Using Technology for Concepts Learning and Rapid Feedback in Statics

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Abstract

In this project our goal is to improve student learning in the foundation mechanics course Statics as well as improve knowledge retention (durability) and knowledge application in a different environment (transferability). We aim to do this by providing rapid feedback to students of their understanding of key concepts and skills being presented. The feedback system acts as the focal point and catalyst to encourage students to assist each other in correcting misconceptions or deepening each other's understanding of the topic or skill at hand. Furthermore, the system allows the professor to assess the students' level of comprehension (or misconception) in a just-in-time fashion, and thus guide his or her pacing and coverage of the material. The rapid feedback is enabled through wireless-networked handheld personal digital assistants (PDAs) or flashcards. In the first two years of the study, we have implemented the system in two sections of Statics using a crossover design of experiment, where one section receives the rapid feedback 'treatment' (i.e., use of the PDAs) while the other (the 'control' group) receives rapid feedback on the exact same topics, but only through the use of flashcards instead of PDAs. After a predetermined period, the sections swap their feedback treatment. Several swaps are achieved during the course, and in this manner each student acts as his or her own experimental control to assess the effectiveness of the treatment. This paper focuses on implementation and feedback methods in statics, a brief summary of statistical analysis, results of student learning and use of feedback in follow-on courses.

Introduction

Core engineering courses, such as Statics, are comprised of key concepts and skills that students need to master in order to succeed in follow-on courses. Students must *comprehend* these concepts at sufficient depth (as opposed to rote memorization of procedure) and *transfer* this understanding to other courses and contexts. In this multiyear project, our hypothesis is that such learning is facilitated in an active, peer-assisted environment in which the students are provided frequent and rapid feedback of their state of learning.

Background and Motivation

Bransford et al.[1] point out that "effective learning is its durability and transferability," which means having a long-term impact on how it influences other kinds of learning or its application in other contexts. Furthermore, they state: "Learning must be guided by generalized principles (concepts) that are widely applicable. Knowledge learned at the level of rote memorization of rules and algorithms inhibit transfer and limit durability. Learners are helped in their independent learning attempts if they have conceptual knowledge."

Providing feedback to students of their current level of understanding of concepts is critical for effective learning. It is also important for the professor. This feedback is typically realized through homework sets, quizzes and tests. All of these techniques, however, suffer the faults of being too slow, too late, and too tedious to apply frequently. Freeman and McKenzie[2] discuss several issues that inhibit better student learning in higher education. For students, there is a lack of individual feedback on learning; few opportunities for dialogue to improve learning; and a feeling that the subject is impersonal. From the faculty members' perspective, the difficulties lie in knowing what students are really learning, providing individualized feedback, addressing students' specific misconceptions, attending to diverse learning styles, and engaging students in learning.

Bransford et al.[1] state: "Learners are most successful if they are mindful of themselves as learners and thinkers. In order for learners to gain insight into their learning and their understanding, frequent feedback is critical: Students need to monitor their learning and actively evaluate their strategies and their current levels of understanding." Freeman and McKenzie[2] support this idea, noting that "Feedback is fundamental to learning... Students may receive grades on tests and essays, but these are summative assessments… What are needed are formative assessments, which provide students with opportunities to revise and improve the quality of their thinking and understanding. If the goal is to enhance understanding and applicability of knowledge, it is not sufficient to provide assessments that focus primarily on memory for facts and formulas."

Our project addresses all of these issues by providing students with timely feedback and opportunities to improve learning. Our goal is to combine rapid feedback with conceptual learning and skills development, and to demonstrate improved student learning through rigorous experimental design and data analysis.

Project Design and Implementation

Course description

At Rowan University, Statics is a required course for sophomores in three of the four engineering disciplines (Civil & Environmental, Electrical & Computer, and Mechanical Engineering). The course content is similar to that of most engineering programs in the US, although the pace and length of the course is unusual. Rowan students take Statics in a compressed, half-semester (7.5 weeks) format, with classes meeting for three 75-minute periods each week. (Students receive two semester-hour credits upon passing the course.) The format dictates a faster-than-usual pace of coverage of the material with little time spent in reviewing course material from previous lectures. Statics is delivered in the first half of the Fall semester, followed in the second half-semester by Dynamics. In the first half of the Spring semester, Civil & Environmental and Mechanical Engineering students continue in the engineering mechanics sequence by taking Solid Mechanics (also known as Mechanics of Materials).

In Fall 2003, we began this study with one of the authors teaching two sections of statics and we treated this year it as a 'trial run' for the subsequent years. For example, we acquired all the PDAs that were to be used for this study, set up, tested and practiced with the software used to collect data, and developed most of the quizzes for which rapid feedback would be provided to students. Data was collected for a variety of in-class questions, quizzes and exams to help anticipate what we would possibly see in subsequent years of the study. In the most recent offering of the course in Fall 2004, we repeated what was implemented in the previous year except that data was taken for subsequent analysis. All of the reported results in this paper come from Fall 2004.

As mentioned previously, one of the authors taught two sections of Statics in Fall 2004. This was done in order to eliminate any differences in teaching style or content between the two sections. Having a single professor also ensured that the two sections maintained the same pace through the course from day to day. At the start of any class, the students in each section are provided with one of two means of receiving rapid feedback: a PDA or a flashcard. With the PDAs, students are paired up and share a single PDA, whereas with the flashcards, each student in the section is provided one. Details about the feedback methods are described later.

The in-class portion of this study is conducted in a similar manner to that described by Mazur.[3] The professor presents a new topic or concept for no more than 10-15 minutes, using traditional lecture, demonstration, or sample problem solution. Thereafter, he poses a 'concept question' or a 'skill quiz' to gauge the students' understanding. If the student responses from the feedback system (PDAs or flashcards) show that a high percentage of students do not understand the concept, the professor elaborates on or further explains the topic. If the responses show that a reasonable fraction of students understands the topic (a distribution of answers, but a plurality with the correct answer), the professor directs the students to take time and explain the concept or skill to each other. Thereafter, the students are asked to either respond again to the same question, or a different question on the same topic may be posed. The final scenario occurs when the responses show a high percentage of correct answer, indicating that students understand the topic. In this case, the professor would simply continue to the next topic.

In addition to assigned homework sets, which were completed by students in two-person teams, quizzes and tests were used for student evaluation. In the 7.5-week period of the course, nine homework sets were assigned, and eight quizzes and two non-cumulative examinations were given. Identical homework sets were assigned to the two sections. Whenever a homework set was submitted by the students, a brief quiz was given which covered some concept covered in the homework. Quizzes were designed to be similar, but not identical, between the two sections. The scores on the quizzes and examination questions were analyzed, as described later, to assess for differences between the two feedback methods.

A crossover design of experiment is used in this study. The method is intended to eliminate potential confounding factors that cannot be controlled for using a standard analysis of variance model. For example, students may not be randomly assigned to each of the two Statics sections (for example, one section may have mostly electrical engineering students, who have a different motivation level than the other section, which might be populated mainly with mechanical engineering students), or the time at which each section is held may affect student performance. Without the crossover a potential treatment effect would have been indistinguishable from a section effect.

In a crossover design, one of two study groups (course sections in this case) will be randomly chosen to receive instruction with the PDA-enabled system (the 'treatment' group) while the other group will use the flashcard system (the 'control') for a fixed period of time. For the next 'treatment period,' the two sections simply swap the feedback method, and this continues for the duration of the course. In this manner, each section acts as its own control to eliminate the noncorrectible confounders. This design has the additional advantages of eliminating any bias that may be introduced by the professor in course delivery in the two sections, and minimizing any attitude bias that may be displayed by students of either section due to receiving a single method of feedback for the entire course if swapping did not occur. The treatment periods generally lasted from two to five class meetings, as was determined to be logical based on the skills or concepts being covered during the period.

Rapid feedback methods

The flashcard method for providing feedback to students was developed by Mehta.[4] In short, double-sided and color-coded cards are used by students to display their answer to a question posed by the professor. Each card can display one of six possible responses. The cards provide a quick means for the professor to scan the class's response and qualitatively determine the distribution of answers.

A fleet of 18 PDAs is used for the PDA-enabled feedback method. Half of the PDAs are Palm-OS-based and half are PocketPC-based. All of the PDAs have wireless networking capabilities (802.11b or WiFi) and communicate with the professor's Windows XP Tablet PC using a peer-to-peer networking mode. The software we use to record and display student responses using the PDAs is a pre-beta version of OptionFinder VP, which is being developed by Option Technologies Interactive (www.optiontechnologies.com).

Regardless of the feedback method, the concept question or skill quiz is posed by the professor through his Tablet PC and is projected to the front of the class, along with the possible solutions. The correct solution is embedded with 'confounders', which are derived from common student mistakes or misunderstanding. Students are given time to reflect on the question posed, discuss it with their peers, and then must select from the possible solutions. The major differences between the two feedback methods are that the PDA/software-based method allows for (1) quantitative and permanent recording of the student responses for future review and (2) a display of the tallied student responses that is projected up on the screen nearly instantaneously after the students respond.

Data analysis

This project is comprised of three major components: The development of a suite of concept questions and skills quizzes for the course, the use of rapid feedback and peer-assisted learning in the classroom, and, for the current year of study, a comparison between the two methods of providing rapid feedback to students. The third component required the bulk of the statistical analysis. The primary focus of this analysis was to see if the method of implementing the rapid-feedback quizzes – using PDAs or flashcards – had an effect on the students' learning. The response variable tested is the exam or quiz score for the corresponding period of instruction, where one section had the treatment and the other the control (or vice versa). This would be done while controlling for factors (or variables) other than the treatment factor which might affect the scores.

To analyze the treatment factor (PDA vs. flashcard) while controlling for the other 'nuisance' factors that could affect scores but are not attributable to the treatment, we employed a general linear model where Freshman-year GPA and the Calculus I, Calculus II and Physics I grades were treated as continuous covariates.

The Class, the Student, the Quiz and the Treatment factors were discrete. The Quiz factor was included because some topics may be intrinsically more difficult than others, which would make the quizzes different in difficulty. Further discussion of the model may be found in the authors' other work[5].

Results

As a comparison between subjects, we measured the students' "gain" in statics through the application of a Statics Concept Inventory.[6] The reader is referred to the referenced work for details on the Concept Inventory and its use as a measure of student learning. In summary, the students from the Rowan Fall 2004 cohort scored an average gain of 35.9%. We have not had sufficient time to make comparison with other data or to draw conclusions from this finding.

A second set of results we obtained was from two surveys administered to the cohort, one approximately halfway through the course, and the other on the final day of the course. Note that the responses from both sections of students were combined and analyzed.[5] In general, the survey results show that students have relatively little familiarity with PDAs (based on the mid-course survey), but still an overwhelming majority in either survey found that the PDAs (and the associated rapid feedback method) enhanced their learning experience. In both surveys, a majority of students found that rapid feedback with either the flashcards or the PDAs was at least 'somewhat helpful' to their learning, with a significant preference in both surveys for the PDAs. We attribute this finding to the immediate availability of the tallied responses that was provided to the students using the computer and software. Finally, in comparing the results between the two surveys, it is obvious that as the course progressed, the students' acceptance of rapid feedback using either method increased. This is seen in the results showing that the percentage of students who found either method to be either 'somewhat useful' or 'very useful' increased from 59% to 80% for the flashcards and from 73% to 94% for the PDAs.

Based on our statistical analysis of the quiz scores, the Treatment was not significant (p-value = .0947). At first this was disappointing, as this was the factor of interest for this part of the project. The result is probably due to the fact that using PDAs vs. flashcards to record the student's answers to the rapid-feedback quiz questions would have little effect on their score. Although we had thought that the 'coolness' of the PDA would affect a student's learning, it really would only affect their interest during the physical activity of reporting their answers in the classroom. In the end their quiz scores would be affected by outside work (such as studying!), inherent interest in the material, or other factors which would not significantly influenced by the fact that a PDA that was used in class (and not taken 'home'). This finding, along with our survey results, suggest that rapid feedback is useful and well accepted by students, and that it does not matter which of the two forms of feedback is used, so long as it is used.

Findings in Follow-on Courses

In order to assess the durability and transferability of the statics concepts and skills, the rapid feedback methods, both flashcards and PDA's, were used in the subsequent mechanics courses of dynamics and solid mechanics (mechanics of materials). Concepts and skills that students learned in statics were tested in the follow-on courses and student performance was tracked. The concepts and skills in dynamics that students should be able to do are draw free body diagrams (FBD), write and add vectors, decompose a vector into its components, carry out a cross product to compute a moment or couple and compute and know when to use a unit vector. In solid mechanics, the students again must be able to do the above as well as write the equations of equilibrium.

Since one of the authors teaches only one section each of dynamics and solid mechanics, no crossover experimental design was conducted. Instead the rapid feedback methods were used in one of two ways, 1) as a precursor to a topic in a follow-on course that was previously learned in statics to detect retention and transferability or 2) during the lecture as new concepts or skills were being taught, similar to the procedure in statics. When a topic such as determining the moment about a point due to an external force was needed to solve a problem in dynamics, a question was posed to the students along with possible solutions before this concept was reviewed in dynamics. Thus, the feedback results were tabulated to determine student retention of concepts learned in statics. If a majority of students answered incorrectly, then they were asked to discuss and answer again before the instructor provided review. If a majority answered correctly, then no review was necessary. Further questions were posed to the students to provide rapid feedback to the instructor when teaching new concepts in dynamics and solid mechanics. In both cases the correct solution is embedded with 'confounders' derived from common student mistakes or misconceptions as previously discussed.

In the first year of the study, students took dynamics from one of the authors in the Spring of 2004. This was a trial run at using the system and students showed some retention of concepts such as free body diagrams, cross products and moments from statics to dynamics on the order of 50 percent. The authors did not teach and thus was unable to implement use in solid mechanics in the fall of 2004. In the second year of the study, 2004-2005, dynamics was moved to the second half of the fall semester, which was the 7.5 weeks immediately following statics. Student retention of concepts such as moments and vector forces was high at 80 to 90 percent, which may be due to the fact that time between the statics and dynamics was less in year two of the study. The same author taught and used the feedback methods in solid mechanics, a 7.5 week course in the first half of spring 2005. The author often asked skill and concept questions to the students to test their ability to draw free body diagrams, write equations of equilibrium and determine reaction forces and moment, all of which were taught in statics. Without reviewing, the author tested the students on free body diagrams and equilibrium for trusses to introduce axial forces to the students. Retention was 50 percent for the correct free body diagram and 90 percent for writing forces into component and writing the equilibrium equations.

Conclusions

We believe that the use of rapid feedback, regardless of treatment type, aids in improving student learning in the foundation mechanics course of Statics. This was shown by analysis of data during the beginning of the study. Both of the feedback methods allow the students to be active learners and provide the instructor will real-time feedback of students' understanding or misunderstandings. Survey results showed that as the statics course continued the percentage of students who found the feedback either 'somewhat useful' or 'very useful' for both types of treatment. We also believe that rapid feedback use improves knowledge retention (durability) and knowledge application in a different environment (transferability) in subsequent courses of dynamics and solid mechanics as seen by preliminary results.

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