Overcoming Barriers to Deliver a Quality Hands-on Mechanics of Materials Laboratory Course at a Distance

David G. Alexander, Ronald E. Smelser
University of Idaho

Abstract

Traditionally, hands on skills have been taught in a laboratory environment where students work in groups to investigate scientific principles. This learning environment is rich in discussion and participation that can actively engage the student in his or her learning. Simulating this laboratory environment has been one of the biggest obstacles for distance education programs. The goal of this research was to develop a hands-on Mechanics of Materials Laboratory course for distance education. The resulting course was taught entirely over the Internet using computer-simulated experiments, online remote control software, email, and discussion groups with a focus on creating a student-centered learning environment. Students also conducted hands-on experiments using small scale testing equipment and participated in an on-campus activity in which larger more sophisticated testing equipment was used. The students' understanding of the material and hands-on skills were as good as and in some areas better than traditional on-campus students. This research indicates that a distance laboratory course that incorporates multi-media computer experiments with hands-on exercises is as effective in teaching engineering laboratory skills as the traditional on-campus laboratory course.

I. Introduction

Through a State Board of Education grant, the Mechanical Engineering Department at the University has begun to develop a series of distance education courses[1]. These courses are unique in that they are adapted from traditional hands-on laboratory courses taught in Mechanics of Materials and Controls and Instrumentation. The first phase of the distance education program was to develop a pilot course in mechanics of materials and offer it to on-campus students. A new distance course was recently designed and offered to seven students during the 1998 fall semester.

The course is a one semester two-credit introduction to mechanics of materials in which students are exposed to fundamental theory through hands-on laboratory experimentation and observation. The traditional on-campus course includes six or seven laboratories in which each focuses on a topic in mechanics of materials. The course is designed to develop skill in instrumentation, data acquisition and analysis and proper laboratory record keeping and documentation. There is also an emphasis placed upon group communication and interaction throughout the course with the goal of developing good teamwork skills.

One of the most significant problems in developing the new distance courses was how to adequately deliver the hands-on portion of the class. A computer cannot simulate every aspect of a hands-on course. To overcome this, the laboratory activities were divided in to three types, a distance part or Distance-Lab, a take-home part or Lab-Kit, and an on-campus part or Lab-Camp.

Not all laboratories were composed of all three types of activities. A detailed description of the activities is included in the next section.

Another major obstacle in delivering the new distance course was how to effectively teach using the Internet. In the distance education model, a shift is made in the way a course is taught. This occurs as a result of the asynchronous nature of delivering the course content and the way in which students and instructors communicate. This shift is of particular interest in educational research. It motivates the need to alter the way in which courses are taught. This change in pedagogy is the shift from a lecture-centered environment to a student-centered one. The classroom becomes an arena for investigation conducted by the student. Many educational programs have been redesigning curriculum to better make this shift[2,3,4,5,6,7]. In the new model the instructor becomes facilitator guiding the student towards self-discovery[8].

Many schools currently use the Internet to deliver course material. However, it is important to use the technology appropriately. Research indicates that using methods that combined computer, video and instructor support provided significantly higher learner performance with 1/3 the instructor time, in comparison to traditional methods with classroom delivery[2]. The task then becomes to effectively integrate the technology with the content and appropriate teaching techniques to provide an engaging, constructive learning environment. This will enable students to not only become proficient with the course content but also develop in areas such as communications, problem solving, and analysis.

By addressing all of the above issues, a new distance course was successfully designed, developed, and offered to students in the Mechanical Engineering Department at the University. The new distance course engages the student through online group discussions, real equipment experimentation, and computer simulations. Using this varied structure, the new distance course takes advantage of the best aspects of each teaching tool. As a result, the distance student is no longer limited to taking only pure lecture courses from a university. The distance student becomes a contributor, participator, and life-long learner in this distance education model.

II. The New Distance Classroom

Each laboratory may have one or more of the following components a Distance-Lab, Lab-Kit, and Lab-Camp. The Distance-Lab is composed of computer or Internet related exercises. The Lab-Kit consists of small transportable experiments that the students receive through the mail. The Lab-Camp is a traditional hands-on component in which students perform some of the more complicated experiments at the University or educational center while under direct supervision. Because each laboratory is different, some experiments are performed entirely over the Internet, while others have major hands-on components. Table 1 identifies each laboratory and details the corresponding components.

The Distance-Lab components involve either a computer simulation or an online instrumentation exercise. Simulations were developed using Working Model® software. Working Model is engineering software that simulates dynamic events. A simulated tensile test experiment was used courtesy of the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado at Boulder. The online instrumentation laboratory involved remotely controlling a viscometer in Idaho Falls and downloading real-time data.

Table 1. Components of the Distance Laboratory

Laboratory	Distance-Lab	Lab-Kit	Lab-Camp
Archery	Working Model Module – Energy balance	N/A	Bow and Arrow
Measurements	Equipment Procedures	Gage blocks, precision dowels, bead canister and hand size data	N/A
Axial Loading	Online tensile test simulation and data acquisition[1]	Rubber band axial loading experiment	Manual tensile test
Rheometer	Online instrumentation and data acquisition	N/A	N/A
Beam Deflection and Material Properties	Working Model Module – Simply supported beam deflection	Large and small deflection beam experiments	Simply supported beam deflection experiment
Pressure Vessels and Strain Gages	N/A	Rubber ball pressure vessel experiment	Strain gage and pressure vessel experiment

[1] Provided courtesy of the Integrated Teaching and Learning Laboratory, University of Colorado, Boulder.

The Lab-Kits are compact experiments designed to develop hands-on training and laboratory skills as well as demonstrate engineering principles. They are easily transportable and relatively simple to operate. The Lab-Kits provide an opportunity for students to develop preliminary understanding of the engineering prior to performing advanced experimentation and analysis. The Lab-Kits also provide the necessary hands-on skills development for the beginning mechanical engineering student. Examples of Lab-Kit exercises include a rubber band and scale for tensile tests, measuring instruments and gage blocks, small cantilever beams for measuring deflection, and a rubber ball and pump for pressure tests.

The Lab-Camp activities consist of experiments that are either too large or fragile to transport safely. These exercises include a hand operated tensile test frame, a bow and arrow stand, a beam deflection experiment and a strain gage mounting exercise.

A World Wide Web page was developed for the course. It is the starting point and communication link for all course activities. The syllabus, schedule, course description, and course goals are all available from the homepage. The homepage also houses the HTML discussion groups that were developed for each laboratory exercise. Each laboratory is contained on one Web page. All the background material and information is available from these pages.

The information is in three major components, an Activity Plan, a Notes page, and a Procedures page.

The Activity Plan was designed to outline the laboratory exercise and identify the skills that would be developed as well as the measures by which the student would be assessed. All the course assignments, termed Tasks, are located on the Activity Plan. This enabled the students to go to one location to find all that was required of them for each laboratory exercise.

The Notes page was designed to give students the necessary background information in order to perform the experiments and understand the engineering principles involved. These pages were designed to take the place of the information an on-campus student would have received during a course lecture. All necessary equations were included. Some of this material was copied into the students' laboratory notebook.

The Procedures page included instructions for each laboratory experiment. This page was a guide for completing the laboratory exercises. Sufficient detail was included to enable the students to perform the experiments by themselves. Included in the Procedures page are tables for collecting and organizing the experimental data.

A discussion page was designed for the distance course. The page is an HTML list in which students post and reply to messages. It serves as the communications hub for much of the course activities. The goal of the discussion group was to foster group discussions and help students to feel more connected to the course and each other. Most laboratories included an assignment in which students were to post a question, comment or discovery to the discussion group. Often the students were also required to reply to a posted message as part of the assignment. Using the discussion group to communicate as a class is relatively new to most students, therefore it was necessary to design assignments that included interacting online. Some of the assignments were aimed at developing engineering understanding while other assignments were designed to stimulate conversation and discussions.

Most class announcements were made using an email distribution list. This ensured everyone got the same information and no one was left out. Many answers to questions that were submitted individually were sent using the distribution list in order to inform the entire class all at once. The distribution list was effective in reaching every student easily and quickly.

III. Course Assessment

Overall, there was strong student support for the distance laboratory. There were numerous positive comments regarding the organization of the laboratory activities. The students also appreciated it when the instructor was in close contact with them either through using the discussion group or email. These two issues drew the most comments. It was important for the students to have their learning materials organized and to have their instructor readily available for help.

The students were satisfied with the organization of the course. The material available to the students was regarded as being well organized and presented. Maintaining the same format throughout the labs helped students feel comfortable with what was expected of them. They knew where to begin each laboratory, at the Activity Plan.

There were repeated comments concerning the use of the discussion group. Most of the comments encouraged its use. However, many students felt it was an under used resource. Some students suggested having more assignments and activities involving the discussion group. Others felt the discussion group needed to be better monitored to enhance student participation. No one felt that it was an ineffective tool.

The Working Model® software was regarded as a useful learning tool. There were some comments about needing to have more instructional material for using the software. It was seen as a good visualization tool and was instructive as a preliminary exercise for the engineering concepts covered in the laboratory. One student felt that the Working Model® Module for the Archery Laboratory was not very well connected to the rest of the activities.

Most students thought the Lab-Kit activities were helpful to introduce the concepts. Many liked experimenting with the rubber band and scale since it was an easy way to investigate axial loading. There is nothing mysterious about a rubber band and scale. There were several comments about how difficult it was to take measurements because of the elongation of the rubber during the loading. Since the rubber stretched, so did the scribed lines on the rubber making an accurate reading of the strain difficult. This is an excellent representation of some of the problems associated with laboratory experimentation. The rubber band exercise is simple enough to show that sometimes experimentation may be much more difficult to implement than one originally considered.

The students responded positively when questions were answered quickly through email or on the discussion group and negatively when there was a lag in the response time. It was important to them to feel as though the instructor was watching for their questions and responding quickly and appropriately. There were comments that not enough students were participating and involving themselves in the online discussions.

The most successful aspects of this course are the way it is structured and the fact that it uses a variety of tools to teach the engineering concepts. Each laboratory began with a simple assignment. The assignments were either a computer-simulated exercise or an experiment using a Lab-Kit. The non-threatening interactive presentation of the engineering concepts allowed the student to build the necessary knowledge base to then tackle the more complicated situation. The atmosphere was non-threatening because the preliminary exercises were performed at a location selected entirely by the student. Allowing the student this flexibility gave rise to greater risk taking and time to experiment than is ordinarily available in a traditional laboratory classroom. Using computer simulations, small experiments, and online demonstrations engaged the students in their own learning process.

IV. Students' Performance

Overall the students were comparable to the two previous semesters in which I have been involved in instructing portions of the course. Because the students for the distance class were volunteers and there was no control group available, there were no statistical methods use to compare the students performance. Also, I was the only one evaluating the students in the distance laboratory whereas in the previous semesters I was responsible for only a portion of the students' overall grade. Another significant difference is that the students who participated in the distance course were actually on-campus students. They did not need to rely on communicating only through the discussion group and email. They could communicate directly with their peers. This is significantly different than what will happen with off-campus students.

The distance students were more independent during the Lab-Camp when compared to the traditional on-campus students during regular in-class laboratories. The Lab-Camp was set up in stations for students to work in small groups and complete each component. Since the students were exposed to similar equipment earlier in the semester and were given the opportunity to explore on their own time, they showed more self-confidence and skill with operating the measuring devices and testing equipment. Also, having seen most of the scientific principles at least once before during the Distance-Labs, the students could spend more time focusing on the equipment and developing their engineering observation skills.

All the students performed well during the laboratory exam. The exam consisted of several small workstations were the student was asked to perform a hands-on task. All the tasks were taken from previously completed laboratory activities. Each student had the opportunity to perform the tasks several times throughout the semester. In previous semesters one or two students would not be able to perform the required operation and in some cases were completely lost. The students who participated in the new distance course were able to perform all the requested tasks.

The majority of the students showed an independence and assertiveness that I have not experienced before in the other classes I have taught. Rather than wait for the instructor to approach the student, most of the distance students were quick to ask questions. Most students did not hesitate to ask for clarifications or extra help in understanding the laboratory requirements. The Distance Laboratory requires students to be much more self-reliant.

The students' ability to keep a neat and orderly notebook needs some improvement. There were several factors that made it difficult to monitor the development of notebook writing skills. Not being present in the classroom while students took notes during laboratory activities made it difficult to observe and make comments regarding their progress. Also, when students work side-by-side in the traditional laboratory classroom, they can compare each other's work and make necessary changes as they go. In the distance course, some students would turn in more than one laboratory at a time. By the time students received comments on their work, it was too late to be incorporated into the current week's laboratory.

The students had a difficult time keeping to the assignment deadlines. The course was accelerated when compared to the regular on-campus schedule. This likely added stress to completing the assignments. There was one major laboratory activity due each week. In the beginning of the semester, I was more flexible with the deadlines. I thought that since the course was taught asynchronously, I would allow students to be more self-paced. Unfortunately, this caused significant problems. Some students stopped participating in the online activities all together because they were too far behind the others.

I readjusted the policy and began to require that work be turned in at the end of each week. However, there were still those who had trouble meeting the deadlines. I believe most students were not used to the independence of the course and had difficulty motivating themselves. This is a significant issue that needs careful consideration when offering this course to true distance students.

The different levels of participation that each student was engaged in throughout the course were definitely a detriment to the class. Often, there were two or three laboratory exercises being conducted at the same time. This made it difficult to track students' progress and made it particularly difficult for students to interact with each other. I made repeated attempts to get everyone to participate in the activities using the discussion group. I assigned several short activities that required students to post a question or answer to the discussion group and respond to others comments. Sometimes this would initiate a constructive exchange between students. However, often the students were not all on the same activity and questions would go unanswered.

V. Recommendations

The most important recommendation for the distance laboratory course is to increase the discussion group activities and require more student accountability. The discussions need to be more frequent and engaging. Short quiz questions or a contest could be performed using the discussion group in order to stimulate interaction. Contests have been shown to be an excellent motivator for activities on the Web[9].

The problem of timing hurt the use of the discussion group. Some students would start the laboratory the night before it was due. Consequently, their messages on the discussion group would be posted much later than the rest of the class. Requiring the students to post a message before beginning the laboratory would be effective in stimulating more communication. An activity could be designed that gave each student or group of students one part of an equation that was to be used in the laboratory. Everyone could then be responsible for posting the equation plus a brief description regarding its use. This would require students to rely on each other and each student would have to start the laboratory at about the same time.

Requiring students to work together on some of the Distance-Labs would help increase the level of participation. The class could be divided into teams for the Rheometer Laboratory. Each individual could be assigned a role such as leader, reporter, and technical specialist. The members would have to communicate using email. Each student could perform his or her own online data acquisition. Their results could be tabulated and compared as a group. One final brief report could be made presenting and discussing their results on the discussion group. Teams would benefit from reviewing others' work. Students would have to communicate with each other within their team as well as communicate with other teams.

Another effective strategy for increasing group interaction would be to have a weekly question for students to answer as a group. The question should be conceptual and thought provoking. Incentive points could be awarded to the team that successfully answers the question first. Figure 4 is an example of the types of questions that could be asked. It was taken from, Askeland's, "The Science and Engineering of Materials"[10]. The answers to these concept-type questions should be due early in the week, on Tuesday for example. The remaining laboratory assignment could then be due on the following Monday, giving the students a weekend to finalize the activities.

An aluminum rod is to withstand an applied force of 45,000 pounds. To assure a sufficient factor of safety, the maximum allowable stress on the rod is limited to 25,000 psi. The rod must be at least 150-in. long but must deform elastically no more than 0.25 in. when the force is applied. Design an appropriate rod [10]

Figure 1 - Example Question

Because there is a time lag between submitting, grading, and receiving assignments it is difficult for students to get feedback from the instructor in time to make changes. By providing examples of good notebook and report writing, the student can begin to make the required changes before submitting material for a grade. Scanning and posting example notebook pages from previous semesters would be an effective way for students to see what an appropriately documented notebook looks like. Example reports can be made available on the Internet for students to download. Figure 2 describes an activity that has been designed to help students develop good notebook writing skills.

There is a discontinuity between Lab-Kit and Distance-Lab activities and the Lab-Camp activities. Sometimes students would not correctly perform the tasks in Lab-Camp, even though a similar assignment was completed successfully during a pre-Lab-Camp activity. Even a simple reminder that a similar calculation was required of them in a previous activity would help students to better establish those connections. Students would do an exercise incorrectly, have it graded and returned, and then make a similar mistake during the Lab-Camp. The students would not check their corrected work in preparation for the Lab-Camp.

The discussion activities were intended to stimulate peer interaction as well as provide a way for students to check their work and understanding with each other. Unfortunately, these activities were not used as effectively as intended. Again, there should be a marked difference in the way distance students take advantage of these activities when compared to the efforts of on-campus students. When everyone participates online to share ideas and check results, students will be able to confirm whether a task was completed correctly.

The Pre-laboratory activities should be used in the traditional classroom course. The on-campus students would benefit from the computer simulations and online information contained in the distance course web page. Some of the Lab-Kits and all of the Distance-Lab activities should be made available to on-campus students. These activities present material using multiple formats. Some of the information is in a text format while other activities involve computer simulations. Students are more deeply engaged when the material is presented using a multi-media approach and learning can be enhanced[2]. These activities would better prepare on-campus students for the in-class laboratory experiments. The on-campus students would have more time in the laboratory for observing and understanding the engineering concepts because they would be better prepared.

Notebook Activity:

Download the two image files found from the links on the Laboratory 1 Web page. The images are of two pages that were taken from a student's notebook in a previous semester. A laboratory notebook is most useful when someone, other than the author, can replicate one of the experiments it describes. Complete the following questions.

1. Read the laboratory notebook entry (downloaded image files) for the Archery Lab.
2. Duplicate the experiment solely based upon the information found in the downloaded laboratory entry.
3. Give three strengths of the downloaded notebook entry.
4. Give three suggestions that would improve the downloaded notebook entry.
5. Use your answers to questions 4. and 5. above to complete your notebook entry for Laboratory 1.

Figure 2 - Notebook Skills Development Exercise

A final recommendation would be to quantify the assessments. A test procedure and statistic could be used to determine whether there is a significant difference between distance and on-campus students' performance. The course is offered each spring semester. A random sample of students could be selected from the pool of registered students. The control group would be those students who take the course on-campus. This would give statistical support for differences in the students' performance.

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David Alexander
David Alexander is a doctoral student at the University of Idaho at Moscow. He recently completed his M.S. in mechanical engineering at the University of Idaho. He received his B.S. in Physical Science from California State University, Chico. His M.S. research has involved the development of a distance mechanical engineering laboratory. Although, his current doctoral research is in a different area, he is still involved in the distance education program and continues to advance innovative and effective teaching techniques.