The Math Emporium: A New Learning Community

Anne H. Moore

Abstract

Virginia Tech's gothic architecture "embodies the solemn, timeless look of academia, imbuing all who come here with a powerful sense of place...until they get to math class"(Wall Street Journal, 1 January 2000). Approximately sixty faculty teach in the Math Emporium, a technology-assisted learning community serving more than 7,000 students each semester. With 500 work-stations, the emporium offers a variety of options for learning mathematics, including online learning, tutorials, tutors, lectures on CD-ROM, group meetings, live lectures, and tests and quizzes online.

A recent article in the *Wall Street Journal* (1 January 2000) suggested that Virginia Tech's gothic architecture "embodies the solemn, timeless look of academia, imbuing all who come here with a powerful sense of place...until they get to math class." This is because more than half of the faculty in mathematics teach in the Math Emporium, a newly developed, technology-assisted learning community at the university that serves more than seven thousand students each semester.

Physically, the Math Emporium is a 56,000-square-foot facility containing 500 computers organized in pods of six. It is designed to give students every opportunity to learn mathematics by offering a variety of teaching and learning situations, including totally online learning, tutorials, tutors, lectures on CD-Rom, group meetings, and live lectures. Testing is available in the form of quizzes, module and cumulative tests, diagnostic skill reviews, and common-time examinations. Students can review their skills through a computer program of self-tests called WhizQuiz.

Faculty and Student Learning

From its beginnings as a pilot project in 1997, the math department approached the emporium as a learning center for faculty and students. To create an effective learning center, the faculty thought they should aim continuously to achieve three overarching goals: 1.) challenge students and assist them to become active learners; 2.) provide multiple ways to accommodate student learning; and 3.) provide appropriate and adequate resources.

Based on student comments and surveys, the mathematics faculty made adjustments in everything from learning activities to course-related logistics. For example, they changed the way quizzes were counted in the grading process and they implemented diagnostic interviews to evaluate individual student participation better and to assess learning on group projects more effectively. The faculty created software with highly visual demonstrations of mathematical solutions for students who need to see what is

happening. For auditory learners, the software also integrates descriptions of mathematical concepts which students can hear at a convenient time and as often as needed. In some courses, only supplementary materials are offered online, while in others all content, including lectures and quizzes, is provided electronically.

Faculty and staff who were assigned administrative responsibilities in the emporium learned from formal surveys and informal discussion what students liked and did not like about learning in this new environment. Students appreciated such things as the self-paced learning, the tutorials for extra practice problems, and the number of options available for learning mathematics. they did not care, however, for unprepared peer tutors, too much reliance on computers, nor the requirement to spend three hours per week in the emporium, especially since the content is available over the university's network.

The mathematics faculty believe that with the right resources, students who teach themselves and who actually "do the math" learn best. In designing learning activities for the emporium, the faculty aimed to assist students in becoming their own best teachers and thus able to solve particular problems in mathematics, and also problems generally over a lifetime. These faculty planned their time and their students's activities so they could coach their students through mathematics problems in the emporium, unsticking them when they got stuck on a problem. To accomplish this, faculty members and teaching assistants work in shifts at the Math Emporium, walking around the learning center to aid students who may become lost in the midst of a computer-assisted learning activity.

Assessing Results

From the beginning, administrators who were tracking student learning outcomes could see that grades were generally improving and failure rates declining. But more analysis was required to know exactly what was occurring. A departmental evaluation, completed in 1998 and based on student surveys, concluded that establishing the emporium had been a good thing, but that it would take more time to document the effectiveness of the new approaches to teaching and learning. The next year, the university's Office of Institutional Research and Planning Analysis began a statistical analysis of the project's effectiveness. The analysis, issued in February 1999, found that "those students who receive their math instruction via the Math Emporium exhibit improved performance."

This semester-long review, sponsored by the provost and culminating in a visit to campus by distinguished outside evaluators from the American Association for Higher Education and Indiana University, led to a report on the design and progress of the Math Emporium to date. This report, released in the summer of 1999, is available at the following URL: http://www.math.vt.edu/temp/emporium_presentation/assesment_report_form.htm.

Robert Olin, chairman of the mathematics department from 1994-2000, acknowledges that students have become more comfortable with the emporium approach over time. Indeed, the first group of students to try learning in the emporium were somewhat skeptical. Since its creation, mathematics professors involved in the emporium have attempted to monitor student reaction closely. In some cases, there have been focus groups in which students have been invited to evaluate faculty performance. Since the faculty member's job is to help them adjust to the emporium, the evaluation is an

indication of the students' accommodation to the process. The average evaluation during the spring semester of 1999 was 3.4 on a 4.0 scale.

New Approaches to Teaching

Some of the new approaches in the Math Emporium have involved attempts to bring more uniformity to the teaching of a particular subject. For example, in the original design of a mathematics for engineers course, more than 20 instructors were teaching more than 40 sections. Each faculty member approached the course differently, and some were successful while others were not. After this course was redesigned for the emporium environment, one person now provides lectures when needed—these are digitized for later computer access—most of the instruction is online, and the learning materials are collectively prepared to ensure uniformity. In doing this, the faculty hope to "level the playing field" for student success.

Since this particular course, Math 1114 (Linear Algebra), is required for approximately 2,000 Virginia Tech students each year, it also serves as an excellent demonstration of a high impact redesign effort. For this reason, what follows is a fuller description of its antecedents, design, implementation, and effects.

Redesigning Math 1114, Linear Algebra

The material covered by approximately 2,000 students each year in Math 1114 is critical to their academic careers. In addition, the material is composed in large part of techniques that are learned more readily through exercises than by listening to lectures. The faculty charged with redesign saw clearly that maintaining or improving quality while controlling costs would require a new learning model—a model that respected individual difference in preparation and learning style while avoiding a proliferation of small class sections.

The Math 1114 project meets these challenges by shifting the basic learning medium from classroom lectures to interactive computer modules, backed up by an array of electronic and human resources. At the same time, the new, student-centered arrangement promotes early development of independent learning skills in a population composed almost entirely of recent high school graduates who are not accustomed to such nontraditional approaches to learning.

The opening of the Math Emporium has made possible the redesign of Math 1114, an early step in a larger transformation project for all large-enrollment mathematics courses at Virginia Tech. Faculty, graduate assistants, and undergraduate peer tutors are on hand approximately 75 hours per week and the lab itself is open 24 hours a day, all week long during the fall and spring semesters. The blend of in-person help and physical and electronic resources provides a wide range of learning opportunities from which students can choose.

The core of the transformed Math 1114 course is a Web-based resource system that includes the following items:

1. Interactive tutorials, programmed in Authorware
2. Computational exercises using MATLAB
3. An electronic hypertextbook, available also in paper copy
4. Practice exercises with video solutions of frequently asked questions
5. Applications
6. Online quizzes, for student self-assessment, tracking of student performance through the semester (for learning diagnostics), and faculty assessment of instructional materials
7. An online testing system with symbolic capabilities, that can be edited by course faculty, that enables students to take randomly generated versions of each test
8. An Oracle database for the system, making detailed student-by-student records of success on quiz and test questions available for analysis

This effort is a first of its kind for a course in this subject area and at this level. The system is designed and programmed by a team of faculty and programmers at Virginia Tech, under the direction of Professor Christopher Beattie. Please see the following URL for more information about the software system: http://www.math.vt.edu/Cyber1114/hometree/.

Rationale

The Math 1114 redesign emerged from a robust institutional and departmental infrastructure and from a mature faculty base. Virginia Tech has a deep and long-standing commitment to use technology to achieve strategic academic goals. The University's Academic Agenda (http://ate.cc.vt.edu/PROVOST/academic_agenda/aca.html) identifies the facilitation of teaching in a distributed learning environment and the integration of technology in research and outreach as well as in teaching to be strategies necessary to implement its strategic directions.

The university intends to improve the learning environment for students in ways that promote both disciplinary competence and the education of the whole person. This commitment is also supported and fully described in the planning document for the college in which the mathematics department resides (*College of Arts and Science Strategies and Tasks for 1997-1999*).

Continuous Faculty Development

The mathematics faculty were better prepared to engage in large-scale course redesign because of Virginia Tech's earlier commitment to faculty development in instructional technology. Since 1993, Virginia Tech has provided ongoing faculty development for the integration of technology into teaching through its Faculty Development Institute (FDI). FDI is a four-year cycling program during which all Virginia Tech faculty have an opportunity to work on instructional projects that incorporate technology. Ninety-six percent of Virginia Tech's faculty have participated in the first four-year cycle. The academic year 1999-2000 marked the second year of the second cycle, and nearly 500 faculty participated in the intensive summer workshops. Ad hoc workshops and conferences run throughout the rest of the year. This intensive program of faculty development was accompanied by an investment in infrastructure (computer labs, technology-

enhanced classrooms, and regularly upgraded computing equipment for faculty), in line with and funded in large part by an internal reallocation process. These initiatives in faculty development and in reallocating resources to other instructional efforts led quickly to broad and diverse innovations in the use of technology to improve courses and promote cost effectiveness.

The university learned several important lessons from its comprehensive development process:

- Despite popular opinion, faculty do not resist the use of technology when given the resources and support to understand it and to use it to improve their teaching.
- Technology can be used effectively to improve teaching in all disciplines and by faculty with varying degrees of technological sophistication.
- Faculty support must be easily accessible, ongoing, and escalated in sophistication as faculty seek new and better approaches to incorporating technology in the classroom.

Mathematics faculty made up one of three pilot groups in the first FDI program in 1993. These leaders and others still contribute an array of curricular innovations. These initiatives continue to stretch the university's imagination about conventional classroom and computer laboratory resources and to expand the possibilities for the future.

Course Transformation

By 1997, it was clear that real course transformation would require new thinking about instructional and computer lab space. The university decided in March of that year to lease new space near campus specifically to accommodate innovative course designs in the mathematics department. Over the next five months, the Math Emporium space was completely renovated, equipped with the latest in electrical and network technology, and opened for classes. The lease, renovation, and anticipated equipment upkeep represents a commitment (over the next 10 years) of approximately $8million in new funds. Other expenses are being met through internal reallocation. The math department's stewardship of the new facility depends on continued progress—to be verified by frequent reviews and ongoing academic assessment—toward fundamental restructuring of courses. The criteria for evaluation include cost-effective improvement in learning and, in particular, radically improved allocation of faculty time.

The overarching goals of a continuous Math Emporium program, together with strategies for advancing these goals, were set forth in a departmental study in the fall of 1999:

Challenge students and assist them to become active learners.

- Create new approaches to teaching and learning that enable students to become more self-directed, active learners.
- Restructure the curriculum to achieve a learner-centered focus.
- Revise course content, where appropriate, to increase relevance to fields of specialization.

Provide multiple ways to accommodate student learning.

- Provide an interactive learning environment using a mix of computer-mediated learning and traditional methods of lecture, seminar, and tutorial sessions.
- Use an open scheduling format to give students maximum access to the emporium learning activities and accommodate different paces of learning.

- Foster a climate of support for active student learning, including spontaneous student-generated collaborations.
- Provide general access to computers and tutorial help to all students enrolled in mathematics courses or needing to refresh or enhance their understanding of mathematical concepts and problem-solving skills.

Provide appropriate and adequate resources.

- Design and implement a well-equipped and flexible teaching and learning facility.
- Demonstrate the effective and efficient use of resources while serving a student population that is increasing in size and diversity.
- Establish a flexible staffing system that responds to the students' technical and mathematical questions.

The report goes on to delineate specific operational steps and a detailed, five-part evaluation plan keyed to the goals and strategies outlined above.

Effective Implementation

In their successful application for a 1999-2001 award in the Pew Grant Program in Course Redesign, Math Emporium faculty fully described objectives, methods (and their connections to the objectives), assessment plans, and cost savings analysis for the Math 1114 redesign program. For more detail, please see the following web sites: http://www.math.vt.edu/temp/emporium_presentation/redesign_grant/index.html and http://www.center.rpi.edu/PewGrant.html.

The Pew Grant proposal process included an itemized comparison of ongoing costs for faculty, teaching assistants, and staff, and of the traditional and redesigned versions of the course. The analysis shows per-student costs decreasing from $77 to $24, exclusive of the transitional costs of converting the course and designing materials.

The course has been in operation since fall of 1997, but design and implementation of this large system was phased in over several years along the following timeline:

- 1996 and 1997: Design and prototype programming of the instructional and quiz software core.
- 1997 to 1999: First classes offered. Quizzes, database, and view-only version of the tutorials in place. Video solutions of selected practice exercises created and distributed. Changes and upgrades made in the software, in response to feedback from students, faculty, and Math Emporium staff.
- 1999, Fall Semester: Online MATLAB-based lab exercises and quizzes in use as part of the weekly assignments.
- 2000, Spring Semester: Fully interactive version of the tutorials ready for class testing. Online midterm tests (multiple choice format) in use.
- 2000, Fall Semester: Interactive tutorials, additional applications, online midterms, and final exams in place. Course in full operation with "final" version of the electronic system. Course materials expanded to accommodate three-credit and sophomore-level versions of the course. Testing system able to handle short-answer and symbolic input.

Impact On Teaching and Learning

The online teaching materials for Math 1114 demonstrate that the learning experience has been changed radically from the traditional lecture-section format. In concrete terms, where a staff of 23 faculty and 15 graduate assistants once handled 38 sections in the fall semester, the current fall semester staff consists of just one faculty member for essentially the same number of students (about 1,500). Math Emporium staff members provide assistance to students in all courses.

In such an environment, the way that faculty spend their time changes. For example, Professor John Rossi calculates his own adjustments in the following way. As a full professor, his responsibilities include research, which takes up 50 percent of his time, and teaching and service, which take up the remaining 50 percent. His teaching load is six credit hours per week and two courses per semester. With this same teaching load, here is how Professor Rossi's teaching activities have changed:

Teaching Activities

Teaching Activities	**1988** No Technology	**1993** Technology Starts	**1998** Emporium
Type of Classes	1Undergraduate	1 Graduate	1 Undergraduate 1600 Students
Direct Student Contact	40%	35%	20%
Indirect Student Contact	5%	10%	25%
Generating Materials	35%	40%	50%
Administration	20%	15%	5%
Change in contact with students:			
Lecturing	25%	18%	12%
Office Hours	20%	15%	5%
Lab Hours	0%	5%	10%
Email	0%	5%	20%
Total	45%	45%	45%
Time spent generating materials:			
Preparing Lectures	25%	25%	10%
Designing Tests	10%	10%	20%
Designing Software and Applications	0%	5%	20%
Total	35%	40%	50%

Breakdown of administrative activities over time:

	1988	1993	1998
Grading	20%	15%	0%
Coordinating With Other Faculty	0%	0%	2%
Overseeing Assistants	0%	0%	1%
Lab Supervision	0%	0%	2%
Total	20%	15%	5%

Professor Rossi sums up the changes in his approach to teaching by affirming that he is still a teacher. In addition, he says that his satisfaction level regarding his teaching has improved and that his students are performing as well or better than before they entered the Math Emporium.

Just as Professor Rossi tabulates his experiences, the Department of Mathematics keeps careful records of student performance. For Math 1114, the tables below indicate that the redesigned course has maintained or improved these results. The numbers are for fall semester, when the enrollment is three times as large as in spring. Fall 1997 was the first semester for the redesigned course and is best regarded as a transition year, since many aspects of the course were changed in light of the experience in that semester.

Year	Course Format	No. of Students	Course Grade	Completion	Retention
1996	Traditional	1589	2.35	98%	69%
1997	Emporium	1580	2.27	97%	68%
1998	Emporium	1585	2.52	98%	76%

In the table above, the Number of Students refers to the number who completed the course and received a grade; Course Grade represents the average, on a scale of 4.0; Completion is the percent of those students entering the course who completed it; and Retention is the percent who completed the course and received a grade of C (2.0) or higher.

Potential For Wider Application

The Pew Grant Program in Course Redesign was announced as "part of an $8.8 million, four-year effort to place the national discussion about the impact that new technologies are having on the nation's campuses in the context of student learning and ways to achieve this learning cost-effectively." The first ten $200,000 awards were intended "to encourage colleges and universities to redesign their instructional approaches using technology to achieve cost savings as well as quality enhancements." As mentioned earlier, Virginia Tech was one of the first ten award recipients for its Math 1114 redesign for use in the Math Emporium; thus, its program might serve as a model for other institutions.

The Web-based system developed for Math 1114 can, of course, be used in a variety of settings, and continuing development will extend the topical range of the course materials. The materials have already been used on a pilot basis for college and advanced high school distance learning courses.

The math department continues to conduct tours at the emporium for dozens of visitors from educational institutions around the world who have expressed interest in adopting the ideas and methods developed here. These range from local public school districts in Virginia to colleges and universities across the U.S., Europe, South America, and Australia. Generally, teams of six or more faculty and administrators from these institutions come to Blacksburg for daylong discussions with developers of Math 1114 and others connected to the Math Emporium project.

The settings in which these visitors aim to duplicate or build upon the emporium experience range from urban to rural. Nevertheless, the espoused aims for other emporium-like efforts often sound strikingly similar to those which the math faculty originally set forth: to assist students in being active learners; to provide multiple ways for students to learn; and to provide resources that are appropriate and adequate to modern learning needs. Indeed, the emphasis remains one of dealing with high demand teaching needs for students of various ages and learning styles who must prepare for productive work in a rapidly changing world. Because the emporium's approach offers a variety of learning opportunities, students have more choices about what best helps them acquire knowledge and skills. Faculty, in turn, have many more teaching options and remain creatively engaged in assisting individual learning.

Author Information

Anne H. Moore is Director of Information Technology Initiatives at Virginia Polytechnic Institute and State University. She chairs Virginia Tech's Center for Innovation in Learning, which awards grants to encourage faculty to integrate technology in strategically targeted curricular areas. She also chairs the Electronic Campus of Virginia, a cooperative of public and private colleges and universities engaged in distance learning.

Dr. Anne H. Moore
Director, Information Technology Initiatives
327 Burrus (0169)
Virginia Tech
Blacksburg, VA 24061
Telephone: 540-231-7108
Fax: 540-231-5843
E-mail: ahmoore@vt.edu