A Technology-based Model for Learning

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ABSTRACT

The Math Emporium, opened in 1997, is an open 7000-squaremeter facility with 550+ workstations arranged in an array of widely spaced hexagonal "pods", designed to support group work at the same time maintaining an academic air. We operate it 24/7 with math support personnel in attendance 12 hours per day. Students have access to on-line course resources at all times, from anywhere. We have used this unique asset to transform traditional classroom-based courses into technology based learning programs that have no class meetings at all. The structure of the program is very different from the conventional one, having a new set of expectations and motivations. The results include: more effective students, substantial cost savings, economies of scale and scope and a stream-lined process for creating new on-line courses.

Keywords: Scalable Course Conversion, Problem Program, Large-Enrollment Class and Faculty Role.

INTRODUCTION

It is important for us to reveal at the outset a primary motivation for the project described in this paper. Continuing governmental budget shortfalls, which have led to a general societal devaluation of our educational system, has imperiled universities. To be sure, our educational system has major flaws, but the shift has taken us from common-good investment to a commodity to be bargained for. The reality is that these conditions will likely remain for the foreseeable future, and with them, under funding. We will be teaching more students with decreasing support. We describe our attempts to respond to these important issues in the sequel. [1,2]

SETTING

The Mathematics Emporium is designed to improve the efficacy of large-enrollment course offerings by integrating computer technology into the teaching of mathematics courses. The facility is located in a former department store building with 7000 square meters of space, and consists of approximately 550 workstations arranged in an array of widely spaced hexagonal pods networked with high-speed internet connections. Most of the course specific software and record keeping resides on an aging SUN Enterprise 3000 workstation. The furnishings are arranged in an open space design with minimal use of partitions. Software includes a variety of web browsers, multi-media applications (e.g., RealAudio, Flash, Shockwave, etc.), Mathematical, Matlab, Geometer's Sketchpad and Office 2000. On the periphery several special areas are designated: a large presentation area, two seminar areas, two lounge areas, and small partitioned spaces for conferences.

The Emporium is open 24 hours a day, 7 days a week, during the school semesters. The number of available seats in the Math Emporium is accessible on a Web page, and thus available to students at any location with a modem or Ethernet connection. Therefore students may optimize the use of their time by avoiding waiting lines.

The Emporium opened in the fall semester of 1997. Initially computer utilization was concentrated in early evening hours, with lower utilization at other times. Over the 6 years the Emporium has been operational, however, this distribution has changed. There is now significantly more utilization at nonpeak times, and, in particular, nighttime utilization continues to increase. This evidently has resulted from the gradual adjustment of the student body to the freedom offered by open scheduling. Indeed, one will find more students in the Math emporium at 3 am than at 10 am!

Virtually all first and second year mathematics courses have technology assignments that may be carried out at the Emporium. However, the linear algebra course required of all engineering and math sciences majors and the two-semester sequence in college algebra and elementary calculus taken by life and social science majors are taught entirely at the Emporium. It is the construction of teaching and testing machinery for such courses that will be the subject of this paper.

Although the admissions standards at Virginia Tech are high, and the large number of engineering and science majors could be expected to lead to fairly high motivation and interest to perform in mathematics, university students here suffer from the same problems which are seen throughout American universities: poor study and time-management skills, weak performance in basic algebra, falling self-confidence as they encounter difficulty in their first-year mathematics courses, and insufficient self-discipline to complete assignments.

These weaknesses, which reflect a student body more diverse, representing a much greater percentage of high school graduates, and more addicted to the visual media than in earlier decades, must be taken into account in formulating an online course.

The student-users of the Math Emporium presently enter the university with a fairly high level of computer literacy and comfort. Virginia Tech requires all entering undergraduate students to possess a personal computer meeting mandated memory, processor and software standards. However, despite the increasing role of computing in the curriculum, the development and usage of a new technology-based model must still take into account the resistance of faculty wed to the conventional lecture-homework-exam paradigm for teaching. Change comes hard in the academy, where traditions have sometimes survived a millennium or more.

COURSE STRUCTURE

The linear algebra one-semester course and each course of the college algebra and elementary calculus sequence enrolls about 1500 students per year. These students never meet in a classroom. Their introduction to the on-line courses is an orientation session that exposes them to the course resources: tutoring labs, on-line course web pages, the testing system, online videos, etc. Thereafter, subject to unit deadlines, the students have complete autonomy over their schedules.

Each course is made up of a sequence of weekly lesson practice-quiz cycles with periodic exams. The lessons are given by mildly interactive web page presentations. Each individual lesson web page consists of three overlays: explanation, examples and a challenge problem. We refer to the collection of web pages (usually about five) on a particular topic as a module. The default schedule would require a student to master about three modules per week, followed by a weekly quiz.
Additionally, five examinations and a final exam have deadlines equally spaced through the semester. In fact, a student may proceed at any pace he or she wishes as long as he or she does not fall behind the default schedule. Theoretically, the able and energetic student could

finish the entire course in a week or two, but this has so far never happened.

The framework created to support the learning modules is the same for each of these courses. It is rigorous and uniform across modules while allowing for great flexibility in the use of multimedia. The machinery permits the inclusion of streaming video, audio recordings, and a variety of interactive tools to enhance the effectiveness of the presentations. The lesson pages, quizzes and examinations are all based on Mathematical templates, which are invisible to the student. Benefits of this framework include a constant interface for the student and ease of authorship.

Students take required quizzes after every few modules (which, based on the default schedule, we will refer to as weekly quizzes). Before taking a weekly quiz, a student may take as many practice quizzes as desired. Immediately after completing an attempt at a practice quiz or a weekly quiz, the student is shown his score and the correct answers for all problems. The problems, which comprise both the practice quizzes and the weekly quizzes, are generated on demand by problem programs. Each problem program is designed to test the understanding of a specific concept covered in the learning modules. Since the student can take the practice quiz as many times as he wishes, and since the pool of problems for these practice quizzes and the weekly quiz itself is the same, the problem programs must be capable of generating a large number of randomly different variations of each problem, as well as a series of one correct and a number of incorrect answers. The student selects the correct answer from a variable number of choices of possible answer. There is one control requirement for the weekly quizzes. Unlike the lesson modules and the practice quizzes, which any student enrolled in the course can access at the Emporium, from his dormitory room, or, indeed, from any internet connection, the weekly quizzes must be taken at the Math Emporium.

The five examinations and the final examination are formulated again individually for each student, by assigned or random selection of the same problem programs. However, the control requirement in these cases is more severe. These exams must be taken in a special section of the Math Emporium that is proctored.

The key feature of the Math Emporium is the availability of one-on-one help provided within one minute of the request by a support staff versed in all offered subjects. The support staff is comprised of instructors with ranks from Full Professor to advanced undergraduate. Just-in-time help is naturally more effective than a general lecture. The faculty role changes in this model from a one-to-many broadcaster to a one-to-one shortterm tutor.

LEARNING PARADIGM

In our experience, the central focus of these emporium courses is the practice and weekly quizzes [3]. Because these quizzes substitute for conventional homework, and because they are the most interactive segment of the course, it is essential that each problem program be carefully thought out. It must present a concept of interest and of importance, it and its selection of possible answers must be posed in such a way that the student both learns the concept and is appropriately tested on it, and the randomly generated versions of the problem must be sufficiently different to properly challenge the student at each attempt. A particular challenge is in generating the "wrong" answers. Of course, the problem program must be certain these are indeed wrong, and not just different formulations of a correct answer, and must among themselves be sufficiently distinct. A somewhat more difficult challenge is to make certain the set of wrong answers and the correct answer do not fall into a pattern from which the student can discern which answer is correct. We have found, in dealing with such a large number of students, that some among them will be surprisingly clever in recognizing (unintentional) patterns from successive attempts at the practice quiz, which enable them to discover the correct answer without any idea of why!

Because of the direct connection between the practice quizzes, the weekly quizzes and the exams -- they are all generated by the computer from the same set of possible problems – students seem far more motivated to spend time working problems than had been our experience with conventional homework assignments. Not surprisingly, we found students more willing to study the practice quiz when we called it a "quiz" rather than homework. All of our measurements indicate that more time spent actively doing problems on their own, rather than listening to presentations, translates to better understanding of the material. We believe this is the single most important advantage of the emporium model over the conventional lecture-homework-test paradigm.

We observe entering students to be ill prepared for the freedom which college life suddenly thrusts upon them. The replacement of five-day-a-week classes and overnight assignments in high school with two or three lectures per week and occasionally collected assignments at the university presents an overwhelming time-management problem for many students, most especially those from inner city schools and nonacademically involved families. Even if the students carried out homework assignments in high school, they do not grasp that substantially more self-guided effort is required between classes. Because the goals of the emporium courses are clearly defined and transparent to the student, and because the emporium course experience provides immediate and continuous feedback, we have seen measurable improvement in the time-management skills of our first-year students. What the student needs to accomplish to be successful in the course is plainly laid before him or her: exams and quizzes are graded instantaneously, all previous tests are available for on-line review, and the student's standing in the course is always known to him or her. Thus, the students see the time that they spend on course activities as immediately rewarding.

COURSE CONSTRUCTION

Normally, constructing anything beyond a simple web page for mathematical content has required a working knowledge of technical word processing, MathML (or equivalent), JavaScript, layout design, etc. This presents a daunting barrier for the average faculty member to become involved in developing online courses, or even components of courses. Our learning modules have now been regularized, so that a new faculty member, whether adding to an existing emporium course, or developing an entirely new course, will be presented with templates that eliminate the need to be concerned with most questions of layout, formatting, linking, etc., thereby enabling him or her to be immediately productive. The templates, to which Mathematical brings its powerful and robust authoring environment, seemingly reduce the writing process to a fill-in the- blank routine. Each component of a learning module – an explanation, an example or a problem -- has its own cell type in a Mathematical notebook. Within each cell type are subtypes to represent different elements, for example, definition, graphic, theorem, hint. The faculty member basically adds content to each of the appropriate subtypes without concern for any formatting issues. Within the first hour, a faculty member with no previous experience of either programming in general or of Mathematical can be successfully writing new modules.

The styling and production of web pages is left to the postprocessor using XSLT. In fact, with a tuning of the parameters in the XSLT programs, the processor can equally well produce PDF output suitable for offset printing. We have used this option to produce textbooks for the students. No modification of the authored source pages was required. Revision control is thereby greatly simplified. Moreover, changes to the on-line presentation pages (e.g. to correct a typo) can be corrected in minutes. The writing of problem programs is somewhat more challenging, as it requires both mathematical subtlety and programming finesse. Nevertheless, we generally see success with initiates after several hours of explanation and examination of sample programs, although supervision is required for some period thereafter. Mathematical is again used as the production environment. It provides both a sophisticated programming infrastructure and effective tools to create suitable web components.

The design goals for establishing the delivery mechanisms for the course were governed by: (i) simplicity, (ii) universality and (iii) scalability. Since every student knows how to surf the net, the web browser was selected as viewer application. Customized viewer applications are expensive to maintain and inevitably platform dependent. Therefore, all of our materials were designed to be presented with a generic browser (i.e., fully standards compliant). All elements of the course may be viewed on any browser on the Internet.

Modern web servers (we use apache) are robust and highly scalable. Thus, delivery of the presentation web pages proves to be no challenge. However, in contrast, the test engine server requires capabilities far beyond the norm. All commercially available test engine offerings fell far short of our requirements. We used java server pages and an Oracle database to create our own system that is capable of serving thousands (distinct!) of tests simultaneously. Next semester it will serve more than 200,000 tests. All aspects of every test given are recorded in the database for later analysis.

ECONOMICS

The conversion of the referenced course offerings to the model described in the preceding has reduced costs by an average of 75%. This is due to the fact that the demand for one-on-one help (sometimes provided by advanced undergraduates) is dwarfed by the costs of more senior lecturers in so many classrooms. Furthermore, when the performance in later courses of students who have completed courses under this new model are compared to those who learned the material under the traditional model, we find that the former significantly outperform the latter. We believe this is due to increased time-on-task and an increased independence.

CONCLUSION

The Math Emporium has permitted us to make a discontinuous change to the methods of operation of our course offerings. We have used this unique asset to transform traditional classroom based courses into technology-based learning programs that have no class meetings at all. The structure of the program is very different from the conventional one, having a new set of expectations and motivations. To summarize, the results include:

- Students are more self-reliant
- Students budget their time more effectively and Satisfyingly
- We enjoy a substantial cost savings
- Students demonstrate increased proficiency in downstream course work
- We have learned much about distance learning
- We have a new fully automated testing system which broadens the impact of testing
- We have a stream-lined process which takes source material into structured web resources effectively and quickly
- We have shown the model we are using scales well (e.g. savings increase) to large enrollment courses!

We continue to aggressively pursue further course conversions.

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