Using Technology to Support Pedagogy in an OR/MS Course

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We tried several methods to improve pedagogy in a graduate introductory OR/MS course. We developed digital video instruction modules, animations, computer-based tutorials, and a course Web site and used Web-based feedback, virtual classrooms, and collaborative learning methods to support students' learning. We learned that the course Web site, Web-based feedback, virtual classrooms, and some collaborative learning methods are easy to develop and implement and provide immediate returns. Others, such as digital video instructions, animations, and real-time collaborative computing, need more time but may provide better pedagogic benefits in the long run. The benefits from all the efforts accumulate over time. Individual instructors will have to decide whether the potential benefits provide enough payback, depending upon the reward structure of their institutions.
(*OR/MS education. Educational systems.*)

The use of computer technology in teaching has developed over the last two decades and has created a highly flexible learning environment for students (Laurillard 1993). Computer-based multimedia, the World Wide Web, course Web pages, discussion groups, bulletin boards, and the distance education model have changed teaching in all disciplines and at all levels (Brown and Neilson 1996, McCollum 1997, McGowan and Sendall 1997, Chrisman and Harvey 1998, Lewis 1998, Veldenz and Dennis 1998, Paulisse and Polik 1999, Seal and Przasnyski 2001). Schools and universities all over the world continually explore ways to use technology to improve teaching.

We used various instructional technologies to develop animation, computer-based tutorials, Web-based learning, and video-based instruction to support our teaching of an introductory operations research and management science (OR/MS) course at the MBA level. These pedagogic supports illustrate and explain course elements to help students visualize difficult and abstract concepts.

Literature Review

In recent years, many have written about pedagogy of OR/MS courses. Some have discussed content (Mingers 1991), while others have looked at the process of teaching and the process of learning OR/MS (Scott 1990, Liebman 1994, Powell 1995, Belton and Scott 1998, Grossman 2001). Belton and Scott (1998) describe their experience in incorporating the independent learning (IL) style in an undergraduate management science course and list the success factors. Scott and Buchanan (1992) propose an approach to learning OR that centers on the goals of the individual students. They believe that such an approach encourages independent learning. Belton and Scott (1998) show that independent learners are likely to develop into reflective and effective practitioners of OR.

Recent advances in information and communications technology have made integrated applications of audio, video, and data, or multimedia that support interactive and independent learning affordable and popular. Researchers find that multimedia

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support both levels of Kolb's (1984) experiential learning model (Jensen and Sandlin 1992, Jategaonkar and Babu 1995, Owsten 1997, Erwin and Rieppi 1999, Landry and Francisco 2000). Smith (1997) showed that multimedia creates a favorable environment for active learning. Many large companies regularly use multimedia in training managers (Gagne 1996).

Callahan et al. (2000) discuss a multimedia-based system called LIPS (learning, information, and performance support) that is used by over 400 government agencies and over 100 private sector companies in 12 countries. Belton et al. (1997) discuss MENTOR, a computer-based multimedia teaching tool for OR/MS. Since its introduction, MENTOR has been used by educators with varying degrees of success (Daellenbach and Petty 2000, Simpson and Edwards 2000). They note that instructors must adjust their teaching styles to use MENTOR effectively, and the software is not yet Web enabled.

Spreadsheets are another tool that helps educators to teach OR/MS courses, especially to business students. Since Bodily (1986) suggested using spreadsheets for modeling OR/MS problems, educators have used spreadsheets for teaching undergraduate and graduate introductory OR/MS courses (Przasnyski 1989, Winston 1996, Eppen et al. 1998, Powell 1998, Ragsdale 2001). Although Gass et al. (2000) argue against using spreadsheets in OR/MS courses, there are benefits in using spreadsheets to teach an OR/MS course. Spreadsheets help instructors to involve students actively in modeling OR/MS problems. Powell (1995) has identified the main steps in teaching successful modeling to students in OR/MS courses and showed (Powell 1997) that MBA students learn OR/MS concepts better when they are active modelers.

We looked into ways of using technology, including multimedia, to improve pedagogy in OR/MS courses, and the time and effort to be invested to make them successful.

Background

Loyola Marymount University (LMU) is a private Jesuit university that offers bachelor's and master's degrees in various disciplines and emphasizes teaching excellence. The College of Business Administration (CBA) consists of four departments: Accounting, Finance and Computer Information Systems, Management, and Marketing and Business Law. In the CBA building, all classrooms are equipped with computers and projection facilities and some classrooms have computers, with Internet connections, on every desk. These facilities have helped many CBA faculty members to enthusiastically adopt modern technology to teach and to interact with students.

We used MBAA 607, "Operations analysis and decision support systems," as our test course. It is an MBA core course taught every semester in the CBA. It covers developing and using quantitative OR/MS models of business operations to support business decisions. We teach the course in a classroom in which each student has a laptop with live Internet access. Students use Excel as the primary modeling tool, supplemented with add-ins such as Crystal Ball and Treeplan. The course is very hands-on. We focus on applications to illustrate the use of OR/MS for decision making. We use many in-class hands-on examples and assign complex projects based on case studies and real-life problems. We create and maintain a course Web site primarily to disseminate information. Students get all their hands-on exercises, readings, problem sets, study guides, and lecture notes from the course Web site. We also provide links to other Web sites and answers to frequently asked questions (FAQs). Recently, we extended the function of the course Web site to include student feedback and group discussions.

Students find the course interesting and challenging. Graduate students can see uses for the tools and techniques in their jobs. Students feel that they benefit from the support of the instructional technology that we provide for the course.

Motivation and Plan

We started our project in the fall of 1999 with a teaching grant of $6,000 from the university, and we completed it by the end of the fall of 2000. The grant provided a stipend but no released time from our regular teaching and research loads. We used the summer semester to develop the animation and video modules. We developed other techniques during the semester, while teaching the course.

Methods Used

Videos Explaining Concepts and Problem Solutions

We created short videos of instructors explaining difficult concepts or solving homework problems as an extension of the classroom. Students can watch these videos multiple times to suit their own schedules and paces of learning.

Shooting the actual videos and the subsequent digitizing and editing were interesting. Being new to video production, we started by shooting a video in a classroom and quickly realized that the lighting was too poor to capture a good-quality image using a home video recorder. Also, our initial footage was long and very tedious to watch. We solved the lighting problem by shooting in the faculty lounge, which had ample natural light. We used the notice board as the blackboard and wrote on large sheets of white self-adhesive paper. Our first few attempts also taught us the necessity of storyboarding the entire video and scripting each scene in detail to keep the segments coherent, manageable, and logically connected. We found storyboarding and scripting fun and instructive. It forced us to identify the essential concepts we wanted to teach. We used Adobe Premier to digitize and edit the video segments. Initially, it took a long time to learn the use of Adobe Premier, but eventually the editing and the production, while time consuming, went without much difficulty. For a 10-minute video, we spent a day storyboarding and scripting, a day shooting the video, two days learning to use Adobe Premier, and a day digitizing and editing the video.

Digitized movies created in this way result in files that are too large to distribute through the Web. To reduce the file size, one can reduce the audio quality, reduce the size of the display window, and decrease the number of frames per second in the final video. These result in lower-quality videos, but smaller files. These options are available with most video-editing software. Alternative approaches would be to stream the videos (which would require a streaming server) or to distribute the videos on CD or DVD.

The students' feedback was positive. However, the large size of the files, the amateur quality of the videos, and difficulties we faced in producing CDs or DVDs made this technique unattractive.

Based on our experience, we would suggest the following:

—Collaborate with someone experienced in storyboarding and scripting, perhaps a faculty member of a film school or communications department.

—Shoot videos in a bright sunny room. Adjust the lighting if necessary to avoid shadows. Speak more slowly and loudly than usual.

—If possible, get some expert help with the software—at least an introduction to the main ideas in video editing.

Screen-Capture Movies for Software Demonstrations and Tutorials

We find that in our OR/MS class, we often waste class time re-explaining how Excel or other software tools work instead of concentrating on OR/MS topics. Screen-capture software can help with this problem because it allows one to record all the screen activities in a digital movie format and thus easily illustrate software use. Students can review the resulting movie to learn the commands and mechanics of the software.

We used Matchware Screencorder, which is inexpensive and easy to learn. It captures the activities on the screen in a video file. The resulting movie can be viewed using the media player included in Windows operating systems. The movie files were an instant hit with the students. The software can also record voice input, but that increases the file size. The movie files are large in size and are impractical to distribute through the Internet without compression. By compressing the original movie files with a standard program such as WINZIP, we could make the file size small enough to distribute through the Internet. The software can also convert the movie into animated graphics files that can be published on the Web. On a fast computer with a fast connection to the Internet, however, the animated graphics run very fast and students may miss parts of the demonstration. Animation software, such as Adobe After Effects or Macromedia Fireworks can be used to control the display rate, but that necessitates additional editing.

Animations Explaining Course Concepts

With animations, instructors can show the inner mechanics of difficult concepts. We considered three software products for creating animations: Macromedia Fireworks, Macromedia Director, and Macromedia Flash. First, we built an animated graphics prototype in Macromedia Fireworks, but found it unsatisfactory. We wanted more complex animations and wanted the users to interact with the animation. Both Director and Flash can be used to make sophisticated animated movies. We chose Flash because it can create powerful animation with small files suitable for distribution through the Web.

We chose different topics to illustrate various concepts. First, we tried creating an animation about the internal calculations of the SUMPRODUCT function in Excel. Others consisted of animated graphics explaining the working of the various Crystal Ball toolbar buttons and a visual-queuing animation showing the mechanics of a queuing system. The animations had on-screen controls for the users, consisting of back, forward, pause, and play buttons.

Even though we both knew programming, learning Flash to create animations was not easy because we had limited skills in visualization and graphics manipulations. Learning to manage graphics over a time line, and understanding the concepts, conventions, and language of the software took us three days. We also learned that animations need storyboarding and scripting just as videos do. These activities were time consuming but essential, as they forced us to understand all the pedagogical elements of the concept we were trying to explain. In spite of our difficulties, we believe that Flash is an excellent animation tool for developing explanatory materials.

Students responded positively to this effort, although not to the extent we expected. Because of our limited skills with Flash, we used simple examples, and the students probably did not find animated demonstrations of simple concepts valuable. We did not have the time or skills to realize our more exciting ideas.

Course Web Sites and Course-Management Systems

The Internet has become an integral part of education today. Course Web sites have become excellent vehicles for disseminating information and managing content. Bhargava and Krishnan (2001) provide an excellent discourse on using the Web for teaching OR/MS. We have been using the Web to teach our courses since 1995.

It did not take long to learn the basics of creating Web pages, but it did take time to develop and organize the content. Working incrementally, we transformed all our course materials to Web format over two to three semesters. The time taken may vary depending on the amount of material available in electronic form at the outset.

Course Web sites must be maintained for them to be of value to the students. For an active course Web site, the instructor must devote time to maintenance activities such as posting announcements, updating course materials, and organizing and posting responses to FAQs. Students quickly learn to depend on the Web for getting course materials and information. Therefore, delayed updates discourage and frustrate them. Initially, these maintenance activities can be time consuming, especially if they are combined with creating new materials and converting existing materials to Web format. However, these efforts pay off over time since much of the electronic material can be reused with only incremental updates.

Web sites provide an excellent repository for all course activities and material, including course notes, models to be used in class, responses to FAQs, and course announcements. Students who live off campus especially appreciate this service because they can easily get to class-related materials from anywhere. The sites can also be effective in teaching if the classroom has PCs or laptops with Internet access.

When creating materials in electronic format, it is important to standardize on widely available application software. For example, we used Microsoft Office on PCs for developing most of our course materials, assuming that students would have compatible software and hardware. Occasionally, that assumption did not hold, and we had to make adjustments for other systems on a case-by-case basis. A final benefit of comprehensive course Web sites is the possibility of using them for distance learning.

One problem in relying on the Web in classroom teaching is the potential disruptions from unreliable or poorly supported technology. However, it is possible to prepare for outages with some planning. We have, for example, trained our students to download needed files prior to class, and we always carry an up-to-date copy of the course Web site to class on zip disks to run locally.

Although course Web sites are becoming ubiquitous, and learning the basics of creating and publishing Web sites is easy, it can be challenging for some instructors and may prevent them from integrating the Web into their teaching. Course-management systems such as Blackboard and WebCT can help in these situations. They provide intuitive interfaces and help instructors to create and maintain course Web sites easily. In addition, these systems provide attractive tools for creating and managing groups, recording grades, and operating virtual classrooms.

The weakness of course-management systems, ironically, lies in their strength. The tools and the interface are rigid and standardized to make the systems easy and user-friendly for beginners. This can be a barrier for someone with existing course Web sites. The rigidity does not facilitate adapting existing course Web sites to course-management systems because users must follow the systems' built-in structure for organizing materials. We, for example, found it frustrating that, unlike FTP programs, the systems did not permit the transfer of multiple files, and we had to upload files individually. We still wanted to use the communications tools available in Blackboard and therefore maintained a hybrid structure between our own course Web sites and Blackboard. We hope that, in the future, course-management systems will provide advanced users with customization ability. Blackboard and WebCT are also costly to install and maintain, although cost was not an issue for us because the university purchased the system.

Community or Group Web Sites

Community or group Web sites such as ecircles.com and eproject.com facilitate students' collaborative learning through virtual discussions, exchange of files, and mutual mentoring. Such sites can help students to collaborate by forming virtual groups. Using these sites is easy. We chose ecircles.com as the community site for the course. The communications, dissemination, and group-management features of the site, although limited, were equivalent to those in course-management systems for holding virtual classes. Course-management systems such as Blackboard have extra course-related functionalities that are typically absent from community or group Web sites. For example, Blackboard supports group interactions through group sites, discussion boards, virtual classrooms, and archiving facilities for the virtual classrooms. We used ecircles.com as a fallback communication medium when Blackboard's virtual-classroom software failed. One problem is that such services may not be stable. For example, the ecircles.com site, a victim of the dot-com bust, no longer exists.

Student-Led Electronic Discussions

We hoped that electronic discussions would allow good students to help and teach others. The discussions would reinforce what all students learned in the classroom and extend the learning beyond the classroom.

Such systems as Blackboard make setting up the technology easy, and students need minimal training in using the systems. When we first set up our electronic forum, which took about an hour, we did not get much discussion on posted topics or questions. Students initially did not see its value. However, as the course progressed, students warmed up to the idea. In a recent semester, many students' questions about projects and examinations were answered by other students, with the faculty members serving as moderators. These electronic forums were also excellent sources for generating FAQs.

These are our suggestions for running a successful electronic forum:

—Direct students repeatedly to the discussion boards for answers to their questions instead of responding to e-mailed questions.

—Encourage students to try to answer each other's questions, assuring them that the instructor watches and moderates the discussions.

—Monitor discussions constantly to prevent the propagation of incorrect ideas and to discover what ideas require further explanations. In the long term, the discussions can form an archive for use in examinations and projects.

—Motivate students by making participation count towards their grades and rethink the design of course modules to provide them with incentives to participate.

Electronic Mail

Electronic mail (e-mail) is easy and is available to everyone in academia. It is a powerful tool for supporting students' learning. In practice, we find that many questions students ask in e-mail messages can be readily converted to FAQs for the course Web sites. In addition, e-mail allows students and instructors to exchange files for problem detection and discussions.

However, e-mail is so ubiquitous that students who are not active learners may shoot off e-mail messages at the slightest difficulty without thinking deeply about problems. Although FAQs on the course Web site partially address this issue, some questions require carefully worded responses to explain the necessity of thinking ideas through. It is also important to manage students' expectations regarding e-mail since many students expect immediate responses to e-mailed queries 24 hours a day, seven days a week.

Web-Based Feedback

We used forms via the Web to obtain instant feedback as we finished each course topic. Traditional evaluations at the end of a course provide feedback when it is too late to make adjustments for the students providing the feedback.

It takes five to ten hours to create the forms and collate e-mail responses, or about an hour if one uses a Web-based form service such as forms.flashbase.com, which performs the administrative aspects of the task (Seal and Przasnyski 2001). Web-based forms provide immediate feedback that allows instructors to adjust the course to address students concerns. The feedback can also be used to promote interaction among students. For the long term, instructors can store the feedback in an electronic repository, facilitating quick access for future reference.

We had to think about where to set up the feedback points in the course and determine the content and style of the forms. We were concerned that long forms and too many feedback points would be ineffective because the students would treat them as a valueless exercise. Further, obtaining feedback too often would have been disruptive because collecting feedback took some class time. Too many feedback points would also increase the instructor's workload because the instructor must respond promptly for the process to be effective. For each course topic, we limited the content of the form to three questions related to the concepts, and to two to three questions about the appropriateness of the content and delivery style. We had a total of six feedback points during the semester.

We offer the following suggestions for administering Web-based feedback:

—Keep the content of the forms simple and consistent so that students become familiar with the structure and can fill the forms out quickly. We found that over time students' questions and concerns became very focused. They helped us to identify weak points in the course quickly and take corrective actions.

—Introduce forms at the end of each topic. For us, this was about every two weeks, giving us enough time to respond properly to students' concerns.

—Use a classroom in which each student has a computer with Web access, and obtain feedback in class immediately after finishing a topic. Students seldom volunteer feedback on their own even if the forms are available on the Web.

—Be cautious about using a Web-based form service, such as forms.flashbase.com. The longevity and control of such services may be a problem. For example, forms.flashbase.com is no longer available. Using e-mail as the response vehicle takes care of such problems, but adds to the processing time for parsing and tabulating responses and does not permit anonymous responses. Ideally, universities should have form creation and maintenance integrated with a database running on university Web servers and overseen by a knowledgeable Webmaster.

Synchronous Course Support: Virtual Office Hours

We used virtual office hours to extend our availability to students. We ran several question-and-answer sessions during our virtual office hours in which we addressed each student's concerns individually, with other students being present in the session.

Conducting virtual office hours requires preparation. All students must enroll in the Web site that provides the tools for conducting the virtual office hours (for example, Blackboard). We had to teach the students to access and use the technology, which took one hour. Setting up the virtual office hours was easy, but conducting the sessions required extensive preparation and organization of the course materials and took about three hours. This preparation is necessary because of the nature of the OR/MS subject matter. Students mainly asked questions about specific homework problems and class exercises. We had to have all course materials, including problem solutions, available electronically so that we could post them on the course Web site or to the virtual window immediately because delay in responses would have disenchanted the students. During the sessions, we had to carry out multiple tasks at the same time: searching for example files, typing and posting responses to students' questions, and uploading files to the course Web site.

The technology used for virtual office hours is still fairly new and presents some difficulties. We had problems with connectivity, speed, and reliability. In particular, the delays from slow-speed access using dial-up modems made some of the question-and-answer sessions unnatural. In addition, currently only HTML files can be displayed in the virtual window, and that without active links. There are no viewers; therefore, reviewing any non-HTML files, such as Excel spreadsheets, is not feasible. We used e-mail and the course Web site for exchanging files during the virtual office hours to work around this problem. A few times, we used conference calls to add voice communication with small groups of students working on group projects. This improved communication, provided for more interactions, and removed the delay caused by typing questions and answers. However, adding voice is not feasible for large groups of students because voice quality degrades as the number of participants increases.

Nevertheless, we believe that the virtual office-hour session is very useful for discussing ideas and alternatives. Students participated enthusiastically in our virtual sessions, especially on weekends before the examinations to get crucial support on projects and examination materials. In formal feedback, students often mentioned the effectiveness of the virtual sessions as they learned from the questions of others, even if they did not ask questions themselves. It follows that we as instructors did not have to answer the same questions over and over again as we would by e-mail or in traditional office hours. Since Blackboard automatically archived all the virtual sessions, we used them to write FAQs and course updates and made them available to students not present in the sessions. This archiving facility, incidentally, is not available in the free version of Blackboard offered on the company Web site. It is available only on purchased versions of Blackboard. Another benefit of virtual office hours is that remote tutors, guests, and other faculty members can join the sessions and share the office-hours load (although their teaching styles may vary) as long as they have Internet connections. Overall, we felt that we were providing better value to the students without inconveniencing ourselves too much.

Special Course-Support Technology: Real-Time Collaborative Computing

Collaborative computing is particularly applicable to OR/MS, where instructors create, manipulate, and demonstrate models. With this approach, students can access and manipulate files on the instructor's computer and on each other's computers in real time. Coupled with the capability for exchanging files, collaborative computing can be a powerful tool for remote teaching.

We used a shareware package called Virtual Network Computing (VNC) available from the AT&T research lab (http://www.att.research.uk.com/vnc/). The software creates the collaborative sessions over the Internet using a client-server model. The software is easy to learn. Students need an Internet connection and can download and install the client component of VNC on their computers in a few minutes. Instructors need about an hour to install and learn the server component of the software, and another three hours or so to get their materials ready, as they would for the virtual office-hour sessions. VNC combined with a conference call for voice support in a virtual session provided facilities that were far superior to those in the virtual classroom in Blackboard.

However, the technology for collaborative computing is new and not without problems. It is not suitable for supporting groups of more than four to five students. File sharing gets chaotic and the voice quality on the telephone lines degrades as the number of participants grows. Web-casting or distance-learning technology may be more suitable for supporting larger numbers of users. VNC is disturbingly slow when remote users are connected to the Internet through dial-up modems rather than broadband connections. The bottleneck is the amount of information sent from the instructor's computer to students' computers for each screen refresh. It is therefore important to keep scrolling, and Windows features with colors and graphics, to a minimum. As more students connect via broadband, speed should become less of an issue.

Security is a concern in collaborative computing. Organizational security measures such as firewalls and proxy servers may prohibit access to collaborative computing sessions. Information theft is another concern. Because the software allows remote users to access and manipulate files on the instructor's computer, the instructor should dedicate a separate computer to these sessions and install only course materials on it. Although instructors can control who has access and the type of access during sessions, they should avoid keeping sensitive information on the computer used. The technology also has the potential for misuse. For example, in online examinations where Web access is permitted, students using VNC or similar software can cheat by viewing and manipulating files on other students' computers. We accept that traditional teaching methods also have scope for cheating, especially for take-home examinations and group projects, but today's technological tools can make misuse easier. We did not encounter any misuse, but it is prudent to build in safeguards.

Technology and OR/MS Instructors

As we familiarized ourselves with the various technological tools for teaching, we wondered if it made sense for us as OR/MS professors to learn about video production, multimedia, storyboarding, scripting, and various computer techniques when we could have called on professionals from those areas to do the work. The reasons for not doing so are these:

—Professionals from outside OR/MS might have produced inappropriate products or required us to devote inordinate amounts of time to explaining concepts and reviewing the final work. They can also be very expensive.

—Off-the-shelf materials would lack the flexibility needed to support individual teaching styles.

—Because OR/MS uses computers and technology, integrating the technology into the instruction seems natural.

We found that exploring the various methods enhanced our understanding of the teaching process. Using technology to set up the course modules was analogous to using spreadsheet modeling in OR/MS. We gained insight into teaching OR/MS just as users of spreadsheets gain insight by developing the models themselves. We think that the experience can be very helpful to any instructors seeking to improve their teaching because

—It forces them to think critically about teaching and delivery,

—It forces them to settle on the main learning objectives of each topic,

—It forces them to break down complex concepts into small, manageable components,

—It makes them prepare and think through lectures in detail,

—It can lead them to rethink and redefine teaching paradigms, and

—It is a good prelude to distance teaching.

Integrating technology to improve course support can lead to reengineering opportunities and continuous improvement. For example, transferring course materials to a Web site is straightforward. However, adapting the materials to take the maximum advantage of the medium may lead to developing new materials and approaches, and new methods of assessment.

OR/MS instructors also gain by actively managing the level of integration of technology into their teaching. With incremental changes, instructors have time to learn and assimilate the technology at a comfortable pace into their courses. The cost also grows incrementally and instructors avoid becoming targets of the administration who might want instant results from a large investment in technology.

Impact on Student Learning

We think our efforts have had positive results. Students wrote spontaneous comments on the traditional end-of-semester course evaluations and gave us positive feedback on our own survey instruments. We cannot be sure of the effect of our efforts, however, without formal statistical studies. Such studies would be challenging because learning is difficult to measure. They could also present an ethical challenge. To evaluate the effects of technology on learning, one would need control groups who would be deprived of that technology. Would it be realistic or feasible, for example, to prohibit the use of e-mail or access to the Web?

We wonder whether students learn more or better, not just more easily, by using these technologies. Some of the approaches we implemented proved more useful than we expected, while others did not provide the impact we anticipated on student learning. In some instances, we may have been so busy developing the materials that we did not integrate them into the course effectively and left the students to use them on their own. They may have used them only sporadically, without achieving the results we intended. To our surprise, modules that took little effort to develop, such as screen-capture movies and Web-based feedback, had a lot of impact, while others that took more time and energy, such as videos and animations, had less impact on students' learning. Still others, such as collaborative computing, hold promise, especially for OR/MS modeling applications, but the technology is not yet mature. Our more successful modules certainly facilitated learning. Did students learn more? Probably not, because we did not broaden the course depth or scope. We feel, however, that there are definite benefits in developing and using these technologies to enhance learning.

The benefits of some of the approaches we used and how well we achieved the course objectives depend on the nature of the course materials. The structured nature of OR/MS plays a key role. The rigorous, straightforward content seemed appropriate for out-of-class delivery by various media. For example, in our OR/MS course, students must use software, and thus the screen-capture movies proved valuable. Similarly, FAQs clearly reduced the number of times we had to respond to identical questions during office hours and via e-mail. Technologies also helped many students (who come from diverse backgrounds and thus find the mathematical nature of the OR/MS course difficult) to overcome their deficiencies on their own and get up to speed without holding up the class. The structured nature of OR/MS, however, did not help to inspire electronic discussions; students simply wanted to learn the correct approach or answer.

Ready access to all the technological support for a course presents a disadvantage. It may discourage some students from participating actively in classes and from thinking through the concepts or issues. The instructor should release support modules periodically so that students think on their own, yet get help when needed. Finally, instructors should focus on the teaching objectives and avoid getting lost in software and hardware issues.

Payback or Benefits to Instructors

Another point worth discussing is the payback of the effort to integrate technological tools in the teaching process. Landry and Francisco (2000) surveyed faculty members and students about the use of multimedia. They found that students and instructors differed regarding classroom use of multimedia. The faculty members gave two principal reasons for not incorporating multimedia in the classroom: "There is no value to multimedia where tenure and promotion are concerned" and "it is not worth the effort." While we understand this sentiment, we also feel that the rewards go beyond those implied by these two reasons. The time and the effort to be invested in using technology in teaching can seem overwhelming, but new tools help instructors to provide pedagogic benefits with reasonable investments of effort and to obtain a lot of professional satisfaction. Use of technology can also improve teaching, which should be reflected in improved course evaluations.

How use of technology in teaching affects tenure and promotion decisions at a university depends on the university reward structure. If teaching is an important component of these decisions, then such efforts will be valued. On the other hand, if the university priority is research, developing these kinds of teaching-support materials may not be worth the effort in terms of payback. Technology benefits students, but it adds an extra layer of administration for instructors on top of the original development effort. For example, students generally expect course Web sites and find them useful. However, to be valuable to students, the Web site must be dynamic, which implies overhead and administrative costs to be borne by the faculty member maintaining the site by posting new FAQs, updates, and responses to students' queries. Instructors must decide individually whether the potential benefits provide enough incentive.

We found that working with another faculty member can reduce the cost factor. Without two of us working on this project, we would not have completed 50 percent of what we accomplished. We had to learn many procedures on our own and some took a lot of time to master. We would have benefited from the help of a professional, which would have allowed us to concentrate on course-related concepts and realize a faster payback.

Strategy for Integrating Technology into OR/MS Courses

Based on our experience, we suggest a strategy for those who want to integrate technology into OR/MS courses. We categorize the technologies into two tiers, largely based on the amount of learning required. The second-tier technologies take longer to learn than the first tier.

The three first-tier technologies that can be incorporated easily as a part of an overall teaching strategy are course Web sites, screen-capture movies, and Web-based feedback. First, start by creating a course Web site, preferably using a course-management tool, such as Blackboard or WebCT, and convert existing materials to a Web format. Update the course site regularly, perhaps after each class, with a summary of the main concepts covered, example problems, and useful links and readings. You thus create an active site and provide incentives for the students to check the site regularly. E-mail reminders with the link to the course site, sent to all students through Blackboard, can also be helpful in increasing visits to the site. Once the course site is fully functional for disseminating course materials, the instructor can introduce interactivity through discussion boards, virtual office hours, and collaborative computing.

The screen-capture movies for demonstrating software provide immediate returns for little cost and effort. They are easy to create, can be recorded during lecture presentations, and then made available to students for reinforcement and self-paced learning.

Course feedback is particularly desirable when the instructor is teaching a new course or experimenting with new approaches, so Web-based feedback seems natural in this context. Depending upon the instructor's Web expertise, the institution's information-technology support for processing forms, and the instructor's workload, this feedback can be either a first- or second-tier strategy. Obtaining course feedback and providing timely responses to students based on the feedback can be time consuming for the instructor. Instructors starting their careers, or new to technology, may want to spread the workload related to the feedback over several semesters, especially for courses offered repeatedly.

Second-tier technologies, such as movies and animations explaining course concepts, can be extremely valuable, especially if the instructor can build a library of such modules. However, creating them is not easy. Enlisting the help or guidance of film and animation instructors or professionals is advisable. Instructors also should choose illustrative examples carefully, specifically with a view to creating a product with a reasonable shelf life that would justify the effort and costs expended.

Real-time collaborative computing using such tools as Virtual Network Computing or Netmeeting is promising, but its time has not come because broadband connections are not yet ubiquitous.

Conclusions

We believe that using technology has tremendous potential for improving teaching even though it takes time and effort to do it well. Some technologies, such as course Web sites, screen-capture movies, and Web-based feedback, are easy to implement and provide immediate returns. Others, such as movies and animations, and real-time collaborative computing, require more time but may provide better pedagogic benefits in the long run. The benefits from all the efforts accumulate over time. For example, libraries of course materials developed by various instructors could be made available through the Internet. Students could benefit by viewing materials created by instructors other than their own.

However, academic institutions should provide reliable, stable, and accountable information-technology infrastructure and support for these kinds of efforts. Ideally, institutions should have dedicated and knowledgeable departments or groups to support instructional technology. It is frustrating and embarrassing when the technology fails in class and one has to return to the old way of teaching after spending time and energy changing the entire teaching paradigm. Students generally are impatient with such failures and are very vocal in their frustration. Murphy's Law and selective memories seem to ensure that in their course evaluations they dwell on the one disaster rather than several successful demonstrations, and that can be dispiriting for the instructor.

A useful extrapolation of these efforts is a peer-to-peer model enabling sharing or exchange of teaching materials via the Web. OR/MS instructors would build materials suitable for their courses and their styles of teaching and, as part of the OR/MS peer-to-peer community, would make those materials available to others. This would benefit faculty and students alike. Critics may warn against poor-quality products being made available, but no one is obligated to use any of the items. The shared materials could become an electronic cafeteria of worldwide dimensions. The Massachusetts Institute of Technology, for example, has already made all of its class materials freely available on the Web [http://Web.mit.edu/newsoffice/nr/2001/ocw.html], starting a movement towards universal knowledge sharing. We hope the OR/MS community follows this lead and takes a step towards a new and improved teaching paradigm.

Appendix
Technical Information About the Methods Used

1. Videos explaining concepts or problem solutions.

Resources required:	Video camera, video-editing software, video capture card, high-end workstation with CD-RW.
Equipment and brands used (with cost estimates):	Home video camera ($400), video capture card ($125), Adobe Premier ($125), Videowave II (free), Dell Dimension, 500 MHz with 33 GB hard disk and 384 MB RAM ($3000, at the time of purchase).
Total cost:	$3,650
Learning time:	• Video camera operation: insignificant. • Recording process (storyboarding, lighting etc.): two days. • Computer editing: two days for learning the basics of Adobe Premier and one day for digitization and editing.

2. Screen-capture movies for software demonstrations and tutorials.

Resources required:	Screen-capturing software.
Equipment and brands used (with cost estimates):	Matchware Screencorder ($39) at http://www.matchware.net.
Total cost:	$39
Learning time:	Insignificant (less than half hour).
Comment:	The same company has a multimedia authoring tool ($49 for the regular version, $399 for professional) that includes Screencorder and allows a lot more for multimedia creation.

3. *Animations explaining course concepts.*

Resources required:	Animation software.
Equipment and brands used (with cost estimates):	Macromedia Flash ($90—educational price).
Total cost:	$90
Learning time:	Three days to learn basics of Flash (even with programming experience) and at least one day for a simple animation development.

4. Course Web sites and course-management systems.

Resources required:	A computer to serve as a Web host, Web server software, Web page creation and editing tools, FTP software, document creation software, or course-management software and associated server.
Equipment and brands used (with cost estimates):	University Web server (free to faculty), Front Page or Dreamweaver ($125—educational price), WS-FTP version LE (free educational download), and Microsoft Office Suite (free to faculty—provided by the university), Blackboard (provided by the university).
Total cost:	$125; however, our university provides course-management software and the server.
Learning time:	• About half a day if one is using course-management software such as Blackboard or WebCT. • About one day to learn the Web-page-creating software (e.g., DreamWeaver or FrontPage) and half a day to organize and set up the Web site. • Initial site creation takes about half a day. However, a fully functioning site takes about two to three semesters of evolution.

5. Community or group Web sites.

Resources required:	Administered group Web site or community sites, Web access.
Equipment and brands used (with cost estimates):	ecircles.com.
Total cost:	Free.
Learning time:	Insignificant (less than half hour).

6. Student-led electronic discussions.

Resources required:	Bulletin board, posting capabilities on Web sites.
Equipment and brands used (with cost estimates):	Blackboard discussions board—university purchased Blackboard 5 from Blackboard.com and installed on a dedicated server. Alternatively, one can access Blackboard free through the Web.
Total cost:	None.
Learning time:	One hour.

7. Electronic mail.

Resources required:	e-mail support.
Equipment and brands used (with cost estimates):	Eudora Client (free—university supported).
Total cost:	None.
Learning time:	None; it is assumed that everybody is familiar with e-mail.

8. Web-based feedback.

Resources required:	Form creation software, e-mail support, server-side database, and support for Web-based data collection, storage, and management.
Equipment and brands used (with cost estimates):	FrontPage or Dreamweaver ($125—educational price); Eudora Client (free—university supported); Flashbase Web site (free at forms.flashbase.com).
Total cost:	$125
Learning time:	• One hour, if using a service such as forms.flashbase.com. • Five to ten hours, if developed from scratch using Web page creation software.

9. Synchronous course support: virtual office hours.

Resources required:	Chat facility, Internet access.
Equipment and brands used (with cost estimates):	Blackboard virtual class chat—university purchased Blackboard 5 from Blackboard.com and installed on a dedicated server. Alternatively, one can access Blackboard free through the Web although with limited capabilities.
Total cost:	No extra cost to the individual.
Learning time:	• One to two hours to learn the tools and the setup. • To be effective, the instructor requires extensive organization, spending one to three hours to have all course materials ready electronically before the session, especially for OR/MS courses.

10. Special course-support technology: real-time collaborative computing.

Resources required:	Network computing software.
Equipment and brands used (with cost estimates):	VNC from AT&T (free download). Alternatively use Netmeeting from Microsoft (free download) or PCAnywhere ($79).
Total cost:	Free.
Learning time:	• One hour to learn the tools and the setup. • To be effective, the instructor requires extensive organization, spending about three hours to have all course materials ready electronically before the session.

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