

Enhancing Learning of Low Performing Students in Multi-section First Year Lecture/Laboratory Classes: Completion of a Three Year Study

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Abstract - A common instructional model for first year engineering is the lecture/laboratory model. The most common implementation is lecture introducing material of a given “unit” followed by laboratory sections used to provide hands-on experience. An alternative implementation reverses the order. Students read assigned material, then attend laboratory sections, then at the end of the “cycle” attend lecture. Lecture is used to generalize from the specifics students have applied in lab, and to demonstrate common student mistakes. The pedagogically larger picture is that “lecture as wrap-up” requires students to take more responsibility for their own learning, and to be more actively engaged in their learning. In fall, 2004, and fall, 2005, we conducted preliminary studies to compare “lecture before” versus “lecture after” models; results seemed to be promising. In fall, 2006, and spring, 2007, we replicated the study before drawing conclusions. In the current report we display our final round of research, the results from it, and our summary for the three year study we have undertaken. Our final round of testing produced results that are not consistent with our earlier reported results. A call for others to replicate the study is made.

Index Terms - first year courses, lecture with laboratory courses, high enrollment courses, order of lecture and laboratory

INTRODUCTION

This is the follow-on paper to research reported at ASEE 2005 [1] and at ASEE 2006 [2]. In the earlier work, we began an examination of the effect of the timing of lecture in relation to laboratory, for high enrollment freshman engineering courses. The research question we addressed was “Does lecture-before-lab versus lecture-after-lab affect student performance in the course?” In the work reported here, we extend our inquiry into this question.

An alternative implementation of the “large lecture/lab” instructional model reverses the order of lecture and lab (or recitation), placing the lecture at the end of a study cycle of (a) reading assigned material, working in monitored and scheduled labs with TA assistance, and (c) attending lecture. In this implementation, students are more obligated to read assigned material before their first unit meetings (labs/recitations) because in lab they must use what they

have learned from the assigned readings to do the work in the labs.

While it may be easy for an unprepared student to “hide” in lecture, this is not as easy in small lab sections. The pedagogically larger picture is that “lecture as wrap-up” should require students to take more responsibility for their own learning, and in the end be more actively engaged in their learning, than the more common “lecture as introduction” path.

BACKGROUND AND INITIAL HYPOTHESIS

Active learning and its importance in transforming the educational enterprise from a view of the student as a vessel into which the professor pours “knowledge” to one in which the learner is actively engaged in her own construction of knowledge is an important pedagogical principle. One example of the introduction of principles of active learning into engineering studies can be found in [3]. The goal of implementing active learning has become wide spread in computer science and engineering to the extent of enabling students to set the term grade they desire, then work towards that goal. [4]

A specific area of active investigation with the goal to enhance active learning/student engagement lies in the large and growing work on the use the “personal response system” (PRS). PRS units are typically small, student held units that resemble a TV remote, and are typically called “clickers” by faculty and students alike. PRS units are used in modes ranging from giving in-lecture quizzes for grade, to use as student-to-faculty feedback devices. As feedback devices, they enable instructors to tailor lecture material on the fly to help meet, for example, the needs of “just in time teaching” (JiTT) [5-6].

Enhancement of active learning is one of the backdrops for research reported here. As noted above, we believe that requiring students to do assigned reading before any class (lecture or lab) that is dependent on the assigned reading could have the effect of actively engaging students in their learning process, certainly more so than the standard lecture situation in which lecture material closely mirrors assigned reading.

Specifically, our research question remains that students who participate in lecture as wrap-up will perform better than those who participate in lecture as introduction. Other than our work reported at ASEE 2005 and ASEE 2006, other

past studies on this specific issue were difficult to find, and in fact, we found no other relevant literature.

SETTING FOR STUDIES IN FALL 2004 AND FALL 2005, VARIABLES AND RESULTS

Computer Science and Engineering (CSE) 131 is a high enrollment (approximately 250-300 students per term), multi-section (approximately 24 sections), freshman engineering course in technical problem solving with MATLAB. It is offered fall and spring semesters with an additional offering in summer term with a substantially lower enrollment. CSE 131 is a required gateway course for most majors in the College of Engineering, Michigan State University. The standard “Calculus 1” is a pre-requisite/co-requisite for CSE 131.

Because of a scheduling “glitch” that first appeared in fall semester, 2004, CSE 131 was offered in two lecture sections at opposite ends of the week. One lecture section met on Monday nights at 7:00 p.m., with associated labs running on Tuesdays, Wednesdays, Thursdays, and Fridays. A second lecture section met on Friday mornings at 10:20 a.m., with associated labs running on Tuesdays, Wednesdays, Thursdays, and Fridays. Lecture section enrollments were approximately the same size in all years or our study. Laboratory sections entailed enrollments of a maximum of 16 students, and were not mixed – that is laboratory sections included students either totally in the Monday lecture section, or totally in the Friday lecture section.

Each student in CSE 131 meets for one lecture session per week lasting one hour and twenty minutes, and meets twice per week in laboratory sessions twice per week with each lab meeting lasting one hour and twenty minutes. Thus the Monday lecture session students met in lecture before participating in any lab assignments, while Friday lecture session students met in lecture after participating in lab assignments for the week. Both lecture sections had identical reading assignments, and both sections had identical laboratory exercises, laboratory quizzes, midterms, term project and final examination.

An exception for the Friday lecture section was that several associated lab sessions met after the Friday lecture for the second of the two lab meetings each week. This exception covered 24 students of the total 109 students in the Friday lecture section.

Because the initial study and its results were preliminary, we continued the same schedule for CSE 131 in fall, 2005, fall, 2006, and spring, 2007, to enable continuation of the research. The same faculty person was lecturer for all lecture sections in all semesters. In all four semesters, the two lecture sections (Monday and Friday) received different treatments:

- lecture material for the Monday lecture section consisted of the typical introduction of a unit. Lectures largely paralleled assigned readings for the unit. MATLAB problems were worked that were drawn from examples in the assigned readings.

- lecture material for the Friday lecture section consisted of wrap-up for a unit. Lectures focused largely on two areas: (a) demonstrating MATLAB points that beginning students are likely to misunderstand and (b) working MATLAB problems drawn from the exercise sets that students were assigned for lab sessions.

We collected the following data on each student:

- totals for all categories of graded work in the course
- total term points (out of 100)
- percentile ranking based on total term points
- ACT composite and area scores
- cumulative GPA as of the end of the semester in which the course was taken, calculated without the grade in the course.

We used a two-dimensional clustering scheme based on composite ACT (as the first clustering dimension) and cumulative GPA (as the second clustering dimension) to classify students into groups of low, medium and high academic performance. The K-means clustering algorithm in SPSS was used to form three performance clusters: Low (mean GPA = 2.67, N = 53); Medium (mean GPA = 2.96, N = 120); and High (mean GPA = 3.34, N = 47). Note that these calculations excluded the students’ performance in CSE 131. We then divided each group based on their lecture sections: Monday (N = 123) and Friday (N = 124). We compared performance between Monday and Friday students in each performance group. Students in the low performance group did better on many course assignments in the Friday section than did those in the Monday section:

- total points from 2 hour exams – Monday: mean = 8.35 N = 27; Friday: mean = 11.78, N = 26; p = .005
- total points on laboratory quizzes – Monday: mean = 11.34 N = 27; Friday: mean = 13.65, N = 26; p = .009
- total term points – Monday: mean = 57.93 N = 27; Friday: mean = 67.36, N = 26; p = .031

The results for total term points are shown in Figure 1.

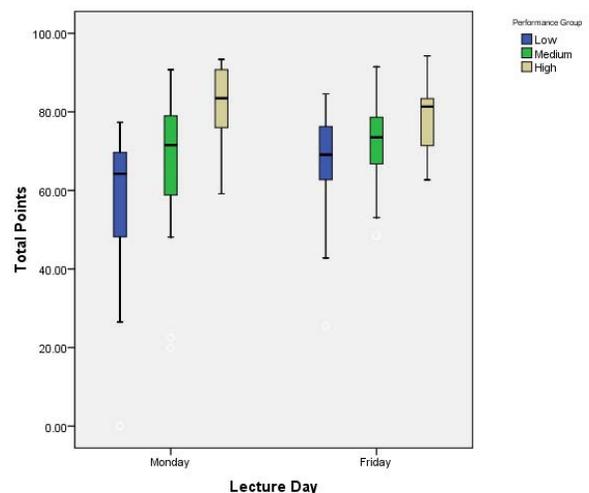


Figure 1: Comparison of Total Points in Monday and Friday sections fall, 2005

Note that the High and Medium Academic Performance groups were not different, but there was a statistically significant difference in performance for the Low group, with the Friday section students doing consistently better on many of the assignments.

FALL 2006

Because the “scheduling glitch” that enabled this study initially was finally to be fixed following the 2006-2007 academic year, we realized that following AY 06-07 we would have no further opportunity in this setting (CSE 131) to continue this research. Hence, we decided a third test should be run to replicate the FS05 study; we thus continued this scheduling in the 2006-07 academic year and repeated the analyses.

The same instructor continued to teach the course and structured the class in the same fashion as fall, 2005. We created clusters of low, medium, and high academic performance based on GPA (excluding the grade in the course) and ACT scores. This resulted in three groups: High, $N = 68$, mean GPA = 3.36, Middle, $N = 107$, GPA = 3.07, and Low, $N = 60$, GPA = 2.60. Note that the mean GPAs in these groups are different from those in fall, 2005. This is because the clusters are formed based on the data from the students enrolled during each semester, not on data from the entire class of engineering students. As in 2005, there were no differences between the Monday and Friday sections in the high or middle groups on any of the academic metrics in the course. There were differences between the Monday and Friday sections in the low performing group. However, this time, rather than the Friday section doing better, the Monday section did slightly better on almost every measure. On two of these, the differences were statistically significant. On the Final Exam, the Monday mean was 7.59, $n = 35$; Friday’s mean was 5.98, $n = 25$, $p < .01$. On the In-lecture Quizzes, the Monday mean was 13.67, $n=35$; Friday mean was 12.06, $n = 25$, $p < .05$.

We were puzzled by this result and investigated further. Closer examination of the data showed that there were seven students who got 0 points on the Final Exam in FS06. Of those, six of the students were in the Friday lecture and in the Low academic performing group. The one in the Monday lecture was in the Middle performance group. Students only received a 0 on the final because they did not take it, so we assumed that students who did not take the final had effectively “given up” on the class, even though they had done work previously in the term and had not officially dropped the course. When we dropped these students from the analyses there were no differences between the Monday and Friday sections on any of the variables for the FS06 dataset. The results for fall 2006 after dropping students with a 0 on the final are shown in figure 2.

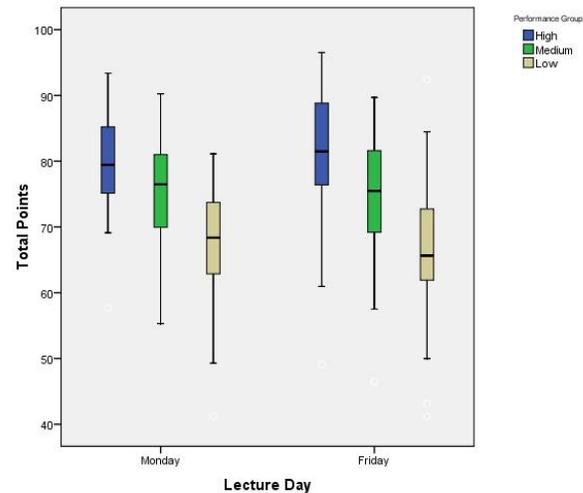


Figure 2: Comparison of Total Points in Monday and Friday sections fall, 2006

REANALYSIS OF FALL 2005 DATA

We thought that the fall, 2005, results might have been due to a similar skewed distribution of students who did not take the final. When we dropped those students, the distribution went from 27 students in the Low performing group in the Monday section to 23 students and from 26 students in the Low performing group in the Friday section to 25 students, so the change was not as lopsided as FS06. Reanalyzing the fall, 2005 data without the students who did not take the Final Exam still resulted in the Friday section doing better on the Midterm Exams (Monday mean = 9.47; Friday mean = 12.18, $p < .01$), the Minitest, (Monday mean = 12.13; Friday mean = 13.81, $p < .03$) and in Total Points (Monday mean = 63.63; Friday mean = 69.03, $p < .03$).

SPRING, 2007 DATA

We analyzed the spring, 2007 data in a similar fashion. We created clusters based on GPA (excluding the grade in CSE 131) and ACT scores, resulting in three clusters: High academic performing, $N = 78$, mean GPA = 3.22; Middle academic performing, $N = 101$, mean GPA = 2.95; and Low academic performing, $N = 52$, mean GPA = 2.70. When we compared the Monday and Friday sections, we found no differences between them for any of the three groups on any of the academic metrics. Again, we dropped students who did not take the Final Exam from the analyses. This time, there were three students with 0 points on the Final Exam in the Monday section, but only one student was in the Low performing group. There were four students with 0 points on the Final Exam in the Friday section, with three of those in the Low performing group. However, dropping these students from the analyses did not alter the outcomes: there were no differences between the Monday and Friday

sections on any metrics. The results for spring 2007 after dropping students with a 0 on the final are shown in figure 3.

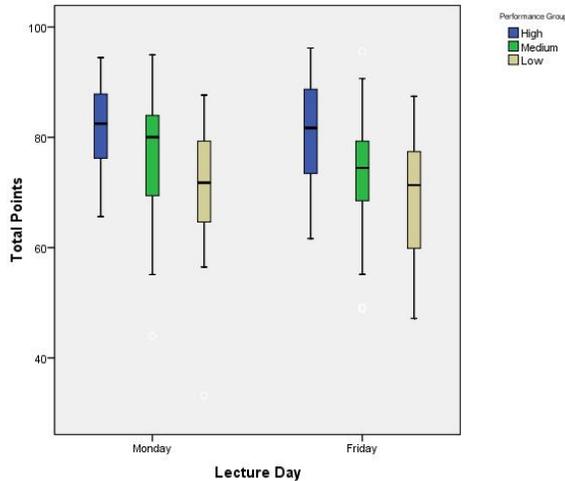


Figure 3: Comparison of Total Points in Monday and Friday sections spring, 2007

ATTENDANCE

Given that the two lecture sections met either on Monday or Friday, we thought that there might be differences in attendance patterns between the two sections that could account for these outcomes. Perhaps the students tended to come to class less in the Friday section. Or, perhaps because the Monday section met in the evening, that impacted attendance. Because we use Personal Response Systems (PRS, or “clickers”) as part of the class instruction, we collect data on each student’s responses that can be used to determine if they are attending class. We assume that if a student answered any of the clicker questions for a particular class day, that student was in class.

We examined attendance patterns for all three semesters. In FS05, there were no differences in attendance between the lecture sections in any of the groups. In FS06, the Middle performing group attended more frequently in the Monday than Friday section (Monday mean = 91.7%; Friday mean = 86.5%, $p < .04$) but there were no differences between these students on any of the course performance metrics. There were no differences in attendance patterns for the Low or High performing groups.

In SS07, students in the High performing group attended more frequently in the Monday section (Monday mean = 93.6%; Friday mean = 83.9%, $p < .03$). However, there were no differences between the students in the High performing group on any course performance metrics. There were no differences in attendance patterns for the Low or Middle performing groups in SS07.

UNDER-REPRESENTED GROUPS

We wondered if there was a disproportionate impact on under-represented students. At MSU, the majority of engineering students are male and white, and the enrollment in this course is consistent with those patterns. However,

given the small number of non-white students, there are very few non-white students in any performance group/lecture day combination.

In FS05, 86% of the students in the course were white. In the breakdown by performance group, the High performing group was 89% white, the Middle group was 87% white and the Low group was 80% white. The Monday section was 92% white and the Friday section was 80% white. Male students made up 82% of the students (80% of the Monday section and 84% of the Friday section); 18% of the students were female (20% of the Monday section; 16% of the Friday section.) The gender distribution by performance group was less uniform, with males making up 72% of the High performing group, 74% of the Middle group and 81% of the low group. In FS05, when we found higher scores for the Low performing group in the Friday class, the Friday class had a much higher proportion of non-white students (20% vs. 8% on Monday.) However, in the Low performing group, where we found the difference in academic performance, the number of non-white students was small: three students on Monday and three on Friday, too few to draw any conclusions.

In FS06, 76% of the students in the course were white. In the breakdown by performance group, the High performing group was 79% white, the Middle group was 85% white and the Low group was 53% white. The Monday section was 80% white and the Friday section was 71% white. The distribution of the mean total course points by ethnicity across lecture days is shown in figure 4. Note that the absolute numbers of non-white students in the course was very small (there were only 16 Black students in the entire course, the largest non-white group) so these results are not statistically significant.

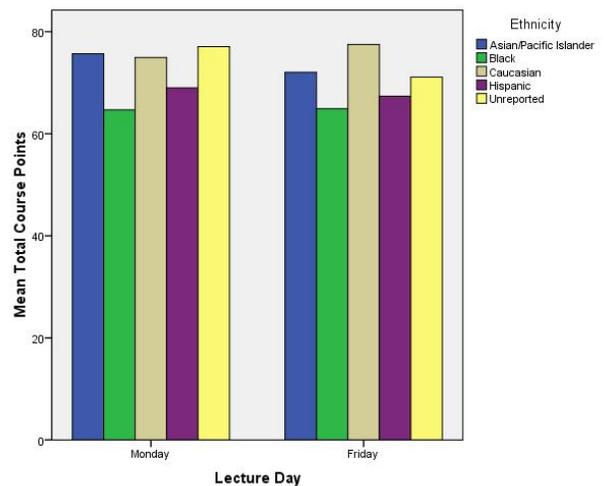


Figure 4: Comparison of Mean Total Points between different ethnic groups in Monday and Friday sections fall, 2006

Male students made up 77% of the students; 23% of the students were female, with equal distributions between lecture days. The gender distribution by performance group

was less uniform, with males making up 78% of the High performing group, 79% of the Middle group and 74% of the low group. The mean distribution of total points by gender between class days is shown in figure 5. Note that the absolute numbers of female students (52 in the entire course) means that these results are not statistically significant.

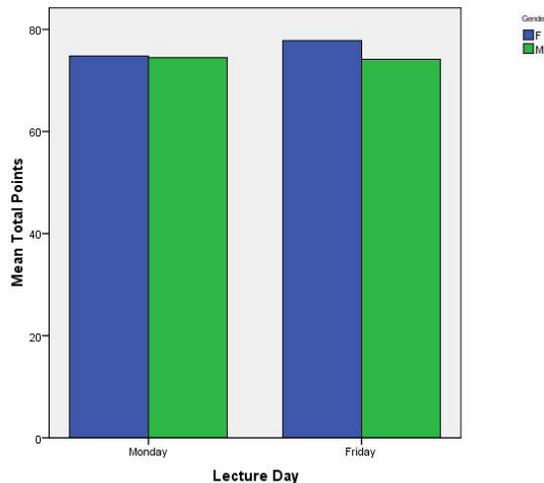


Figure 5: Comparison of Mean Total Points between female and male students in Monday and Friday sections fall, 2006

The results shown in figures 4 and 5 are typical for all three semesters.

In SS07, 81% of the students in the course were white. In the breakdown by performance group, the High performing group was 75% white, the Middle group was 90% white and the Low group was 88% white. The Monday section was 80% white and the Friday section was 82% white. Male students made up 76% of the students, 24% of the students were female, with the distribution uniform between sections. The gender distribution by performance group was uniform with males making up 83% of the High performing group, 81% of the Middle group and 84% of the low group.

Given the small numbers of non-white or female students in any one lecture section and performance group, we cannot draw any statistical conclusions about unequal impact on under-represented groups.

DISCUSSION

In FS05, we found higher scores for the Low performing group in the Friday class, the class in which the lecture was used as a wrap-up for the lab sections. We replicated (as closely as possible) the design in FS06 and SS07. However, we did not find the pattern to hold in those semesters. On first examination, it appeared that the effect was reversed for FS06, with the students in the Low performing group in the Monday section doing better. However, when we controlled for students who did not take the Final Exam – and by inference those who had given up on the course – this

difference vanished in FS06, even though the effect remained for the Friday section in FS05.

We then attempted to understand what may have been different during FS05 than the FS06 and SS07 semesters. While students in the spring semester are often in a different point in their academic program, any impact of this difference in course backgrounds should have been consistent from FS05 to FS06. We could not explain the difference based on different distributions of students between the lecture sections. While class sizes are large, the numbers of under-represented students are small enough that we have very few students in any particular group/lecture combination, hence we were not able to draw any conclusions about impact on under-represented groups.

We wondered if there had been some difference in advising in which students who were academically at-risk had been advised to enroll in particular sections. The Associate Dean for Undergraduate Education in the college was not aware of any changes in advising patterns over this period of time.

This leaves us with three explanations for our results:

1. The FS05 results were simply a statistical fluke. While the results were statistically significant, the study was based on post-hoc examination of the data and may have been due to normal variation in the data. However, since the results on multiple academic measures were all in the same direction and they held after controlling for students who did not take the Final Exam, we expect that there may be some underlying phenomenon.
2. FS05 was only the second time that the instructor had taught this “split” format of the course. In FS04, he had done this for the first time and had never offered a “lecture as wrap-up” course structure before. In that context, he had the opportunity for feedback and reflection to prepare for FS05, when the Friday classes were better structured based on the previous experience. However, in FS05, there was still a “newness” to this format. It is possible that there was some Hawthorne Effect with the instructor approaching the Friday section with more enthusiasm than the traditional format of the Monday section.
3. By FS06 and SS07, it is possible that informal communication among students had spread the word about the difference in formats of the two sections, so students may have made their enrollment choices of section based on the format, rather than simply based on the “fit” with their class schedule. Survey data from the students in all three semesters show that many did not like having to prepare for the lab sections on their own when they were in the Friday class. Thus, students who prefer to come to class without doing the preparatory readings might chose to enroll in the Monday rather than Friday section.

We consider explanation #3 to be the most likely, although we cannot rule out either explanation #1 or #2 - or some other explanation that has yet to surface.

CONCLUSIONS AND RECOMMENDATIONS

Beginning in fall, 2007, the scheduling glitch for CSE 131 was finally cleared; CSE 131 is currently taught in two lecture sections, but the two meet on the same “end” of the week. There is one lecture section on Thursday nights, and a second on Friday mornings. Because labs are now scheduled to run before both lecture sections, CSE 131 is now on the “same schedule” for both lecture groups. Currently both are being conducted following the “lecture as wrap-up” model. Because the scheduling of the lecture sections no longer is supportive of the research situation we used over our multi-year study, no further exploration to compare “lecture as introduction” versus “lecture as wrap-up” is planned for CSE 131.

This leaves us in an unsettled state. In our earlier work, particularly the work we reported in ASEE 2006 [2], we had what appeared to be good evidence indicating that the “lecture as wrap-up” mode is statistically significant in helping the lowest performing students to achieve higher as compared to the “lecture as introduction” treatment. The advantage to “lecture as wrap-up” held for a number of metrics for learning outcomes including total course points earned.

However, the analysis of data from fall, 2006 and spring, 2007 did not produce confirming results. Fortunately, the “lecture as wrap-up” does not seem to have a negative impact on student performance, since that is the format in which both sections are now being taught.

Because at the current point in time, we cannot take the issue of “lecture as introduction” versus “lecture as wrap-up” further, we would recommend that those in the community who have access to high enrollment, multi-section, lecture/lab courses consider ways this work could be pursued. Should the results point to a substantial and statistically significant advantage for “lecture as wrap-up” with respect to the lower third of our students, we would have a compelling new model that may benefit academically at-risk engineering students.

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