A Multimedia Model for Undergraduate Education

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A B S T R A C T: In the search for greater productivity in undergraduate education, increasing enrollments have typically forced a continuing tradeoff between quality and cost. Large lectures (with 300-500 students) have become standard for introductory courses in many institutions. Educational technology has long been touted as an important tool for increasing productivity. However, its most common applications in undergraduate education (such as videotaped lectures) have been disappointing in terms of the quality of education they provide; and more innovative, computer-based applications have been deemed costly. Educators at Rensselaer Polytechnic Institute have developed a new interactive, multimedia model called the "Studio" that replaces the traditional lecture/recitation/labformat with a single Studio classroom of 48-64 students. Student performance and satisfaction are high, and total cost is lower than in the traditional model 7-be Studio is the core of an ambitious set of interactive, collaborative, multimedia, and distance learning techniques at Rensselaer which are attracting widespread interest among educators nationally and internationally.

The Quest for Quality and Productivity

Since the post-World War II period, when enormous numbers of GIs (and, for the first time, large numbers of women)flooded into the universities, productivity has been an ineluctable factor in the equation that constitutes undergraduate education. What does it cost to deliver a quality education? At small, private institutions, the quality of education could be kept high with low student/faculty ratios enabling direct and frequent contact with excellent teachers-by increasing tuition and/or holding admissions level. But at state universities, this luxury essentially did not exist. At those institutions, the quantity of education delivered-the numbers of students enrolled and degrees granted-increased at the expense of quality. This was particularly true as the "baby boom" passed through in the mid-1960s through the early 1980s.

The primary mechanism by which quantity was increased while holding costs down (i.e., improving productivity) was by expanding the enrollment in introductory courses at the undergraduate level and instituting ever-larger lecture sessions, typically with several hundred students, with smaller recitations and a separate laboratory providing the more interactive and hands on elements in science and engineering. At the graduate level, these problems were not acute, since from the late 1950s on, graduate education was supported largely by the thriving academic research enterprise-and, of course, sheer numbers of students were seldom a serious problem in graduate schools.

By the late 1970s and early 1980s, as the college-age population declined and the cost of operating a university rose dramatically, even the small private institutions found themselves searching for ways to increase educational productivity. Tuitions could rise only so high before the ability of the market to bear them was outstripped. In these elite institutions, too, student/faculty ratios have risen sharply.

In the continuing effort to increase productivity and reduce the costs of delivering undergraduate education, university administrators have grown almost resigned to the prospect that each new cost-cutting or productivity enhancing measure taken would threaten once again the quality of education delivered. Claims to the contrary usually have had the false ring of “voodoo economics”

Educational Technology - The Promise and the Practice

Across the past quarter-century or so, one entire category of productivity enhancement tool has stood out in terms of both the scope of its promise and the consistency with which it has been advanced. Educational technology-now often referred to more broadly as information technology has long been held out as something of a holy grail for academia: the means by which more education could be delivered to more students, at no sacrifice in quality and with no appreciable increase in costs. But upon closer inspection, these claims seldom held up. Continuing education, offered remotely to working adults pursuing specialized graduate degrees, has been a modest success; but it is limited in its educational impact. At the core of the educational technology armamentarium, for undergraduates, has been the televised (either live or videotaped) lecture. Where it has been used, this medium essentially replaced the live professor with a two-dimensional stand-in. But even where the lecturer and the lecture were superior to the live alternative, it has not been a successful technique. Students are even more alienated by such lectures than by the traditional mode. Recitation classes and labs, taught mainly by inexperienced teaching assistants, often speaking English only as a newly acquired second language, do not make up the deficit.

More recently, attempts to make remote live lectures interactive have proven unwieldy and expensive. Computers are typically used mainly for lecture demonstration aids or simulations, microcomputer-based laboratories, and out-of-class problem-solving on spreadsheets and in programming environments. Greater use of electronic mad cannot replace the face-to-face contact with a faculty member. CD-ROMs and software tools, while they greatly facilitate student research and problem-solving, do not substitute for the fun learning environment that all university students experienced 50),ears ago.

The problem with information technology in education has been threefold. First, from an educational standpoint the technologies themselves have been developed and applied in isolation from each other; taken individually and collectively, they have offered neither the power nor the critical mass needed to revolutionize education. Because the technologies were poorly integrated, difficult to use, and unproven in an educational context, most faculty members have been unwilling to invest scarce time and resources in trying them out.

Second, these technologies typically have been applied on top of the existing educational model of lecture/recitation/lab. In fact, if they are as powerful as claimed, they ought to drive fundamental changes in the structure of the educational experience. And third, the cost of the latest computers, displays, software, and communication and networking links has always been prohibitive compared with the status quo of chalk, blackboard, and overhead projector. This fact has made administrators wary of experimenting.

However, this situation has now changed. At long last, the old claims are becoming valid. Information technology has arrived at a point where it is powerful enough, versatile enough, and affordable enough that new configurations of technology can effectively alter the structure of undergraduate education, yielding a high-quality educational experience with maximum productivity, at the same or even modestly lower cost per student. Long after the computer and other information technologies have revolutionized the way science and engineering are carried out, they are finally beginning to revolutionize the way these subjects are taught.

The Rensselaer Model

We believe this revolution is occurring because we have seen it taking place at our own institution, Rensselaer Polytechnic Institute. Rensselaer is a national research university that emphasizes pedagogical innovation to an extent that is rare among research institutions. In recent years in particular, Rensselaer has sustained its strength as a research institution while becoming recognized around the world as a leader in interactive learning.' Indeed, in campus-wide strategic planning, Rensselaer designated interactive learning among its top strategic initiatives.

Since 1993, a visionary group of faculty members at Rensselaer have pursued a series of experiments aimed at re-engineering the learning process interactively for undergraduate students in large introductory courses, using multimedia and computer/information technology. The success of these experiments is already evident and is being further documented as the new model for interactive learning they have developed is distributed across more departments and even into upper-division courses at Rensselaer. This “Rensselaer Model” is winning awards and generating intense interest among educators across the nation.

Organization for Innovation

Major process changes in any large organization usually require the dedicated efforts of a “champion.” The Anderson Center for Innovation in Undergraduate Education (CIUE), under the leadership of Jack Wilson, Dean of Undergraduate

Education, took charge of the re-engineering process. CIUE is a research and development center dedicated to advancing education by infusing it with technology and cognitive science. Long a believer in the potential educational benefits of information technology, Wilson felt strongly that Rensselaer should be applying this technology in the classroom.

The first step was to redesign the classroom format based on the university's goals for students. Only after changing the format were he and his

colleagues able to see how and where the technology would be best used. The philosophy underlying the Center's efforts is that the re-engineering of the educational process itself should drive the technology.

A Committee on Interactive Learning, led by the Dean of Science, was established to coordinate the large-scale re-engineering effort across departments and help raise funding for facilities. The CIUE formed an International Center for Multimedia in Education with the assistance of a $500,000 grant from the AT&T Foundation. A $4,000,000 NSF grant in Mathematics and its Applications Throughout the Curriculum augments other funding within the Center to support curriculum development. In 1990, Rensselaer led a national consortium of universities and their respective professors, faculty, staff, and students in developing the first multimedia-based course for Rensselaer's physics curriculum-the Comprehensive Unified Physics Learning Environment (CUPLE).

In the spring of 1993, the CIUE convened a meeting of national experts on course innovation. They invited six architects who had gained national attention for their innovative designs for educational facilities. Also included were representatives from Perkin Elmer, General Electric, IBM, United Technologies, and Boeing. This diverse group reached a surprising degree of consensus on such points as the need to: reduce the emphasis on the lecture, improve the relationship between the course and the laboratory, scale up the amount of doing while scaling back the passive watching, include team and cooperative learning experiences, and integrate rather than overlay technology into all of the courses-all while reducing costs.

The meeting of experts led to a course design for large introductory courses that was a natural combination and extension of the CUPLE system and that included the use of cooperative group learning techniques. In early 1995, the Faculty Senate approved a top-to-bottom re-engineering process of curriculum reform that is often known as "the 4x4 Program," since the goal is to reorganize the curriculum into 4-credit courses. The student would then typically carry a load of 4 courses of 4 credits each. The Dean of Engineering is leading the 4 X 4 implementation team. This program will force a complete rethinking of the undergraduate curriculum at the upper levels to follow innovations being implemented at the introductory levels.

Of all these initiatives at Rensselaer, the most fundamental and high-profile has been the re-engineering of the large-enrollment freshman courses as interactive “Studio courses.”

Studio Courses at Rensselaer

A typical freshman course at Rensselaer (as at many research universities) ranges in size from 600 to 1000 students. This is true for Calculus, Physics, Chemistry of Materials, Computer Science, and Introduction to Engineering Analysis. In the past, these courses were often taught with two lectures of 300-500 students per lecture, 20-30 recitations of about 30 students per lecture, and 30-40 laboratories with 24 students per laboratory. At Rensselaer, this traditional model has been evolving over the past 5 years toward a rather different new model, the Studio course.

The premise of the Studio courses is that, in all aspects of the course, students learn more by “talking about and doing” than by “listening and watching.” There are fundamental problems with the lecture format. Students may be introduced to a topic in a lecture, but typically two or three days will pass before the student sits down in the lab session to work on the computer-based or hands-on project that has been designed to reinforce the topic. If, after introducing a topic in lecture, the instructor works some examples on the overhead, the students must wait until later to see whether they have actually understood the problem-solving approach and can work similar problems themselves. Cognitive scientists have demonstrated how important it is for students to have personal experience with concepts very soon after first learning about them. The time delay between lecture and problem-solving is well known for its adverse effect on learning.

In the Studio courses, lectures are de-emphasized, books are augmented by interactive multimedia materials, and students enjoy a better classroom climate that can accommodate the diversity of interests, preparation, and learning styles that we see in students today. Lectures are replaced by cooperative learning experiences, mini-lectures, teacher mentoring, and much more hands-on experience. The student assumes a greater responsibility for his or her own learning. Having the right tools is integral to supporting greater student involvement and to developing key learning objectives such as higher-order thinking and problem-solving. In addition to the use of multimedia technology, the students have the resources of the entire networked world at their disposal; and Rensselaer is beginning to deploy collaborative networked desktop video4inked learning environments in which students who are geographically distant can feel as if they are right in the middle of the Studio classroom.

In this new model the professor is just as important (actually more important) as in the old model; the fear that a CD-ROM is going to replace the physics professor is unjustified. (Of course, any professor who can be replaced by a CD-ROM should be replaced by a CD-ROM; but most professors are in no real danger.) The Studio model has the students actively involved in their education, incorporates leadership and team skills, exposes the students to professional-quality computing tools throughout, and is a much more exciting place to teach and learn. This approach to education involves more of the students' senses-including tactile, visual, and auditory senses-through hands-on experiments, still and motion video, music, and narration. Cognitive scientists tell us that people learn differently and the more learning styles we can address, the more effective we are as educators. Specially developed teaching materials are used that reinforce techniques, concepts, and tools used in other, non-Studio courses.

Because time is spent more efficiently, the Studio model replaces the lecture/recitation/Lab model-which normally requires 5 hours per week-with 4 hours of Studio per week. There is just one classroom and not three. Some classes meet for two 2-hour periods, while others meet for three periods of varying length. The same 600-1000 students who were accommodated in the 2 lectures, 20-30 recitations, and 30-40 labs can now be accommodated in 10-20 sections of the Studio classes with 48-64 students, one faculty member, and one graduate student assigned to each studio. Since many of the traditional recitations are taught by faculty at Rensselaer, the Studio model actually reduces the demand on the faculty teaching load.

A typical 2-hour session in Studio Physics, for example, starts with a review of assigned readings and exercises. The class then progresses to an experiment that might involve a motion detector attached to a computer to measure the velocity of a falling golf hall. The session often ends with a "mini-lecture," in which the professor summarizes what the students have learned and assigns homework.

The first Studio courses were deployed in freshman calculus in 199293. Physics followed shortly after that, taught in the CUPLE Physics Studio. Chemistry deployed a series of Studio pilots which will be scaled up for introductory chemistry. Currently there are numerous Studio courses deployed at Rensselaer. In addition to those just mentioned in physics, chemistry, and mathematics, other re-engineered disciplines include computer science, engineering, materials science, biology, humanities/communications, and a joint management and engineering course called the "Design and Manufacturing Learning Environment." (The first course in the Design and Manufacturing Learning Environment is an award-winning case study of the Sony Walkman. The course includes realistic video simulations and requires students to make decisions that affect product design, manufacturing, and profitability.) The Laboratory Introduction to Embedded Control (LITEC) course is an upper-division course with many of the characteristics of the Studio. Since these early efforts, many other upper-level and graduate courses have been taught as Studios.

As of winter/spring 1996, Rensselaer is teaching 1100 students in the reengineered calculus course, 1100 in the physics course, and 700 in the hands-on chemistry course. Another 300 per semester participate in the multimedia engineering lab for sophomores, and 60 upperclassmen take the "Design and Manufacturing" Sony case study course each semester.

The re-engineering of courses led directly to a redesign of the classroom facilities. During 1993, we completely renovated two classrooms for the first offerings of the Studio Calculus, Studio Chemistry, and Studio Physics courses. We have added five more Studios since that time and are in the process of renovating one building and planning the renovation of another to contain more Studios. The classroom layout has been described as “theater in the round.” In the studios, there are 6-ft worktables, each designed for two students, with open workspace and a computer workstation. Often the tables also contain the equipment for the day’s hands-on lab. The tables form three concentric partial ovals with an opening at the front of the room for the teacher’s worktable and a projection screen (see Fig. 1). The workstations are arranged so that when students are working together on an assigned problem, they turn away from the center of the room and focus on their own small-group workspace. The instructor is able to see all workstation screens from the center of the oval, and thereby receives direct feedback on student progress.

When the instructor wants to conduct a discussion or give a mini-lecture, the students turn back toward the center of the room. This removes the distraction of having a functioning workstation directly in front of the student during the discussion or lecture period, yielding a classroom in which multiple foci are possible. Students can work together as teams of two, or two teams may work together to form a small group of four. Discussion and interaction are facilitated by the semicircular arrangement of student chairs. Most students can see one another with a minimum of swiveling of chairs.

This type of classroom is friendly even to those instructors who tend toward the traditional style of classroom in which most of the activities are teacher-centered rather than student-centered. Projection is easily accomplished, and all students have a clear view of both the instructor and any projected materials.

As a facility in which the instructor acts more as a mentor/guide/advisor, the Studio classroom is unequaled. Rather than separating the functions of lecture, recitation, and laboratory, the instructor can move freely from lecture mode into discussion, assign a computer activity, ask the students to discuss their results with their neighbors, or ask them to describe the result to the class. Laboratory is just another classroom activity integrated with other activities. In the Studio model, Rensselaer has created a powerful link between the lecture materials, the problem solving, and the hands-on laboratories. This is a link that is tenuous at best in the traditional course. Research faculty who teach Studio courses report that the Studio approach reminds them far more of an undergraduate research setting than it does of the large enrollment lecture classes.

Initial Results of the Studio Approach

The Studio model represents a classic example of curriculum research and development; as such, the measurement and analysis of outputs is an important element of the work. The metrics for success being employed include student satisfaction, student performance, teaching quality and teacher satisfaction, comparative cost, and awards and other forms of recognition.

Student Satisfaction

The Studio Calculus course was the first of the freshman courses to be conducted and has been through two complete cycles of evaluation. The Physics course is one semester behind. We have seen a tremendous improvement in student satisfaction in the re-engineered courses. Nearly twice as many students agree that they enjoyed the Studio course as compared to the traditional lecture/recitation/lab format. Part of the appeal of the Studio method is obvious: reducing class size from 350 to 50 or 60 greatly increases the opportunity for interaction between instructors and students.

Attendance in the introductory Studio courses shot up to an unprecedented 90%. (Nationwide, attendance in large lectures often drops below 50% at research universities.)

One question on an external survey conducted by the Dean of the Undergraduate School stirred quite a bit of interest in the administration and faculty. When students were asked whether they would cite a particular Studio course (calculus) as “a positive reason to attend Rensselaer,” over 90% of the students agreed! This compares to 63% who agreed with this proposition in other mathematics courses that had been downsized but did not abandon the traditional lecture approach. The traditional introductory courses were in the 40% range. When student responses were controlled for popularity of the teacher and course, there were significant (actually spectacular) gains in students’ satisfaction. This response rate has held up over five straight semesters. That is not to say that every student enjoyed the Studio courses. Some wanted to revert to the traditional approaches, but they were a small minority.

Student Performance

Researchers from Rutgers University came to Rensselaer to study the Studio model using a variety of techniques, including pre and post-testing of subject-area knowledge and skills and an assessment of conceptual development. Students also were interviewed using a protocol developed at the University of Washington.

Students in these courses are performing as well as or better than students in the traditional courses, in spite of the roughly one-third reduction in class contact time. This was demonstrated by student performance on tests matched in difficulty, length, and content to tests from previous years and those given this year in the traditional course. In both mathematics and physics, more topics were covered in the Studio courses than in the lecture courses-and this in 1-hour less class time per week.

Rensselaer researchers also are following the progress of students from the Studio courses as they enter the upper-level courses in physics and engineering to determine how successful these students are in comparison to those from the traditional sections. Preliminary anecdotal results look very good, and are encouraging optimism that the university community as a whole will become convinced of the need to restructure undergraduate education along these lines.

Teaching Quality, Teaching Satisfaction

. Initial results indicate that faculty are rated far higher in teaching evaluations in the Studio courses, but the researchers want to collect data over a longer period of time to validate this finding. Evaluations are a significant issue at institutions like Rensselaer, where student evaluations of a faculty member and success in research play equally major roles in salary, promotion, and tenure decisions. More and more research universities are revamping their criteria to reemphasize the teaching aspects of the professor's role, and this trend is expected to continue and even accelerate in the next few years. Professors say the Studio approach has caused them to think more about their teaching. They are delighted to hear students ask questions that are more thoughtful than those asked in lectures.

It must be acknowledged that not every professor will be as pleased with the Studio format as those who have been involved in its development at Rensselaer. Helping students work through problems on the computer requires more patience and interpersonal skills than does lecturing from the front of the room. Formality can be a barrier.

Others will be concerned that the need to invest time in revamping courses will detract greatly from the time devoted to research and the search for research funding. However, Rensselaer faculty have found that the effort has not been the "time sink" that some feared it would be.

Lower Cost

Discussion of the tradeoff between cost and quality is always controversial in academe. As was noted at the beginning, the traditional approach has been to sacrifice quality to increase productivity and/or decrease costs. The Studio courses were designed from the outset to break this cost/quality linkage. Using the general definition of productivity as the ratio of output results to input resources, the goal was to achieve a significant increase in productivity by increasing the quality of education significantly, while holding costs (including the expenditure of faculty resources) at or below those of alternative models.

A spreadsheet analysis of the total costs demonstrates that the Studio can be quite cost-effective. Several studies conducted by Rensselaer's CIUE suggest that the Studio classes can be offered at a consistently lower cost per student than the traditional introductory courses in math, physics, and chemistry. The reduction in class time produces substantial savings for the large introductory courses-$13,000 in Math 1, $84,500 in Physics 1, and more than $200,000 in Chemistry and Materials, Rensselaer's introductory chemistry course. Most of the savings comes from the reduced demand for teaching assistants, who have been heavily used in recitations and labs, and from decreases in faculty contact-hours (even though face-to-face interactions are improved substantially in the Studio format). The savings on personnel expenses more than offsets the approximately $100,000 cost of creating a Studio classroom, if the costs are spread over 5 years.

The cost issue is controversial because skeptics claim that the real driver of change in undergraduate education is the cost-cutting itself, rather than the attempt to improve instruction. This skepticism is understandable and derives, we believe, from the fact that most attempts to improve educational productivity in recent memory have been explicitly cost-focused in nature. In the case of the Studio approach, however, cost savings are an incidental and certainly welcome-side benefit. It really is a rare example of "having one's cake and eating it, too." At Rensselaer, the money saved in implementing the Studio model is being used to distribute the model more widely across campus.

External Interest and Recognition

The importance of these educational advances is being widely recognized. The Studio classroom and associated interactive curriculum development efforts (including the CUPLE project) have already earned Rensselaer two major national awards. The 1995 Theodore Hesburgh Award for Faculty Development to Enhance Undergraduate Teaching was presented by TLWCREF' at the meeting of the American Council on Education. Secretary of Education Richard Riley presented the award. President Clinton was the featured speaker and presented Rensselaer with a letter of commendation.

Later in 1995, Rensselaer was awarded the first Boeing Outstanding Educator award, out of a field of 43 finalist universities. In both cases, the studio courses in Calculus, Physics, Chemistry, Biology, and Introduction to Engineering Analysis were cited as major contributors to the award decision. A member of the Hesburgh Award judging panel said, "I think the Studio approach is going to transform all those courses that everyone suffered through." Another panelist called the Studio model, ."..both high-tech and high-touch."

The Anderson Center hosts hundreds of visitors annually by educators from colleges and universities around the world who want to see interactive learning in action at Rensselaer. In 1995 alone, visitors came from 40 institutions and 6 countries. Many of the visitors are particularly interested in the Studio classrooms, and some are exporting this model back to their home institutions. For example, California Polytechnic State University at San Luis Obispo is testing a Studio prototype, and the U.S. Air Force Academy has modified its physics curriculum along the lines of Studio/CUPLE.

Rensselaer educators are frequently asked to address other academics about interactive learning and the Studio model. For example, in 1994 and 1995, the Institute for Academic Technology invited Rensselaer to present its experiences in re-engineering the undergraduate curriculum during a series of satellite conferences “attended” by some 350 U.S. and Canadian colleges and universities. Our educators have been invited to address the American Association of Higher Education, EDUCOM, the National Learning Infrastructure Initiative, the American Society for Engineering Education, and other important fora, regarding these developments. The Rensselaer model has been featured in the New York Times, Investors’ Business Daily, and articles in several education-oriented journals. Television projects are under development featuring the interactive education programs at Rensselaer.

Collaborative Learning in Language and Design

Interactive learning promotes learning through interaction with the instructor and hands-on problem-solving. The ability to collaborate with others is also important as both a means and a result of education. Students learn more effectively in a collaborative environment, and employers increasingly look for collaborative skills in their employees.

To give students the opportunity to collaborate, Rensselaer offers an advanced course in “Language and Design”-a joint effort among humanities, science, and engineering faculty. The course is taught in a fully multimedia environment. Students from engineering work together with students from business management to design a product using computer-based simulation software. By working closely with “management types,” engineering students gain practice in communicating their designs and considering more than design factors in their products. The management students gain a better understanding of the technical constraints and process issues in product development.

Students in the course also are exploring the role of multimedia in communicating designs. For instance, one project allows students to communicate with an AT&T manufacturing plant. Design problems with plant equipment can be communicated back and forth via computer multimedia conferencing. There is more involved here than conventional video-conferencing; students can actually send blueprints and interact with the manufacturing plant equipment from computer workstations at Rensselaer. In some cases, they are even able to control plant equipment from a distance.

Future Plans

Distance Learning. Rensselaer is a leader in remote, “distance” learning.

RSVP, the Rensselaer Satellite Video Program, was designated as the best distance learning program in 1993 by the U.S. Distance Learning Association. The design of the Studio courses led Rensselaer naturally into the question of whether a similar experience could be provided to students in a distance learning format. To answer that question, we worked with the NSF Chautauqua program in 1995 to create a "virtual classroom" experience for faculty who came to the University of Pittsburgh and Rensselaer to take a workshop in using distributed learning systems to teach science. We win repeat this experiment in May 1996.

Based on lessons learned in the workshop, Rensselaer educators are now designing Studio courses to be offered over a national network, in collaboration with a major software and a major communications companies. Plans are not yet final, but they call for a first offering of Physics and Calculus within the next year.

LearnLinc

The vision for LearnLinc was launched during a collaborative project between AT&T's Bell Laboratories and Rensselaer's CIUE when they created a prototype for an interactive, distributed multimedia desktop classroom environment. The LearnLinc environment combines the rich communication capabilities of multi-point (from one to many) videoconferencing with real-time application-sharing of computer-generated examples. The level of interaction is very high and the environment offers the possibility of sharing between trainer and students and students with their peers. Shared applications may include instructional applications, text and graphics screens, CAD/CAM, animation, and video and audio clips used to enhance learning and collaboration.

LearnLinc incorporates an authoring tool which enables any content expert to develop a course that integrates live and taped video, the demonstration of any MS-Windows applications, and linkages to other existing courses. These courses will all have consistent user interfaces and do not require programming or networking expertise. The courses, whether or not they are linked to other courses on a local area network, can be integrated into a distance learning session or used on a stand-alone PC at an individual's convenience.

The aim now is to develop a robust, full-featured, integrated system, scalable to hundreds of participants, with a user interface appropriate for commercialization. LearnLinc is being sold by ILINC, a Rensselaer for-profit spinoff. CIUE is now developing plans to offer Rensselaer's Studio Physics and Calculus courses to students at other universities over the network. The tentative start is set for fall 1996.

Evaluation

Under a $507,000 grant from an anonymous donor, Rensselaer is beginning a long-term formal evaluation of the impact of interactive learning on the costs and outcomes of education. A group of 250 students will be surveyed longitudinally over a 5-year period that will include not only the second half of their undergraduate education but also the early years of their careers or graduate studies. The study will be conducted through a variety of evaluations and surveys of students, their teachers, and their eventual employers. Questions to be addressed include:

- How well the 250 students perform in advanced Studio courses, compared with their performance in introductory Studio Courses.
- How well students with experience in Studio courses perform in independent learning environments such as undergraduate research projects and internships, compared with students from more traditional introductory courses.
- How well students compete for and perform in jobs after graduation.
- Student satisfaction with Studio courses, with traditional courses, and with their major fields.
- The costs of Studio courses on two levels: implementation/transition costs and steady-state operating costs.

Rensselaer recognizes that scientifically documented answers to questions like these will be necessary to convince the nation's academic community as a whole that the kinds of interactive and collaborative multimedia learning environments described here are both a feasible and effective way to structure undergraduate education.

Dissemination

In addition to the plans to offer Studio Physics and Calculus courses, other dissemination efforts are being pursued. An introductory Studio Calculus text is being released by Harper Collins College Publishing in 1996, and a corresponding full multimedia interactive hypertext is being developed to allow this course to be offered in other universities. Physics materials were fed into the CUPLE CD-ROM and manual published by the American Institute of Physics for the "Physics Academic Software Program." Other materials found their way into the "M.U.P.P.E.T." manual, which was designed to introduce simple programming into introductory courses in physics.

A New Model for Computing in Education

The next step beyond expansion and dissemination of the Studio and other interactive courses is already being undertaken by the CIUE. It is the development of a new model of computing in university education-a model that is affordable, continuously renewing, and educationally enriching. Most aspects of this program are already in place at Rensselaer: the developers have completed preliminary design and recently began testing.

We refer to the new design as the educational equivalent of the "client/server" model of computing. Here the *student* is the client and enduser computing is performed by the student. The university is the server and is responsible for providing a robust network architecture, high-capacity servers, and a rich array of worthwhile educational applications. This division of roles leads to a computing model in which the students are “fat clients,” or clients with significant local processing capability provided through portable (laptop) computing systems, while the universities are the providers of network access and powerful applications.

In all its educational innovations to date, Rensselaer has put the educational value of the computer/information technologies for the student first, and done so while reducing costs. With the pilot testing of the overall client/server educational model using a laptop, we are moving toward what is perhaps the culmination of the Rensselaer Model, what we term the Client Server University.

Context

Knowledgeable observers of the innovations underway at Rensselaer have concluded that if we are successful in this effort to transition away from the traditional lecture/recitation/laboratory format to new formats based on interactive and collaborative learning approaches such as the Studio, we will have succeeded in re-inventing the university. The success of our pilots, combined with the enormous interest being shown by educators around the world as we move toward wider deployment of the model, suggests that we are already well on our way toward that achievement.

Our students have told us that nothing that can be done will have a greater effect on undergraduate education. The ability to offer effective, high-quality education at lower cost, while improving the satisfaction of students and teachers alike, represents a breakthrough. It appears that technology, for the first time being applied effectively to increase the productivity of education, may at last be living up to its long-vaunted promise.

R. Byron Pipes, the17th president of Rensselaer Polytechnic Institute, is a pioneer in revitalizing undergraduate education, a leader in creating new partnerships for university research, and an international expert in the field of advanced composite materials. His 24-year career in higher education has been marked by many honors in research and teaching, including membership in the National Academy of Engineering and the Swedish Royal Academy of Engineering Sciences. As president, Pipes has led the revitalization of Rensselaer’s historic campus and encouraged the celebration of its rich history as the nation’s first engineering school. His leadership in creating an enhanced learning environment for undergraduates has been recognized by the university’s receipt of the prestigious Theodore M Hesburgb Award and the Boeing Outstanding Educator Award. Before becoming president of Rensselaer in 1993, Pipes served as Provost and Academic Vice President of the University of Delaware, where he earlier served as Robert L. Spencer Professor of Engineering, dean of the College of Engineering, and co-founder and director of Delaware’s

Center for Composite Materials. Dr. Pipes earned a bachelor's degree from Louisiana Polytechnic Institute, a master's degree from Princeton University, and a doctorate from the University of Texas.

Dr. Jack M. Wilson is Acting Provost and Dean of Undergraduate and Continuing Education at Rensselaer Polytechnic Institute. He came to Rensselaer in 1990 as the founding director of the Anderson Center for Innovation in Undergraduate Education (CIUE). From 1984 to 1990 be was Professor of Physics at the University of Maryland, where he also served as the Co-Director of the Maryland University Project in Pbysics and Education Technology (M. UP.P.E. T.). Dr. Wilson served as chair of the Department of Physics at Sam Houston State University. His Pb.D. in Physics was obtained in 1972 from Kent State University. Dr. Wilson has directed over 30 education and research projects funded by NSF, IBM, AT&T, Annenberg/CPB, Exxon Educational Foundation, and others. His recent work in restructuring undergraduate physics education was recognized by the 1995 Theodore Hesburgh Award from TIA-CREF and the 1995 National Boeing Outstanding Educator Award. His experience spans 27years in the American Association of Physics Teachers and the American Physical Society, serving on many committees and task forces. He was awarded the Distinguished Service Citation of AAPT in 1995.

Notes

1. Interactive learning is an emerging educational paradigm that changes the emphasis from what teachers teach to what students learn. interactive classes place less emphasis on teachers and lectures and more emphasis on students working in teams to discover knowledge on their own.

2. Teachers Insurance and Annuity Association-College Retirement Equities Fund.

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