Optimizing Engineering Materials Laboratory Time with Technology

By

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Abstract

The background of engineering students has changed over the years, resulting in new challenges in teaching hands-on laboratories. Engineering design involves visualization. This visualization spans the spectrum from understanding how pieces of a structure fit together to having a first hand knowledge of how material deforms, flows or fractures under different loads. Engineering laboratories provide critical hands-on experiences that build visualization skills at the same time that material or structure behaviors are demonstrated. But engineering laboratory time is limited because of credit reductions in the curriculum and cost cut backs. Engineering laboratories are expensive from the machines needed to conduct the experiments to the staff time needed to train and support the activity. Historically, students often came to engineering from farm or other backgrounds where they developed skills working with their hands. Today these backgrounds are less common and it is proposed that it takes considerable more time to prepare students to conduct laboratory experiments than it did in earlier years. To address this problem in a civil engineering materials course, we developed nine on-line tutorials and two on-line demonstrations. These tutorials consisted of media clips that provided step-by-step instructions on how to conduct specific laboratory exercises and what to look for during the laboratory session. An on-line learning assessment quiz was conducted before students were allowed access to actually conduct the laboratory experiment. We tried different delivery options for the tutorials including CD distribution and on-line access through a streaming server. In this paper, we describe the construction of these tutorials and their impact. Construction required development of detailed scripts followed by digital video recording and editing. Assessments have revealed a 20 to 25 percent reduction in lab time needed to complete experiments and teaching assistant training has been expedited.

Introduction

Engineering design involves visualization. This visualization requires understanding how pieces of structures or machines fit together and how they will function when exposed to loads. Engineering laboratories provide critical hands-on experiences that build visualization skills at the same time that material or structure behaviors are demonstrated. But engineering laboratory time is limited partly because of credit reductions in the curriculum and cost restrictions. Engineering laboratories are expensive from the machines needed to conduct the experiments to the staff time needed to train and support the activity. The project reported here is focused toward optimizing the use of laboratory time.

Historically, students came to the university with a strong set of hands-on skills already in place. These skills were often developed from farm work that involved working with machines or structures. In other cases, it was common for an engineering student to have taken apart or rebuilt a car during high school. The educational process in engineering laboratories was a natural extension of these backgrounds. Students often came into the laboratory with more advanced skills in working with their hands - a key experience for building visualization skills. Life on a farm or taking apart of an old car often provided experiences that lent relevance to engineering laboratory topics. For example a rotating shaft on a piece of farm machinery provided a practical application to concepts in torsion.

We propose that today these backgrounds are less common and these critical visualization and hands-on skill sets less developed. This is unproven at this point but we are contemplating different approaches to prove or disprove this premise. Engineering laboratory exercises involve the use of complex equipment and detailed procedures to observe material behavior. Without advanced preparation, students are simply unprepared for the experience, which by necessity is a fast-paced, one-time only opportunity. Students who are not used to working with their hands may become intimidated and encumbered with the details of test procedures that they easily lose sight of the primary importance of their laboratory work, or simple mistakes are made, leading to useless laboratory results and frustration. Some students come to the laboratory preoccupied and distracted by various personal or academic pressures. For some students the laboratory time may not be an optimum learning time. Laboratory education today is often throttled by the inability to enlighten large numbers of students on the educational possibilities available in the laboratory and provide the training essential to safely realize these capabilities.

With this background, our objectives were:

- better prepare students for in-lab activities (optimize student learning time in the laboratory),
- deliver rote portions of laboratory instruction in a more efficient manner in less time and
- redirect teacher (faculty, teaching assistants and staff) to student instructional time toward discussion and more advanced concepts.

These objectives were pursued in the context of a required three credit materials course for civil engineering undergraduates with an enrollment of approximately 90. The course format consisted of two 50-minute lectures and one 2-hour laboratory each week. The teaching assistants each worked with a laboratory section of approximately 14 students. These students were expected to conduct hands-on experiments and prepare laboratory reports. This course is intended to develop competence in fundamentals of behavior of construction materials including concretes of various types, metals, wood, and plastics to learn the details of standardized laboratory and field measurement techniques used to evaluate construction materials performance, to practice and improve technical/professional skills such as report writing and teamwork.

Note that our objectives were neither to transport the entire course to an on-line format nor to replace the hands-on laboratory experience. As described above, we propose that the engineering education and the development of visualization skills would suffer without the hands-on interactive capabilities that occur in a physical laboratory setting. While some aspects of training can easily be conveyed using video and other forms of media, in general, we believe the most effective educational process requires a mix of delivery formats with direct teacher to student interaction.

Methodology

The methodology directed toward these objectives is outlined with three key steps:

1. identification of what we wanted to convey and how to convey it,
2. creation of media clips,
3. creating a web-based delivery system and incorporating it into the existing course.

Enhancing laboratory education required consideration of the types of material and learning that occurred in the laboratory and sorting that information according to type and current educational delivery process. The first step was to separate the rote aspects of the laboratory experience from the more creative aspects of instruction that are often truncated because laboratory instructors run out of lab time and the logistics of training students to simply complete the laboratory exercise in a reasonable manner are too time consuming. This realization highlighted two important points, the first is that any laboratory exercise involves conveying procedures and introducing students to equipment for conducting the laboratory that are routine, and second, that students often are not adequately prepared prior to the laboratory on these procedures and equipment. The unprepared students slow the progression of the entire class and demand individualized instructor time.

Laboratory procedures were identified as the component of the course that could be readily segregated for media enhanced delivery. Media clips were developed to illustrate and demonstrate laboratory procedure. These procedures will eventually be linked to video clips showing the practical significance of the laboratory procedures. It was decided that the detail inherent in the laboratory exercises warranted video recording rather than a series of still shots or other depictions. The videos were then offered on-line such that students could revisit the web site and view the procedures of the up coming laboratory as often as needed. They could pick the time 24 hours per day when they wanted to learn the procedures. The ability to deliver media to the students under a variety of conditions created a series of trade-offs that will be discussed in more detail later.

Video Production

Creation of the laboratory videos required a team consisting of faculty and teaching assistants, an instructional media designer, a media producer, a web developer and the film crew. A rough draft videotape of the actual laboratory session was gathered to provide a working draft for the team to consider.

Using the rough draft video, the first draft of the script was developed by the producer. Working with the lab notes provided to students and the reference tapes for the labs, she developed content outlines and then extended narration into full scripts. The audio portion of these scripts provided the backbone of the videos.

Once completed this first draft was distributed to the two faculty working on the project. for review and editing. The faculty identified key concepts that needed emphasis and provided other revisions. The reviewed scripts were then returned to the producer for rewriting. In addition, the producer began to fill in the video, noting images needed to match pieces of the narration. These were then returned to the faculty for final review. When final approval was received, the videotaping was scheduled. With adequate preplanning, video was gathered in one attempt. Reshooting was minimized and used only in extreme situations.

Experienced teaching assistants (TAs) were assigned the lead roles for the shoots. They received advanced copies of the scripts. The producer would scout the location of the lab and walk through the procedure with the TA. Then she would write a shooting script, in which she would identify the shots needed to match the audio in the script. The TAs would prepare any necessary samples, pre-test materials, equipment setups or other arrangements in the lab. To spread out the workload, the TAs split the labs according to expertise. Only one TA attended the videotaping per lab.

The labs as a group were not done in order, using the equipment and lab rooms when they were available. Each individual lab was shot in chronological order to the extent possible. On average, each lab took about 3 hours to shoot. The taping crew consisted of the producer, TA (sometimes the faculty member), videographer (who also lit the shots) and sometimes a lab technician for special technical assistance.

After the videotaping was completed for each lab, the producer would review the footage and recheck it against the narration. If there were questions about the usability or accuracy of a shot, the faculty would review the raw footage to see if it was accurate or fit the video's intent.

If there were any changes or additions necessitated by the shooting, that needed to be made to the narration after the lab, they would be made. The narration was then recorded. For financial and efficiency reasons, non-professional voices were used. Project members with good, clear and resonant voices filled this role.

The producer would then edit a rough cut of the video, with both audio and video tracks. Some graphics would be inserted. The video was then compressed into a QuickTime movie and put on CD for review by the faculty. The faculty would either sign off on the rough cut or make changes. The producer would incorporate these changes. She would then edit a fine cut with full graphics, making final technical adjustments.

Eleven two-hour laboratory sessions were enhanced with on-line video of laboratory procedures. As a first step, the focus was primarily on conveying procedures following this methodology.

Web Development

Parallel to the video production was the design and programming work for the web site as a delivery vehicle to the students. The University of Wisconsin-Madison (UW-Madison) uses WebCT as its educational management interface. For reasons of economy and future site maintenance and revision, the decision was made to use in-house personnel to develop the website. However, we were also able to tap the talents of personnel in the Department of Information Technology for assistance in matching our goals and objectives for the web site with the course management tools and web design software supported by the university. The same was true for server issues and use of the computer labs on campus. One difficulty was wading through the different departments to find the correct person to solve a problem or answer a question

WebCT provided a standard interface for course content but we combined this interface with html pages of our own content and structure. The videos were conveyed with streaming server maintained at the university level.

The website was to be used not only as a delivery interface for the video but as an overall course site. Students would visit the site for the syllabus, information on assignments and reading, data collection for homework, videos for labs, quizzes, grades, etc. The design was developed primarily among the faculty and the Web developer. Gate keeping quizzes were developed that required students to complete before attending the laboratory session. These quizzes were graded and students could only receive credit when the quiz was completed prior to attending the lab session. Students were allowed to take the quiz up to 4 times. A more stringent requirement of not allowing students access to the laboratory until the quiz was successfully completed was debated amongst the project team but was not adopted.

Integrating the videos into the web site required balancing the pedagogical mission of the course with the logistical and technical requirements of the College of Engineering and the UW-Madison. The goal of the web site was to provide flexibility to students while offering a range of information and course management tools. Students could navigate through the website both in chronological order of course coverage and by subject matter.

The beta version product consisted of a web-site that was tested during the spring of 2002. The data intensity of the video-media could not be satisfactorily compressed to offer modem access and thus recommendations to students were to use the website on-campus only. To further address the needs of students using computers off campus, a compact disk was produced and distributed. Students still were required to login on-line to complete quizzes and to access other information.

Outcomes and Discussion

Establishing an easily managed strategy to measure the outcomes and impact of the course change was the most difficult aspect of the project. We debated splitting the class, with half making use of the media enhanced laboratories and the other half following the traditional format. This option was eliminated for several reasons including the cost of running the course in two formats, the inability to tailor lectures to take advantage of the on-line developments, and the difficulty in fairly and statistically splitting the class to measure performance.

Measuring performance outcomes is critical to course enhancement. It is important to be able to document for university administration, students and yourselves the real impact of course enhancements. There are few who naively believe that simply adding technology to a course will automatically improve it. Technology enhancements can be an expensive investment and clear identifiable improvements must be measured to justify these costs. A vague notion of improved learning alone is rarely a sufficient justification for technology enhancements. In our case we were looking for specific efficiencies in staff time, in teaching assistant (and staff) training and, then and only then, in improved learning.

Performance outcomes assessed for the beta-version of the media enhanced course consisted of TA feedback (including feedback from TA's whom had taught the course with and without the media enhancements), student surveys and faculty observations. We are contemplating new assessment techniques for the next course offering.

Teaching Assistant Preparation

An anticipated outcome was that the on-line laboratory videos provided an efficient means to train and prepare the teaching assistants. The course content covers a broad range of materials topics and it is unreasonable to expect that graduate students will be experts in all of them. The on-line materials provided a common basis of procedures for not only the students but the instructional staff as well. The contents of the videos were reviewed by faculty and industry professionals for accuracy and can be readily updated in the future.

Reduction in Laboratory Time

The teaching assistants reported a 20 to 25 percent reduction in the time required by students to complete the assigned laboratory experiments. Whether to simply reduce the laboratory time or to reinvest that time in discussion of results is being considered. In any case, one of our primary objectives on time efficiency was accomplished.

Response of Student Survey

The enhancement of a laboratory course with media does not immediately translate into improved student satisfaction and higher student evaluations. The introduction of the on-line laboratory preparation materials enforced with a gate keeping quiz required students to prepare for the laboratory. Granted student preparation for a laboratory session is not a novel concept. Although reading preparation was required in the past, in fact many students did not take the time to prepare. This observation comes as no surprise to most laboratory instructors. The introduction of the on-line materials to a student body that was aware of the course format prior to these enhancements was met with some resistance by a portion of the students.

A segment of the student population was very pragmatic concerning investment of their time. Our survey revealed that 40% of the students indicated that they would not have visited the laboratory web site had there not been gate keeping quizzes. They were generally intolerant of technology failures such as system crashes, computer lock-up, etc. As a result of limitations in use of the website off-campus and occasional on-line failures, the class was equally split as to whether the videos should only be delivered on-line only or whether the videos should also be provided on a CD. A majority of the class (56%) said their opinion and use of the web site would improve if they could complete the laboratory with a 20% reduction in laboratory time. In answering this question, they did not realize that they had already achieved a 20% reduction in laboratory time.

Yet, 70% of the class considered the on-line materials as "very effective" in preparing them for the laboratory and 97% felt the videos provided a "clear illustration" of the laboratory procedures. It appeared that the on-line developments were viewed as bitter medicine but most students acknowledged they were better prepared at the expense of an out of class time investment.

Other Lessons Learned

Good templates for combining traditional and media enhanced instructional delivery in laboratory courses do not exist. Similar efforts in other science fields such as chemistry were helpful in guiding our efforts but did not offer a template for achieving our objectives. As a result we learned as we progressed on how to more effectively make these course changes. Here are some of the other lessons learned in developing these course enhancements.

- Balance big plans with small measurable steps. Because of limitations of time and resource availability, it is difficult to transform a course all in a single semester or in one step. Your final goal may be quite grand, but divide the work into discrete and manageable steps to accomplish it. Develop a plan for accomplishing each and all of those steps over several semesters.
- Tie goals and objectives to evaluations. When you're developing your goals and objectives, determine up front how you will be measuring and evaluating your progress.
- Know your project. Try to determine as much as you can what material you'll need; how the material will be integrated in the course; who will use the material; how the users will access and use the material; how often it will need to be updated, etc
- Set out clear timelines and deadlines. Construct a realistic strategy for accomplishing your goals. All team members should know the process and how and when it will move forward.
- Stay on track. The project team should meet altogether on a regular basis.

If possible, include a project manager in your budget. Be committed to completing the small steps and the long term goals. Plan for the time limitations of faculty, who are teaching courses and conducting research with little time left for course reconstruction.

- Use the team approach. Use all the staff talent and personnel your institution has available. Check within your college or school, your department and any IT department available. Talk to other people on campus about their projects. Play to people's strengths in building a team. Use staff people rather than grad students for some team practices, since it keeps the knowledge within the institution and builds a skill and knowledge base.
- Allow enough time to test <u>everything.</u> There will be many pieces to fit together in most projects. Allow enough time to test how the pieces work individually and together. Then test again.
- Assume everything will take 3 times as long as you estimated. There is no clear pattern or practice that fits all projects. New technology means changing application on a frequent basis. A strong plan and clear goal and strategy will help immensely in keeping the project moving forward.

Summary and Conclusion

Today's technology offers new options for learning and delivering course instruction. Adoption of this technology need not be an all or nothing proposition. We have proposed new efficiencies in teaching and more effective learning can occur together by adopting a blend of delivery methods. We believe hands-on laboratory instruction provides a critical learning experience to students' development of visualization skills that cannot be learned as effectively through a video monitor. Yet engineering laboratories are a significant university expense and most effective utilization of those laboratories can be gained using technology and a mix of delivery options.

Through enhancement of a civil engineering materials course with on-line video of laboratory procedures, we have achieved a 20% reduction in the in-lab time needed for students to complete experiments. We created a series of modules that greatly improve the ease of training teaching assistants and we have provided the students to an ability to learn and review laboratory procedures at their own pace and their own timing. We have created the opportunity to raise the level of learning in the same amount of in-class time. The on-line materials were rated as "very effective" by 70% of the class in preparing them for the laboratory and 97% felt the videos provided a "clear illustration" of the laboratory procedures.

Course modification is an evolutionary process that involves some trial and error. Do not expect to effectively transform a course from one delivery and teaching style to another in one shot. Do not expect all or even the majority of students to immediately embrace what ever changes you have foisted upon them. Carefully identify your objectives for changing course delivery, structure your methodology around those objectives and carefully document the outcome of your changes.