AC 2011-2754: EVALUATION OF EFFECTIVENESS OF JUST-IN-TIME TEACHING AND PEER INSTRUCTION METHODS IN CIVIL ENGINEERING COURSES

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Evaluation of Effectiveness of Just-in-Time-Teaching and Peer Instruction Methods in Civil Engineering Courses

Abstract

This paper evaluates the effectiveness of just-in-time-teaching and peer instruction methods in a typical required junior level civil engineering geotechnical course sequence. These methods are compared with more traditional methods including computational problem sets, pre-class reading assignments, and publishing of lesson objectives. The analysis presented uses data from 8 different course offerings over a four year period and includes data from 296 individual student assessments. These 8 course offerings were taught by 3 different instructors. Students report computational problem sets are the most valuable learning tools of those assessed. Additionally, just-in-time-teaching and peer instruction were perceived by the students to be the next most valuable learning tools. Importantly, student perceived just-in-time-teaching kept them on-schedule and resulted in less cramming as compared with other courses taken at the same time.

Background

In the 1990's undergraduate science programs, physics programs in particular, began to develop active learning techniques to supplement or replace traditional lecture methods. Two of the more effective methods developed were just-in-time-teaching (JiTT)[1] and peer instruction[2]. These active learning techniques have proven to be effective methods and have steadily been deployed in undergraduate classrooms over the past 15 years. While not limited to use in the physical sciences, these techniques have seen much wider use in science classrooms than in engineering classrooms. The results of a national survey of faculty using peer instruction show 94% of users from the natural sciences and only 3% from engineering[3]. While there is some published scholarly work describing JiTT or peer instruction implementation in engineering programs[4,5], the majority of the published assessment work for JiTT and peer instruction comes from natural sciences programs.

The author has been using JiTT and peer instruction methods in civil engineering courses since the fall of 2006 and has collected four years of assessment data on the effectiveness of these active learning methods in introductory courses in geotechnical engineering. This paper presents the results of this four-year assessment and briefly describes the implementation of JiTT and peer instruction in civil engineering classes.

Overview of JiTT

JiTT is a learning technique that takes advantage of web-based communications to enhance active learning in the classroom[1]. The concept is to provide instructors immediate feedback on the students' level of understanding of a course topic soon before class. The instructor then has the opportunity to modify lesson content immediately before class in response to the data from students. JiTT involves providing pre-class exercises, sometimes called warm-ups, which students respond to via the web. The pre-class assignments are carefully designed to address learning objectives of a specific lesson and are composed of questions where the correct answer is not obvious and several enticing false paths are available to students. A typical question from a pre-class assignment is shown in Figure 1.

The students complete reading assignments and respond to the pre-class assignment the evening before class via the web. A few hours before the class, the instructor is able review the students responses, determine level of understanding of the particular learning objectives for the upcoming lesson, and adjust the classroom activities to respond to the students' current state of understanding. Student responses are easily incorporated into active learning components of the class. JiTT can complement and enhance interactive classroom learning strategies and provides feedback and support to both weak and strong students[1].

> Figure a) below shows a footing carrying a structural load, *F*. Figure b) below shows an embankment covering a large area. Both loadings are placed on the same soil and both loadings apply the same vertical stress at the ground surface. Will the settlement induced by these two loadings be the same? If not, which will be higher and why?

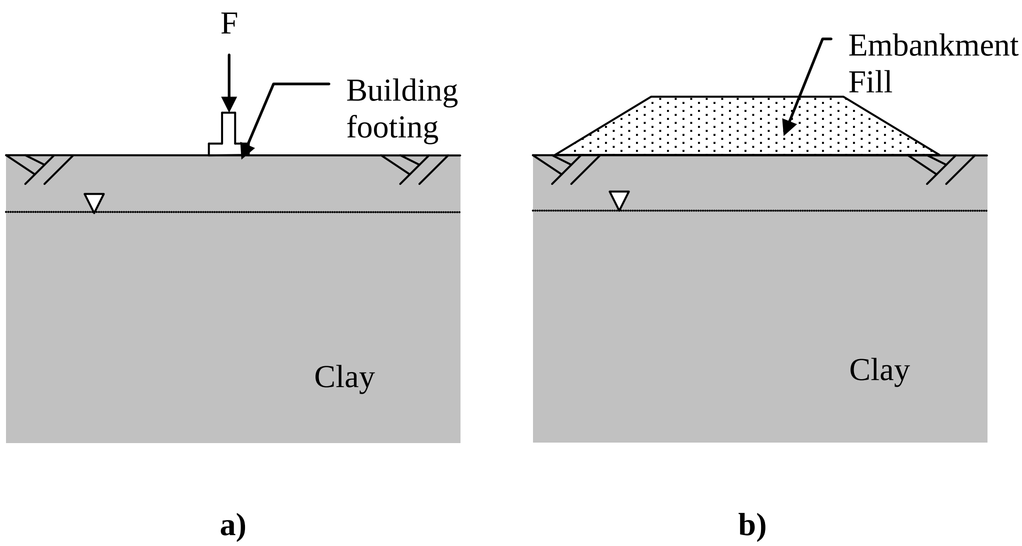

Figure 1: Typical question from a JiTT pre-class assignment

Courses used for assessment

The assessment was performed in a two course series comprising an introduction to geotechnical engineering. The courses were taught over two 10-week quarter terms. The first course in the sequence is a 2-unit course and the second is a 3-unit course, for a total of 5-units in the quarter system or approximately 3.3 units in the semester system. Enrollment in individual class sections ranged from approximately 30 to 45 students. The courses were required for all civil engineering majors and generally taken in the junior year.

The courses are intended to be taught as a seamless sequence, but there was no control over the flow of students from one course to the next. Some students may have a one to two quarter break between the two courses. Additionally some students may have started the sequence in a non-JiTT based class and moved to a JiTT based class in the second course, others students may have had a JiTT based class for both courses. A preliminary review of data from each course indicates no statistical significance in mean values of data collected (at a 90% confidence level).

A total of 8 different course offerings taught by 3 different instructors were included in the assessment. The instructors were all experienced civil engineering faculty with 7 to 20 years of teaching experience in this subject area. Six of the sections were taught by the author and the other two instructors taught one section each. No attempt was made to distinguish among data from the three different instructors.

Learning tools used in courses

The learning tools used in the courses included: assigned reading from a traditional textbook, comprehensive learning objectives for each lessons, JiTT pre-class warm-up exercises, and traditional computationally oriented homework exercises. One of the instructors, the author, also used peer instruction methods in the classroom. The inclusion of JiTT warm-up exercises was specifically designed to improve students' pre-class preparation, keep students on-schedule with the syllabus, and reduce cramming before exams.

Assessment tools and methods

The assessment instrument consisted of an online student survey collected using the Blackboard learning management system. Surveys were collected at the end of each course offering. The surveys were designed to measure the students' perceived effectiveness of each of the learning tools, level of class preparedness, and compliance with the course schedule. The survey consisted of 14 multiple choice questions and one open-ended general feedback question.

Typical questions related to effectiveness of learning tools included:

- Were the assigned problem sets effective in helping you learn the course material?
- The assignments posted on Blackboard included learning objectives for each lesson. How often did you use the learning objectives in your studies?
- Were the web-based pre-class warm-ups effective in helping you learn the course material?

Typical questions related to class preparedness and schedule compliance included:

- What percent of the time did you read the textbook or other assigned course materials before class?
- Do you feel you stayed more or less caught up in this class as compared to other classes you took this quarter?
- Did you complete the problems in the assigned problem sets as soon as the material for that particular problem was covered or did you wait until the problem set was nearly due to complete all of the problems?
- Did you put off studying for the exams in this class and end up cramming for the exams (saving nearly all your studying for the day/night before the exam)?

The questions generally used a three- or five-level Likert-type scale for responses. A few questions used numerical responses. Students were asked to provide their student ID numbers. These were used after completion of the survey to correlate the student responses to grades earned in the courses. To prevent any perception of grading bias, the surveys were not examined until after the posting of final grades for each course. A total of 296 students completed student surveys which were used in this assessment. The exact return rate was not determined, but this represents a return rate above 80%. In the statistical analysis of data, p-levels less than 0.10 or 10% were assumed to be statistically significant.

Student perceived effectiveness of the learning tools

The students were specifically asked how effective they felt each of the learning tools was: JiTT pre-class warm-up exercises, the traditional problem sets, the availability of learning objectives, and peer instruction techniques. The results of the perceived effectiveness of these tools are shown in Figure 2.

Based on the frequency of highly effective and effective ratings, students rank the effectiveness of these tools, from most to least effective, as

- Traditional problem sets
- JiTT pre-class warm-ups
- Peer instruction
- Availability of learning objectives

Problem sets, JiTT warm-ups, and peer instruction were particularly perceived as effective with over 60% of students rating them as highly effective or effective. In contrast, only 46% of students rated the availability of learning objectives as highly effective or effective. These data clearly show that both JiTT warm-ups and peer instruction are valuable learning tools, but they do not replace traditional problem sets which are critical to learning engineering subjects.

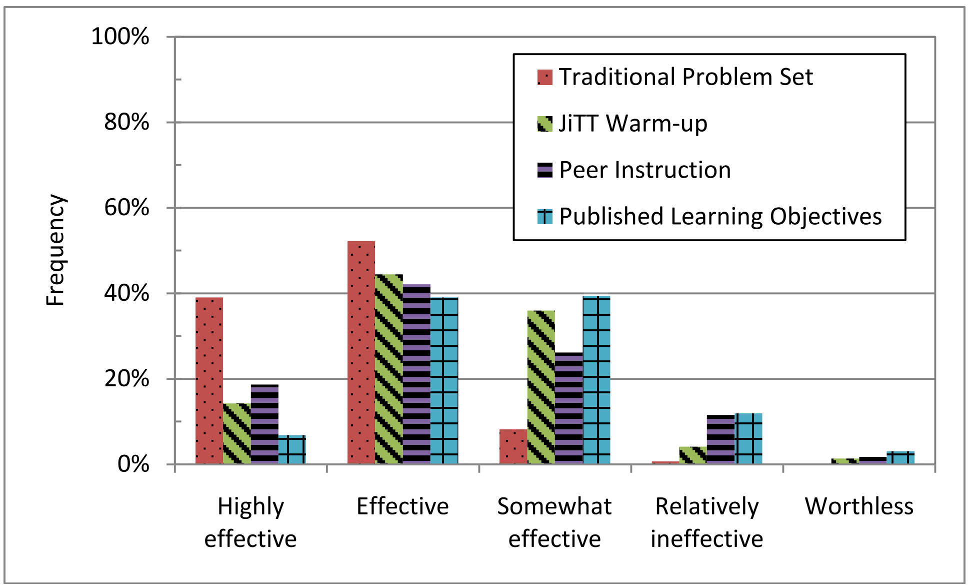

Figure 2: Student perceived effectiveness of learning methods evaluated in this assessment

Improvements in class preparedness and schedule compliance

Two survey questions dealt directly with student's pre-class preparation. Figure 3 shows student responses concerning the number of pre-class JiTT warm-ups completed during a term. Fully 78% reported completing over 60% of the warm-ups while only 4% reported completing less than 40% of the warm-ups. Since the students earned credit for completing the warm-ups and they were relatively easy to complete, it's not surprising to find such high compliance. Compliance with completing reading assignments was much lower, as shown in Figure 4. Even so, 56% of students report completing 60% or more of the assignments on time while only 15% report completing less than 40% of the assignments on time.

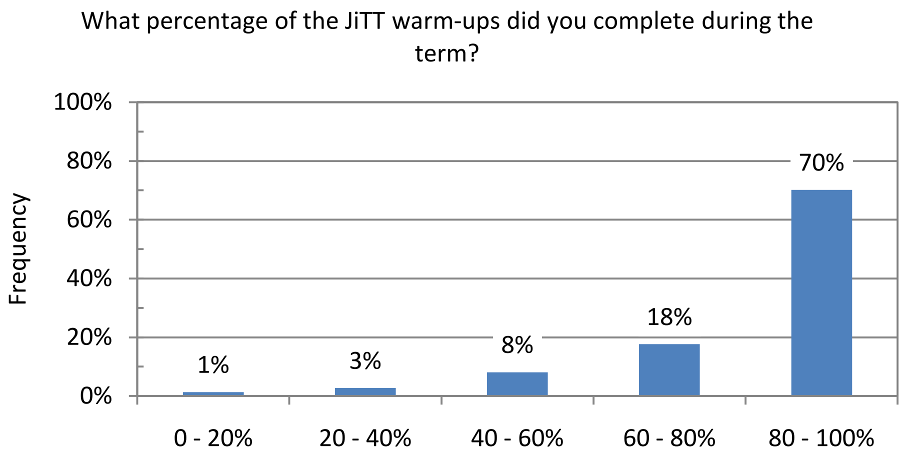

Figure 3: Student reported completion rate for JiTT pre-class warm-up exercises

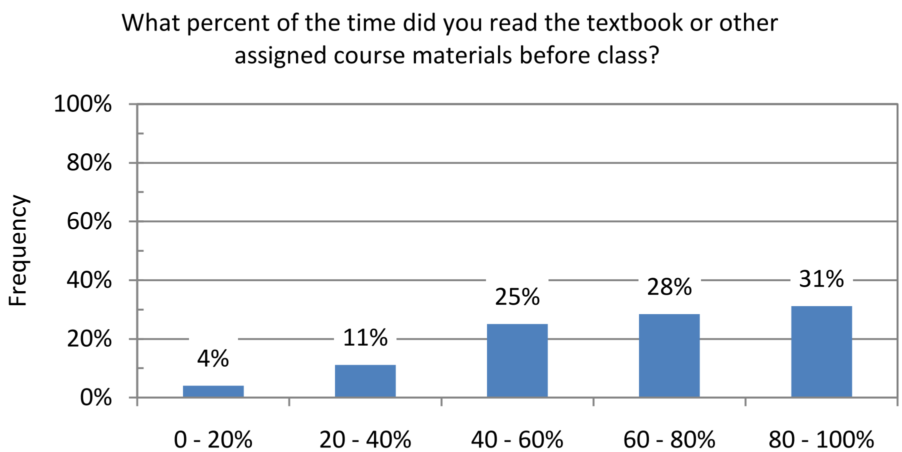

Figure 4: Student reported completion rate for assigned pre-class reading

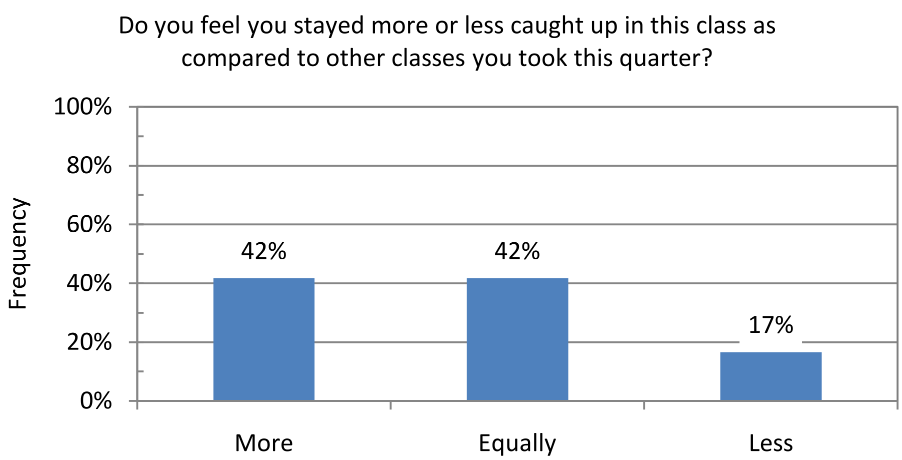

Figure 5: Student perceived compliance with course schedule compliance compared to other courses taken during the same term

In terms of schedule compliance, as shown in Figure 5, 42% of students report being more on-schedule in these courses compared to others and 42% report being equally on-schedule. The students report that the JiTT warm-ups were significant in keeping them on-schedule. Figure 6 shows that fully 88% report that the warm-ups helped to keep them on-schedule. Perhaps most importantly, students report significantly less cramming in these courses compared to other classes taken at the same time. As shown in Figure 7, only 37% of students reported cramming for classes in this assessment while 66% report cramming in other classes taken at the same time.

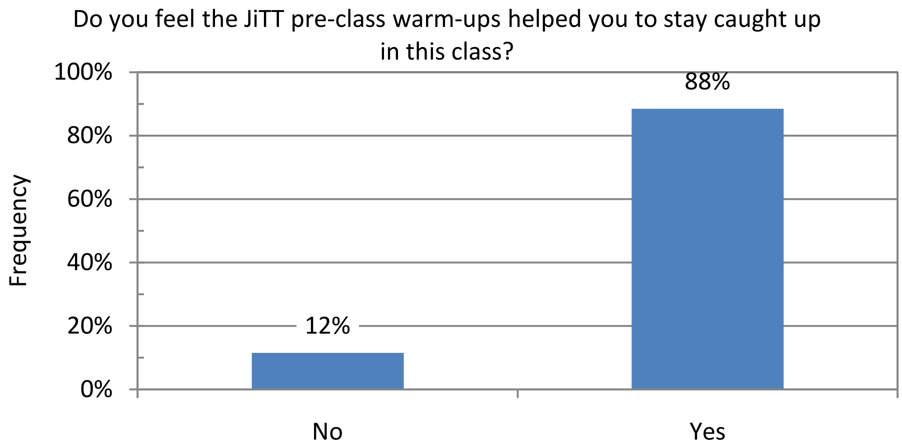

Figure 6: Student perceived impact of JiTT warm-ups on schedule compliance

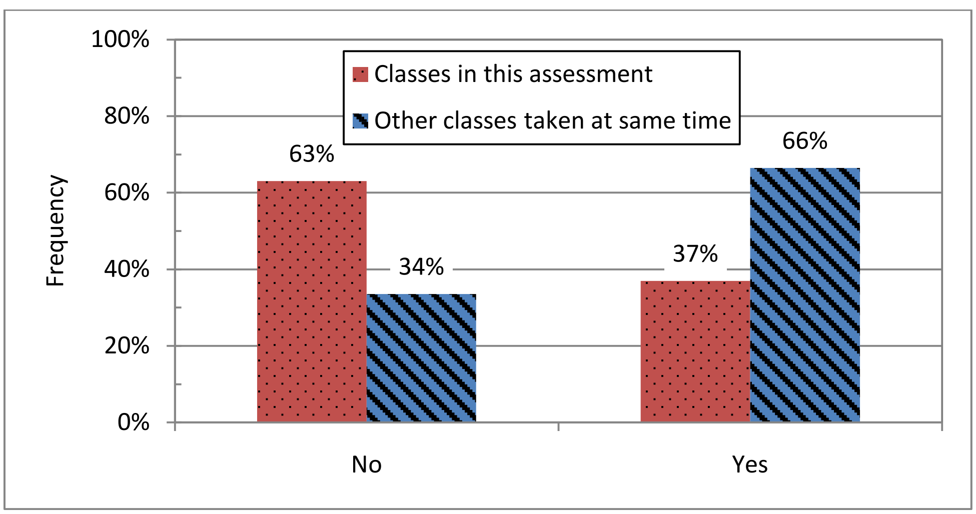

Figure 7: Student perceived cramming in assessed class versus other classes taken during the same term

Student reported behaviors and grade performance

To provide a more objective assessment of the effectiveness of the various learning tools, student responses to objective questions such as "how many problem sets did you complete", were compared to grades the students earned in the course. In this analysis the grade point average of students in each category were computed as well as the sample standard deviation. A one way analysis of variance was then performed to determine if the difference in grade point average

(GPA) among the groups were statistically significant. If there were only two categories of students, then the T-test was used to determine significance.

Importance of traditional problem sets

The analysis of grade performance as it related to completion of problem sets supported the students' perceived importance of problem sets. Students who submitted more than 75% of the assigned problem sets had an average GPA 0.72 greater than students who submitted less than 75% of problem sets, as shown in Figure 8, with a P-value less than 0.01. Additionally, the number of problems within each problem set that were completed was also significantly related to grade earned. Figure 9 shows that students who often or always completed all the problems in a problem set had an average GPA 0.63 greater than students who not often or seldom completed all the problems, with a P-value of 0.018.

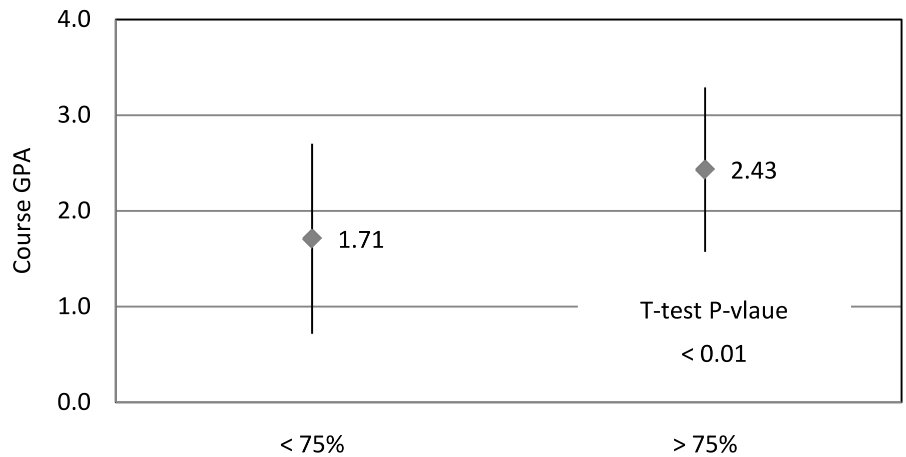

Figure 8: Comparison of course grade earned by students based on the percent of assigned problem sets completed—bars indicate plus and minus one standard deviation

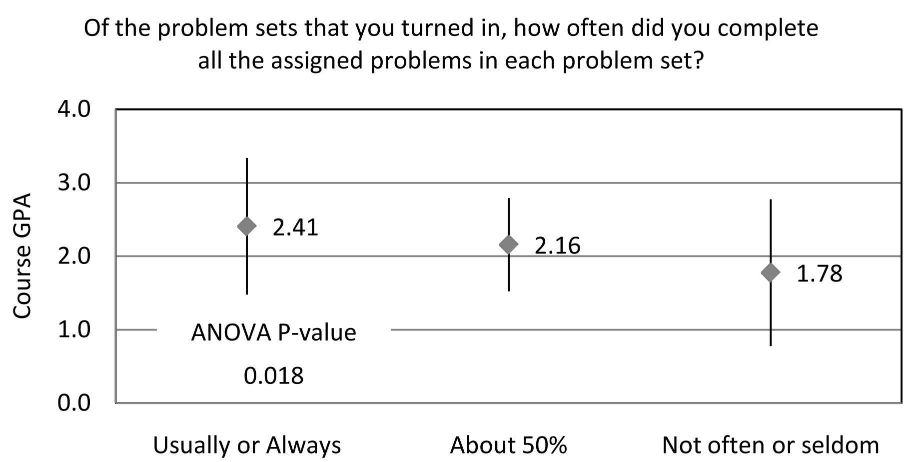

Figure 9: Comparison of grade earned by students based on completeness of the problem sets submitted

Importance of completing reading assignments before class

Students who completed more reading assignments before class earned higher grades than those who completed fewer reading assignments, as shown in Figure 10. The average grade difference between students who completed less than 40% of the assignments and those completing more than 60% of the assignments was 0.46 and the trend is clearly shown in Figure 10, with a P-value less than 0.01. While less important than problem set completion, this change is significant.

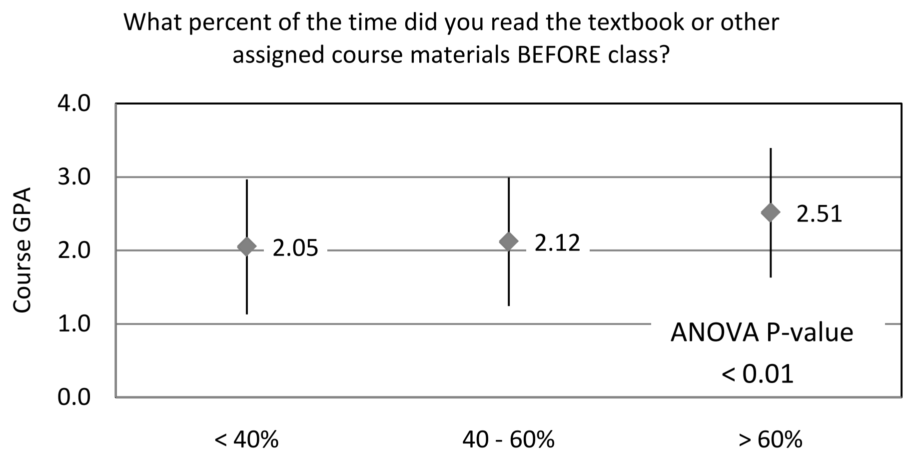

Figure 10: Comparison of grade earned by students based on percent of reading assignments completed before class

Importance of use of learning objectives

The relationship between the students' use of the published learning objectives and earned grade is shown in Figure 11. There is a clear and statistically significant (P-value of 0.06) increase in the average grade as the use of the learning objectives increases. However, the magnitude of grade increase is modest at 0.40. This is consistent with the students' perception that the value of having published learning objectives was positive but less important than other learning tools.

Relationship between cramming and earned grade

The relationship between whether or not students crammed for exams and the grades they earned is shown in Figure 12. The difference in average grade for the cramming versus non-cramming student is 0.30, with a P-value less than 0.01. While this is the smallest of all the average differences reported, this corresponds to nearly one third of a letter grade.

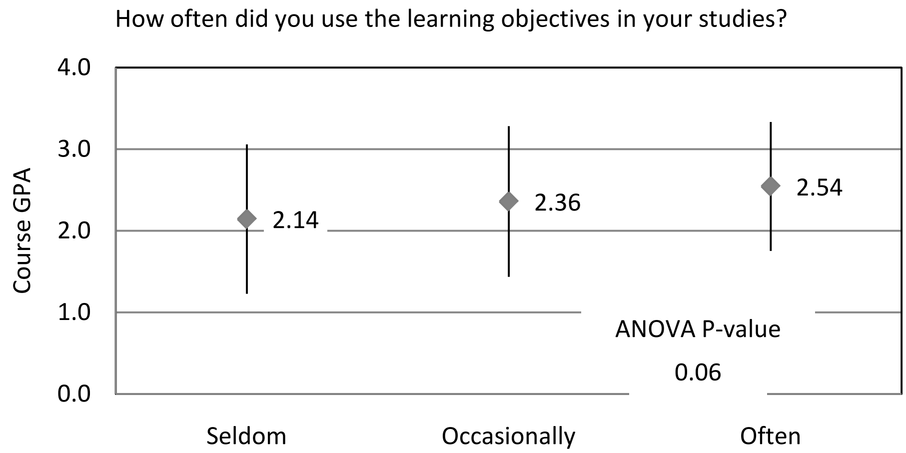

Figure 11: Comparison of grade earned by students based on usage of learning objectives

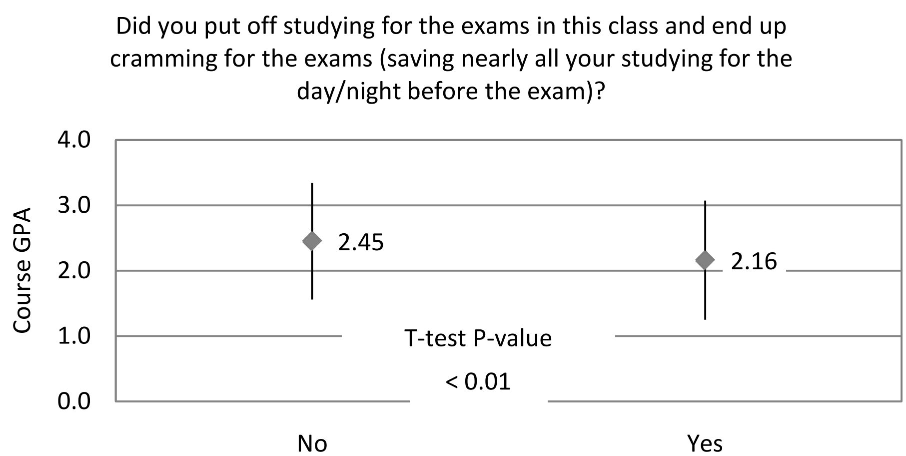

Figure 12: Comparison of grade earned by students based whether or not student reported cramming for exams.

Conclusions

This paper has evaluated the impact of JiTT and peer instruction in a typical junior level required civil engineering course and compared the effectiveness of these learning methods with more traditional methods, such as problem sets and reading assignments. The data set was relatively large, encompassing 296 student assessments over a four year period, and including data from classes taught by three different instructors.

Completing computational problem sets remains the most valuable of the learning tools evaluated in this research. Both the students' perceptions and the grades earned by students, support the importance of thoroughly completing problem sets when students are studying engineering courses. While no causal relationship can be established using the data collected, it is clear that students who complete most of the problem sets are student who earn higher grades.

The JiTT pre-class warm-up exercises not only helped to keep students on track with the course schedule, but were also perceived by students to significantly improve their learning in the courses. In addition, students reported significantly less cramming in these classes compared to other classes taken during the same term. The non-cramming students earned grades slightly higher than those who did report cramming. Peer instruction was perceived by students to be an effective learning method.

Finally, while students did not perceive the availability of learning objectives for each lesson as particularly important, the grade performance of students regularly using those objectives was noticeably higher than those who did not regularly use them. Similarly, students who regularly completed the reading assignments before class had noticeably higher grades than those who did not regularly complete the reading assignments. Again while no causal relationship can be established, students who take advantage of these traditional learning tools are students who earn higher grades. These traditional tools appear to be valuable and should be supported and encouraged.

Summary

Active learning methods such as JiTT and peer instruction can clearly enhance and support more traditional learning methods typically employed in engineering classes. They can improve student preparedness for class and enhance learning. It is relatively easy to implement JiTT methods using existing learning management systems without any additional specialized software. This technique has been well proven in the sciences, and engineering faculty who have adopted the approach are finding it improves student learning. The engineering education community should continue to publicize JiTT and peer instruction applications and encourage their further implementation and adoption by programs.

References

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