Laptops in the Lecture to Promote Active Learning

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Abstract

Use of the traditional lecture format to teach software tool syntax and procedures is not engaging. Students find it difficult to take effective lecture notes and may not schedule time to practice with materials demonstrated by the instructor until several days after the lecture. The addition of active learning exercises to the lecture, enabled through use of a mobile LAN of wireless-equipped laptop computers, should improve the students' learning of course material as it better enables students to follow along with the lecture. This paper will discuss the effect of using laptops on student learning in ENGR 106, Engineering Problem Solving and Computer Tools, at Purdue University in the spring of 2002. A pilot was conducted with a class size of 48 students. To control for the effect of class size, a separate section of equal size was taught using the traditional lecture format. To minimize lost time at the start and end of each class to deploy the laptops, the lecture schedule was amended from two 50-minute lectures to a single 110-minute lecture per week. Results show that while students in both of these small classes were more satisfied with the course and performed better in meeting selected learning objectives than students placed in a larger lecture section, there were some performance measure differences that do support the use of laptop computers in the lectures. New assessment measures and preliminary results for the Spring 2003 implementation of the pilot will be discussed.

Background

Learning about computer software tools, even in an engineering problem-solving context, can be a sleep-inducing experience, particularly in a traditional lecture setting. Even when students are given lecture outlines in advance, note-taking is awkward at best, and especially so if the lecturer deviates from the outline. By the time the student rewrites or reviews the notes and attempts to perform the computer-based tasks covered therein, much of the clarity of the lecture has vanished. The solutions to this problem seldom address the fundamental problem: engaging the student immediately in learning the target materials.

At Purdue University, Freshman Engineering students are required to take ENGR 106 - Engineering Problem Solving and Computer Tools. This course introduces students to engineering fundamentals, including graphical representation, statistics, and economics, and computer tools used to solve engineering problems, specifically MATLAB, Excel, and UNIX. Enrollments in ENGR 106 average approximately 1500 students in the fall and 400 students in the spring with traditional lecture section sizes of approximately 450 students in the fall and 400 students in the spring.

A pilot study was conducted in the spring of 2002 that divided the course enrollment into two small lecture divisions, an experimental lecture section (N=44) and a control section (N=54), and one regular, large-lecture format, section (N=269). In the experimental lecture section, students used wireless-equipped laptops connected to a mobile LAN to perform active learning exercises during the lecture period.

In a 1987 article, Chickering and Gamson[1] presented and discussed "Seven Principles for Good Practice in Undergraduate Education." These have subsequently been expanded, modified slightly, and discussed further, but the original article remains a landmark document. At least four of these principles, as noted in the inset paragraphs, were addressed by this experiment.

2. Develops reciprocity and cooperation among students.

Students were simply not allowed to work alone on the laptops. If an odd number of students attended on a given day, a threesome was created, in order to force the issue of student cooperation. Teaming is a significant part of the ENGR 106 experience, and this was emphasized in the experimental lecture section. The use of pairs for this part of the learning experience also parallels the "Thinking Aloud Pair Problem Solving" technique. This active learning technique has been presented at numerous workshops by noted engineering educator James E. Stice and was published in 1987 by Lochhead and Whimbey[2].

3. Uses active learning techniques.

Active learning was strongly encouraged. The instructor and the undergraduate assistants circulated among the students, nudging them in the direction needed to master the current concept. Noise was encouraged during the active learning portions of the lecture period. Students were continually reassured that conversation was an essential part of the learning experience, so long as it related to the concept being studied.

4. Gives prompt feedback.

Students found out virtually immediately what they did not understand, as computer software tends to only know the right way to do things. As soon as a hand was raised, a member of the instructional staff made note of it, and help was on the way, with instruction about the correct way to complete the activity.

5. Emphasizes time on task.

While there may not have been a great deal of time spent on task in the lecture environment, the time so spent was more effective than would otherwise have been the case because of its immediacy.

It is likely that the "gee whiz" or "gadget value" of the technology in the classroom added a short-term benefit to the students participating in the experimental class. Such a benefit can probably not be filtered out of the preliminary findings reported herein. It is hoped that an extension of the experiment will be able to account for this. Certainly, this effect should have contributed in some way to keeping the students effectively engaged in the lecture period, and that is a positive result no matter how short-term.

The Setting

As has been noted, the experiment was conducted so as to compare an experimental lecture section of 44 students, a control lecture section of 54 students, and a traditional, large lecture section of 269 students. Of particular interest in this study was the performance of the first and second semester students taking the course for the first time, as this is our target population. Enrollment in the experimental section consisted of 8 first semester freshman engineers and 25 second semester students primarily from Freshman Engineering and the School of Science (N = 18). The control lecture section consisted of 8 first semester freshman engineers and 28 second semester students also primarily from Freshman Engineering and the School of Science (N = 16). There were 55 first semester freshman engineers and 134 second semester students primarily from Freshman engineering and the School of Science (N = 102) in the large lecture section. The remaining students came from a variety of schools, were classified as third through seventh semester students, and/or were repeating the class.

One instructor taught both small lecture sections and another taught the large lecture section. The traditional section followed the standard schedule for ENGR 106 of two 50-minute lecture sessions and a 110-minute laboratory. Both small sections followed a schedule of a single 110-minute lecture session and a 110-minute laboratory. The single longer lecture period was utilized to reduce the time lost for distribution and collection of laptops. Weekly material coverage was the same for all lecture sections, as were other aspects of course administration.

For the experimental lecture section, a mobile LAN consisting of 25 wireless-equipped laptop computers, a wireless access point unit, and a security cart was purchased. This equipment was stored in a locked location in the building where ENGR 106 was scheduled and moved to the classroom each day at the start of the experimental lecture class. At the beginning of the lecture, one laptop for every two students was distributed by undergraduate assistants; students were encouraged to work with members of the teams they were assigned to in laboratory. The 110-minute lecture period then consisted of two or more cycles of lecture materials followed by active learning exercises. The period concluded with wrap-up comments by the instructor and collection of the laptops.

Attempts were made to minimize confounding effects. All assignments (i.e. labs, projects, homework assignments, and exams) were identical for all three lecture sections. Exams were scheduled in the evening so that a common exam could be given to all students in the course. This not only enabled a common grading scale for the entire course, but also enabled a rational comparison of student performances by lecture division.

While there is substantial interest in the differences between the performance of students in the experimental section and that of those in the traditional section, it is likely that the differing lecture sizes will confound the findings of the research. The control section was created to provide a similarly sized section for comparison to the experimental section. In addition, though the control section did not "need" a schedule involving just a single weekly lecture, it was felt that scheduling both of these class sections for 110-minutes would provide some reassurance that research findings would be related to the experiment rather than to side effects. Thus, in the quantitative sections of this paper, the comparisons between the two small lecture sections of the course are the critical findings.

Instructor Observations

Presented here are some of the instructor's anecdotal observations of the experimental class vis a vis the control class and his past experiences with large lecture sections of the same course. Bearing no small importance for this or any class, attendance seemed to be better for the experimental class. This could be due to the experiment: gadget value, active learning, or a greater level of engagement. Alternatively, it could be due to the fact that the control class was scheduled at 7:30 am, while the experimental class was scheduled at 1:30 pm. A comparison with attendance in the large lecture, scheduled at 9:30 am could prove more revealing, and a quantitative look at this will follow shortly. Another contributing factor in the seemingly improved attendance is the fear factor. Students missing a single lecture in either small class missed an entire week's lecture material, while those missing a class in the traditional section missed a half week's material, perhaps even with a chance to catch up by attending the other lecture that week.

While student – instructor interaction seemed to be better in both the experimental and the control class as compared with the instructor's experience with the traditional setting, this improvement seemed to be greater in the experimental class. Students in the experimental class seemingly sat in the same location in the classroom more consistently, aiding in learning of students' names, possibly contributing to this effect. Of course, one cannot rule out the possibility that a contributing factor to this improvement is an instructor feeling less intimidated by 44 or 54 students as compared with 269 or more. There is an even greater likelihood that the students in the smaller classes felt more encouraged to interact with the instructor.

Two very important observations regarding the instructional staff were noted in the experimental course. First, the undergraduate assistants in the experimental lecture section were actually envious of the students in the class, wishing they could have enjoyed the advantages they perceived of the experimental format. This theme was repeated many times by the students working in this class. The undergraduate assistants working the control class, by contrast, seemed bored most of the time. With only two undergraduates working each lecture, this observation suffers from a small sample size, but is presented nonetheless because of the prior experience of these students, who took the course in the traditional format. The other observation is directly from the instructor: the experimental course was simply more fun to teach. Even if everything else about the experiment turns out to be of little or no quantifiable value, the students enrolled in the course should have received substantial benefit from feeding off the instructor's excitement.

There were, unfortunately, no pleasant surprises regarding the logistics of the conduct of the experiment. Time was lost at the beginning of the class period distributing the laptops, and again at the end of the period collecting them. While these were expected results, the magnitude of the time lost was much greater than expected early in the semester until the students gained experience working with them. Unfortunately, no data were collected on the magnitude of this loss, so this remains, for the time being, an anecdotal observation only.

The doubling up of lectures was done to minimize the aforementioned time losses, and was very effective in this. As previously noted, the traditional lecture schedule for ENGR 106 includes two 50-minute lectures per week while the modified schedule utilized in the experimental and control lecture classes included one 110-minute lecture per week. The 10 minutes gained offset the laptop distribution and collection time losses in the experimental section, and the 10-minute break given in the control lecture section was extremely popular with students as they headed to the Eta Kappa Nu lounge for coffee and doughnuts. The downside to the 110-minute class period was an increase in difficulty scheduling lecture materials. This was particularly notable when attempting to schedule exam reviews.

Student Survey Results

A minor blunder in scheduling of course assessment activities resulted in a smaller than desired sample size of student survey data. The surveys and evaluations were scheduled during a time when the course was virtually completed, and students were not explicitly required to attend to complete the surveys and evaluation instruments. Participation rates are indicated in Table 1 and include any student taking ENGR 106 regardless of semester or school classification.

Table 1. Participation in ENGR 106 final course evaluation.

Lecture Section	Participating/Enrolled	Percentage Participating
Experimental	27/44	61.4
Control	7/54	13.0
Traditional	57/269	21.2

These participation rates leave a lot to be desired and provide incentive to design a better assessment plan for the second pilot. However, they also tell a story in and of themselves. Students in the experimental class continued attending near the end of the semester, even knowing they were not required to do so, at a far greater rate than the students in either of the other two groups.

The survey conducted listed eight course objectives (Table 2) and asked the students to rate, on a 5-point ordinal scale, their abilities related to the specific objectives.

Ignoring the control class, due to the small sample size, requires that these data be taken more lightly than might otherwise have been possible. This is because of the effect of class size on the learning objectives. Examining the data with the foregoing caveat in mind, it can be seen that there are noticeable differences for four of the eight objectives between the ordinal scores of students in the experimental lecture and those in the traditional lecture.

The first three objectives deal with programming skills, and in two of the three cases, the experimental lecture students rated their capabilities higher than did the traditional lecture students. In the third case, the scores were essentially a toss-up. Students in the experimental class may have actually learned these skills better, either due to the class size effects or the active learning.

Table 2. Student self-rating of achievement of course learning objectives.[a]

	<u>**Course Learning Objective**</u> As a result of the successful completion of this course, I am able to:	**Experimental**	**Control**	**Traditional**
1	Develop a logical problem solving process which includes sequential structures for fundamental engineering problems	3.8	4.4	3.6
2	Develop a logical problem solving process which includes conditional structures for fundamental engineering problems	3.8	4.1	3.8
3	Develop a logical problem solving process which includes repetition structures for fundamental engineering problems	3.8	4.4	3.5
4	Translate a written problem statement into a mathematical model	3.2	4.0	3.1
5	Solve fundamental engineering problems using computer tools	3.2	4.0	3.2
6	Perform basic file management tasks using an appropriate computer tool	4.2	4.0	3.8
7	Work effectively and ethically as a member of a technical team	4.5	4.3	3.9
8	Develop a work ethic appropriate for the engineering profession	3.9	4.4	3.8

[a] 5-point ordinal rating scale, with: 5 = excellent, 4 = good, 3 = average, 2 = fair, and 1 = poor.

Objective 6 involved skills related to basic computer literacy, and again, the students in the experimental class rated their skills higher than did the students in the traditional lecture section. In this case, students gained a great deal of practice on these skills under the watchful eye of the instructor in the lecture, so the active learning exercises on the laptop computers in the experimental class format may indeed have been responsible.

Objective 7 deals with teaming skills. While the experimental class was not designed to significantly impact these skills, the paired use of the laptops may have had a much greater impact on these skills than was intended.

Students were also asked to evaluate how well each course element served its purpose, as stated on the syllabus. The results from all first and second semester students taking the course for the first time are presented in Table 3.

Table 3. Student self-rating of how well each course element served its purpose.[a]

Course Element	Experimental (N=31)	Control (N =29)	Traditional (N =179)
The purpose of the **lecture** is to introduce and explain the theory behind the course material and relate the material to engineering applications.	3.6	3.4	3.6
The purpose of the **laboratory** is to provide you with "hands-on" exposure to the course material and allow you the opportunity to experiment with the computer system and the various software packages	4.2	4.0	4.2
The purpose of **homework** is to allow you to practice using problem solving and computer skills developed in laboratory.	3.8	3.5	3.7
Exams are designed to provide you with opportunities to give evidence of your understanding of course topics.	3.6	3.5	3.5
Team Projects are designed to provide you with an opportunity to apply your newly acquired problem solving and computer skills to the solution of engineering problems.	4.0	3.6	3.7
The purpose of **teaming** is to help you learn to become an effective member of a technical team.	4.0	4.0	3.9

[a] 5-point ordinal rating scale, with: 5 = very well, 4 = above average, 3 = average, 2 = below average, and 1 = poorly.

Students in the experimental lecture section rated all course elements as serving their stated purpose higher than the control section across the board and equivalently or higher than the traditional lecture section. Significance was not assessed.

Performance Results

In analyzing the performance measures collected for the purpose of assigning grades, analysis was limited to those for first and second semester students taking the course for the first time. Again, this is the primary target audience for the course.

Overall, comparisons of the means of the data are generally favorable to the experimental lecture format. As common exams were used in the course, student learning was assessed on a common basis, though exam design may have been less than ideal. The average scores, in percent, obtained for the three lecture sections are shown in Table 4, along with the results of a two-sample, unequal variance, one tail t-test. H_0 (the null hypothesis) is that the means are equal, H_1 (the alternate hypothesis) is that the means are higher for the experimental class scores. The t-test values in the table are the probabilities calculated for each comparison of means.

Table 4. ENGR 106 Spring 2002 exam averages for first and second semester students.

Examination	Experimental (N = 33)	Control (N = 33)	Traditional (N = 189)	Exp vs Ctrl t-test	Exp vs Tr t-test
Written Exam 1	78.1	76.0	74.5	.2983	.1109
Written Exam 2	82.3	81.4	80.8	.4079	.2871
Written Exam 3	71.2	66.5	70.1	.1734	.3778
Lab Practical 1	76.6	63.1	69.7	.0018	.0070
Lab Practical 2	84.8	69.3	78.4	.0003	.0172
Exam Average	77.8	69.9	73.8	.0290	.0677

It is clear that the performances on written examinations show no significant differences. However, on the lab practical exams, the students in the experimental lecture outperformed those in the other lectures at a highly significant level. This difference in performance is sufficient to impact the comparison of the overall exam averages, with a significant difference between the means for the experimental lecture and the control lecture. It is very likely that the lecture format had significant impact on the learning of first- and second-semester students, particularly with regard to those items and skills tested on the lab practical exams.

Table 5 lists additional performance measures used in ENGR 106. Laboratory performance in ENGR 106 is measured with a "check for understanding," or CFU, at the end of the laboratory period. Based on the results above regarding the lab practical exams, differences in performance may be expected on the CFUs between the three classes because the CFUs measure somewhat the same learning as the lab practical exams. One would expect that homework and project grades would be minimally affected by the lecture class format as the effect of lecture would be diluted by students laboratory experience and study habits.

As expected, the CFU grade average for the experimental class was significantly better than that for the control class. While the experimental class achieved a better average on homework and projects, only the difference for the grades on Project I was statistically significant.

Attendance grades in ENGR 106 are based, at least part of the time, on an in-class assignment or quiz in addition to the presence of the student. Attendance is taken about 10 times during the semester. Typically, out of 10 points available for a given class attendance grade, students receive 5 points for being present and 5 points for correctly answering two or three questions based on the reading for that class period. Because different instructors use the quiz a different percentage of the time when sampling attendance, the attendance grades are not compared here; rather, the actual attendance is compared. As was observed by the instructor of the small classes, attendance was substantially better in the experimental class than in the control class, and the difference is highly significant statistically.

Table 5. Additional and Summative ENGR 106 Spring 2002 performance measure averages (percent) for first and second semester students

Performance Measure	Experimental (N = 33)	Control (N = 33)	Traditional (N = 189)	Exp vs Ctrl t-test	Exp vs Tr t-test
CFU Average	92.4	86.2	87.2	.0115	.00004
Homework Average	85.9	79.5	85.3	.0498	.4048
Project I Average	97.8	90.0	95.2	.0009	.00003
Project II Average	95.4	92.6	91.3	.1380	.0038
Attendance Average	95.5	77.1	81.3	.0004	3×10^{-10}
Course Average	86.4	78.1	82.7	.0061	.0113
Course GPA	3.39	2.82	3.09	.0064	.0198

Given the performances by the students on individual portions of the overall grades, the overall course average and GPA contain no surprises, but are presented for the sake of completeness. The course average for the experimental lecture class is significantly better than that for both of the other class formats, and the difference vis a vis the control class is highly significant. As course grades are based almost entirely on the student's course average, the same holds true for a comparison of course GPA statistics.

Clearly, the size of the class was not the only variable causing improved performance, and, it is hoped, learning as compared to the traditional format. The statistics for the control class were at least somewhat similar to those of the traditional class, while those for the experimental class were clearly not. Based on the foregoing, as well as on the anecdotal observations of the small class instructor, the experiment is worth extending. Some lessons were learned, especially about the need for more carefully planned assessment, and will be applied to the next iteration of the project.

What Next?

In offering the experimental class a second time, the mobile LAN must be stored in the classroom where it will be used. The time lost in simply moving the computers to and from the classroom is a simply unacceptable cost of offering the improvement. Negotiations have taken place, and a compromise has been reached with persons in position to grant permission for such storage. What remains is to fashion a tie-down sufficient to secure the unit against possible theft or vandalism. This will be handled soon, and all other administrative measures have been taken to offer the experimental and control courses in a second consecutive spring semester.

Scheduling of the classes is being given more careful attention for the next iteration of the experiment. By beginning the scheduling earlier in the administrative cycle, times have been selected for both the experimental class and the control class that are generally seen by students as more desirable. This should eliminate concerns with the differential desirability of 7:30 am versus 1:30 pm lectures.

Data from the grading files will again be used in assessing the various class formats. Surveys, however, will play a greater role in assessing the updated experiment. There will be additional survey content, measuring items beyond the student self-assessment of course learning objectives. Further, steps will be taken to assure a higher percentage of students completing the surveys. With the right approach, virtually all the students in the course should be convinced of the importance of their input, particularly in the small lecture classes. Finally, experts in educational assessment will be consulted to assure a more sophisticated assessment of learning in all three class formats. If the updated experiment goes well, perhaps enough attention may be drawn to the successes to prompt the discovery of an appropriate means to scale up the experiment to cover all the students taking ENGR 106.

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