far as to give the students the following table of *typical study approaches*. The approaches model Kolb's learning cycle [Stice 87] and we encourage students to find individual approaches which work best for them.

From Beginning to End	Working Backwards	Back and Forth
I. Read through the Lesson Pages	I. Look at what is in "Onward and Upward"	I. Glance at the Practice Problems and "Onward and Upward"
ii. Try the Practice Problems	ii. Find worked practice problems which might help	ii. Read the Lesson pages a few at a time
iii. Go back to the Lesson Pages as needed	iii. Read the Lesson Pages when you get stuck	iii. After a few Lesson pages, go back to the Practice area
iv. Perfect the Practice Problems	iv. Perfect the Practice Problems	iv. Read Lesson Pages and perfect Practice problems
v. Do the activities in "Onward and Upward"	v. Do the activities in "Onward and Upward"	v. Do the activities in "Onward and Upward"

Figure 1: Typical Study Approaches forCalculusQuest Materials

Students enrolled in Dorbolo's Web-based introductory philosophy course divide themselves into five separate groups based on personal philosophical framework. Each group sees a different set of readings. Future versions ofCalculusQuest may divide students into groups with different general goals for learning Calculus.

QuestWriter

QuestWriter is the name given to a collection of course management and course authoring tools which interact with an SQL database containing registration information, authentication information, and a *gradebook.* The gradebook is a collection of *student vectors.* The components of the student vectors are *activities* which can be graded or simply marked as completed. The majority of activities are on-line, but the instructor can create custom activities such as proctored tests. A basic design principle is that information on repeated or re-graded activities is never thrown away. The default is to show only the last recorded score.

The highest level activity in QuestWriter is the creation of a new course. The software creates the directories and database needed to manage the course and to author and edit activities. Students apply for registration via the Web. This process is independent of institutional registration procedures and is filtered through the instructor.

Progress and Grades

The gradebook is a dynamic record of student progress. Students can view their own (and only their own) entries. Instructors can scan the entire class list. This is a valuable aid to student retention. A conscientious instructor can literally check for stragglers each morning and, since all students are on-line, send encouraging or inquisitory email messages to students in danger of falling too far behind. The key is the timeliness of the information and the immediate contact with the students.

The instructor can weight and curve activities and thus generate a score for the class, but QuestWriter also has the ability to archive and retrieve detailed components of a student's performance rather than just the final grade. This raises new possibilities. By adjusting weights, for example, different departments might use different criteria to determine if the same student taking the same course has met program requirements. The QuestWriter gradebook will eventually allow us to build pages which deliver material *dependent upon a student's current state of progress or advancement.* Finally, QuestWriter is a prototypical of the administrative tools needed for Oregon's standards-based K-12 educational reform (House Bill 3565) and for the Oregon State System of Higher Education's new Proficiency-based Admissions Standards System [PASS] [Conley & Tell 1996].

Question-based Activities

Our original intent was to build an environment for authoring quizzes that offered optional feedback and drew questions randomly from a database of questions. We have not yet implemented the randomization procedure, and we have come to realize that "quizzes" represent a general form of interaction as characterized in the following figure. We call these *question-based activities.* Answers to question-based activities can be recorded for future reference and/or evaluated either for the gradebook or just to provide feedback.

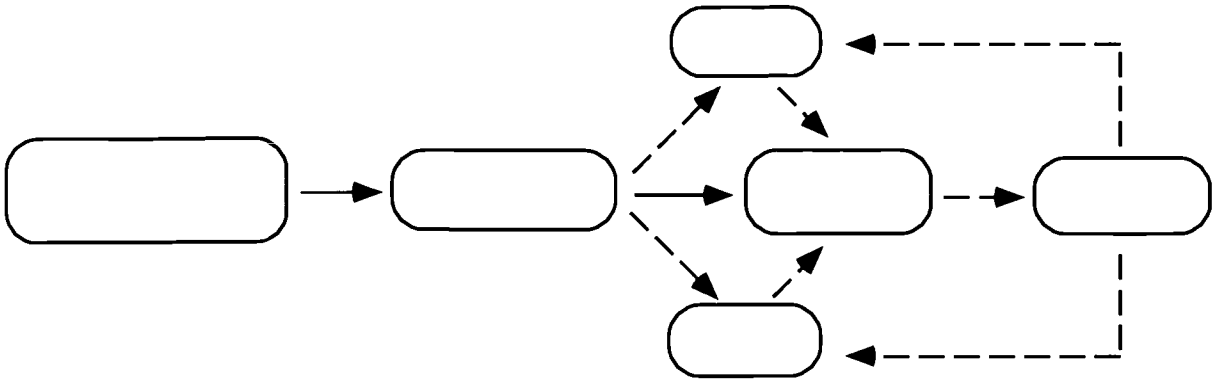

Figure 2: Feedback Loop for Question-based Activities

This model can be used for graded on-line quizzes and tests, for self-assessment exercises where the emphasis is on feedback, and for building student notecards. A *notecard* is a Web page containing HTML forms with questions for the student to answer. After correction a version of the page incprporating the student answers can be saved as a permanent and personalized reference. A 1994 site visit review of Web-based philosophy materials generated the comment that, at the end of the course, the students had nothing akin to a text or set of notes to take with them. Notecards respond to this: a virtual rolodex of notecards can guide a student through a Web-based or partially Web-based course and provide a permanent record.

Question-based activities can also be used in conjunction with the gradebook as gateways which block access to material until a certain level of response is attained. This has wide application as an internal pedagogic tool and as an external placement device.

QuestWriter offers an environment for authoring question-based activities linked to particular classes. Currently, we support three types of questions – true/false, multiple choice, and fill-in-the-blank. The instructor constructs a header and footer for each activity, generally containing instructions and links to URL's which the student might want handy while completing the activity. Each response to each question has a place for optional feedback. Different types of questions may be included in one activity and questions may be edited, added, and deleted from existing activities The instructor may choose between various evaluation options and may indicate if the activity can be saved by the student.

Communications Activities

Students in Dorbolo's Web-based philosophy course are required to engage in "discussion activities", now termed *communication activities*. A typical such activity is a simple exchange between two students Alice and Bob. Alice and Bob receive instructions to write a letter to Plato. The letters are exchanged and each student, in the persona of Plato, replies to the other. Other activities involve loops of three or four students.

Communication activities require special automated administration. The fundamental problems are forming groups, passing information among students in a group, and insuring that progress is being made. QuestWriter contains an authoring tool for communications activities which involve 2 students and any number of "passes". Thus Alice could send off an assignment (one pass), receive input (2 passes), send off a reaction (3 passes) and receive a reaction (4 passes).

If there are *n* passes, then there are *n* roles to be played in the communication chain. *In our model, each student plays each of the roles.* This raises the question of how to pair up students. We have two ways.

The exchange model: As students declare themselves ready, they are paired off and stay together. Initially, both partners complete the first pass and exchange results.

Figure 3: The Exchange Model of a Communication Activity

The "lazy scheduling" model: Say Alice is ready to begin a discussion activity. She receives instructions and sends off the first pass. This goes to the first student (other than Alice) who is ready for the second pass. This could be Bob. Alice is ready for the second pass, but her input could come from *any* student, not necessarily Bob.

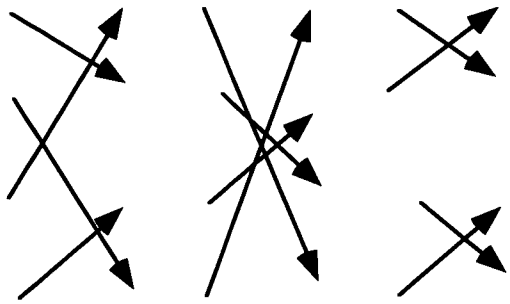

Figure 4: The "Lazy Scheduling" Model of a Communication Activity

The assignment of partners is facilitated by the gradebook. Deadlines can be set for each pass and for the entire activity. QuestWriter generates automatic email reminders and, depending on the model used, will reassign students if a partner is not participating. The instructional staff can masquerade as students. This is necessary to deal with a "left over" student and provides a second monitoring mechanism.

QuestWrtier includes an instructor front-end for both the authoring, viewing, and evaluating communications activities. The instructor can see all responses made by a particular student or follow a thread. There is also a viewing tool for the students.

Summary

The Web and Internet comprise a new medium with new pedagogic opportunities and challenges. CalculusQuest takes advantage of client-side and server-side technology to implement extensive interactivity aimed at provoking student thought while making the learning experience enjoyable. Artifices such as varied background colors, hub pages, and pop-up windows are used to create a content-rich environment which is none-the-less easily negotiated and flexible enough to accommodate diverse learning styles and backgrounds.

Creating and administering a Web course is a time-consuming and daunting prospect. QuestWriter provides the infrastructure without which this cannot happen on more than an ad hoc basis. The SQL database at the core of QuestWriter has great potential in the contexts of outcomes-based and Web-based education. We have introduced two general concepts, the question-based activity and the communication activity, which use the communications potential of the Internet and Web for a variety of specific pedagogic purposes.

Concrete issues we have not addressed include the problems and frustrations of dealing with emerging technology and the difficulties of communicating mathematics on the Web. We have not detailed the actual team process of building a course like CalculusQuest and have only touched upon some fascinating issues of

educational Web page design. We have also not discussed many technical points of CalculusQuest and QuestWriter, nor have we said anything about issues of privacy, data protection, and authentication. We intend to report on all of these things in appropriate forums. Hopefully by the time we do so we will have hard data speaking to one overriding question*Did it work in practice?*

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