Evaluation of immediate feedback tools in an undergraduate statics/solid mechanics course

Kenneth Marek
Mercer University

Abstract

In an age where students' ability to learn course material is understood to depend on many factors including personal learning styles, family background, and the accumulation of past personal experiences and educational opportunities, the problem of teaching large classes of diverse students and evaluating their performance in an effective, efficient, and equitable manner can seem daunting. In an effort to improve the student learning process, an instructor introduced two significant changes into a statics and solid mechanics course in the spring semester of 2016. Homework was changed from a paper assignment to the textbook publisher's online platform, and frequent in-class quizzes were introduced, in which students graded their own work and were awarded full credit for turning in the quiz, regardless of the assigned grade. These two measures had the mutual benefit of reducing the instructor's grading load, while simultaneously providing students with much more immediate feedback on their learning progress. Additionally, the feedback available to students was also available to the instructor, who could therefore make more immediate lesson changes to accommodate student needs. To collect specific feedback on overall student perception of these changes, an anonymous survey was given at the end of the semester, in which students rated the effectiveness of various tools and techniques employed in the course. Other than the items already described, the survey asked about lectures, the course textbook, publisher-based online resources other than the homework system, and independently obtained learning resources. These surveys, combined with other available feedback data, are analyzed in a continuing attempt to improve the teaching of this course.

Keywords

teaching, methods, statics, active, technology

Introduction

While introductory engineering courses have traditionally been taught in a lecture format with chalk and board for many years, it has long been argued that this educational style must evolve in terms of both technology and teaching methods employed (for example, by the Board on Engineering Education[1]). In particular, active learning methods have been advocated by many sources, and have been shown to improve student performance in engineering statics courses[2].

This paper addresses recent changes made to a statics and solid mechanics course taught by an early career instructor. After experiencing some frustration with a traditional grading model of homework, quizzes, and exams, the instructor made two changes the following semester which, among other things, provide students with immediate feedback on their work. One was to change

the mode of homework assignments to take advantage of available technology, and the second was to change the quizzes to promote more active learning (similar to a method cited by Crawley *et. al.*[3]), both of which are discussed below. While the overall goals of these changes include improving student motivation and satisfaction, providing more immediate learning feedback to students, and ultimately improving teaching/learning effectiveness, the evaluation of these methods are limited at present to two measures. First, the changes were evaluated by a student survey at the end of the semester. Second, an attempt has been made to correlate each activity to exam performance.

Teaching Methods

The first teaching alteration made was to assign online homework rather then homework out of the textbook. This change presents several advantages to the instructor and to the students. It frees up considerable time for the instructor which might otherwise be spent grading homework, while also providing an automatic and impartial grading scheme. It also provides immediate results to students regarding the correctness of each problem solution, and gives them several opportunities to try again if their first answer is incorrect. While these are significant improvements, there are also some downsides to this system. First, since the problems are essentially the same as the problems in the book, with the possible exception of changed numbers, students might have used the solutions manual for a crutch with problems assigned from the book are still able to do so; and if they do, the tell-tale sign of turning in homework which looks exactly like the solution manual no longer occurs. Additionally, there is an extra cost passed onto students when this method is used. The feedback they receive on incorrect answers is also generally not helpful toward finding the correct solution, except in a few special cases such as when the wrong sign or units are entered. The non-specific feedback is particularly frustrating when the online system gives ambiguous instructions or does not accept correct answers, which happens more than might be hoped.

The second change to be made was that, while quizzes are still included in the course, they have been transformed into a group learning and immediate feedback activity. Quizzes are given once every one to two weeks. Students work individually for a period of 5 to 15 minutes (depending on the difficulty of the quiz) and are then allowed to reference their notes and/or discuss their solution attempts with their neighbors. This continues for another 5 to 15 minutes, before either a student volunteer (for extra credit) or the instructor shares a solution with the class. Students then grade their own quizzes on a scale of 1 to 5 as shown in Table 1. All students receive full credit in the gradebook for turning in a quiz regardless of the self-grade, but the grading system allows students to gauge their own understanding of the material in a low-stress environment, along with letting the instructor track learning progress (from the students' points of view) without having to meticulously grade quizzes on a regular basis, and allowing the instructor to maintain this record of student progress to assist in discussions if the student is having trouble in class. In addition to the grading system, the quiz system allows students to work in groups or alone with notes according to their preference, while forcing them to evaluate their own understanding based on their initial attempts to solve the problem. Frequent quizzes are also helpful in encouraging regular class attendance. Downsides to this method appear to be few. One might be that the time spent on quizzes is "wasted" for some instead of using more time to lecture or discuss homework, *etc.* Another potential disadvantage is that, while the students self-evaluate

their work, some might get a more honest evaluation of their understanding from the instructor rather than their own review of their performance.

Table 1. Quiz self-grading scale.

Self-grade	*Typical statement descriptive of student understanding after solution is discussed*
5	"I found the right answer mostly/completely on my own."
4	"I found or nearly found the right answer, with little or no help."
3	"I needed some help to arrive at the correct solution."
2	"I wasn't able to figure it out, but now I think I understand how to work the problem."
1	"I still have no idea what is going on."

Evaluation Criteria

At the end of the semester, students were asked to fill out an anonymous survey regarding teaching techniques/tools. No indication was given regarding the particular interest in the quiz and homework changes, other than what might be understood from the survey wording. The following instructions were included:

> Please rate the following activities by how much they helped improve your understanding of concepts in statics and solid mechanics. Negative numbers indicate that time spent on these topics was unproductive or inefficiently used; positive numbers indicate good productivity and efficiency. You may also circle N/A for activities that you did not do or barely participated in.

Students were then provided the following long descriptions in Table 2 below, which shall be identified in this paper by the corresponding short identifier. A list of integers from -3 to 3 was given to be circled, along with the choice N/A. If multiple numbers were circled, the average value was used in the results; if no choice or N/A was circled, that data point was not considered. Space for comments was also included for each item; for the sake of brevity and because generally did not add significant insight to the problem being considered, only the specification of Other resources is discussed in this paper.

Table 2. Student survey categories. Ratings for each category could range from -3 to 3 or N/A.

Long Description	*Short Identifier*
In-class lectures	Lectures
In-class quizzes used to review concepts	Quizzes
The fact that quizzes were a "free grade" evaluation	Quiz Grades
Homework problems	Homework
The fact that homework was submitted and graded online	Online HW
Reading your textbook	Textbook
Online textbook resources at pearsonhighered.com	Online Resources
Other resources – please specify (*e.g.* online tutorials, paid tutor, studying with friends)	Other

In addition to the survey, some attempt is made here to correlate quiz and homework results to performance on exams. This provides some ability to correlate quizzes and homework as preliminary assessments of student understanding, but does not necessarily provide useful information regarding these items as teaching tools *per se*. Unfortunately, no data is currently

available regarding the teaching of statics material with and without these tools, so a direct comparison may not be made in that regard.

Results and Interpretation

Out of 28 students finishing the course, 22 provided survey responses. The results have been summarized in Table 3 below, including the number of responses for each item, the average value and standard deviation for each response, and the number of responses for each item which corresponded to the highest and lowest rating given on a given survey (such that each survey might have more than one highest or lowest item; however, no survey rated all items the same).

Of particular interest is the Other category, which simultaneously had the highest average rating and the lowest standard deviation. Some discount should be given to this rating based on a self-selection bias, as only those students who felt the need to search out other resources would have rated Other resources at all. Nonetheless, the response does indicate that at least half the class looked to outside resources of at least one kind. Of the 16 Other responses, 9 (56%) indicated that they studied with or had help from friends or acquaintances, 5 (31%) indicated the use of various online resources including YouTube, Khan Academy and other generic descriptors, 1 (6%) indicated the use of tutors, and 2 (13%) did not indicate what Other resources they used. One student indicated two Other resources, resulting in a total of above 100% for the responses as listed.

After Other, Quiz Grades and Quizzes rated the most popular items, followed by Homework and Lectures, and then Online HW and Textbook. Although a selection bias might be expected for the Online Resources similar to Other, the fact that they are they only negative rated resource suggests that they were either very unhelpful, poorly marketed, or otherwise difficult to use.

In addition to being well liked on average, Quizzes and Quiz Grades received fairly uniform ratings, with standard deviations of less than 1, and both earning a large number of highest ratings. Online HW and Textbook, while liked on average, showed the most diversity of opinion, with standard deviations of 1.7 and 1.5, respectively; they also each received more highest ratings and fewer lowest ratings than Lecture, which was rated higher on average than each of them.

Table 3. Student survey results.

Short Identifier	*No. Responses*	*Average Rating*	*Standard Deviation*	*No. Highest Ratings*	*No. Lowest Ratings*
Lectures	22	1.9	0.9	5	9
Quizzes	22	2.5	0.9	15	3
Quiz Grades	22	2.6	0.8	17	2
Homework	21	2.0	1.2	8	3
Online HW	22	1.6	1.7	6	8
Textbook	20	1.5	1.5	6	5
Online Resources	6	-0.1	0.6	0	5
Other	16	2.8	0.4	13	0

Of the two "instantaneous feedback" learning tools, the students clearly felt more favorably about the Quizzes and the easy Quiz Grades than the Online HW, although opinion was significantly varied with the homework, and both were perceived favorably according to the survey. The relatively high number of students who studied with friends might indicate that the group work aspect of Quizzes helped with their high ratings, and the easy grade aspect almost certainly helped, although with the present information, it is difficult to determine specific motivations for all students. It may be noted that several students also gave comments indicating that the Quizzes were good indicators of what might appear on an exam. Compared to the Online HW, the Quizzes definitely lacked many disadvantages such as the technical problems and lack of helpful feedback for wrong answers which often plagued the Online HW.

In addition to the helpful information provided by the student survey, it is also of interest to see how well quiz and homework grades correlated to exam grades. While this does not test their effectiveness as teaching tools, it does provide some indication as to their effectiveness as early evaluation tools before exams. In the semester of this study, two midterm exams and one final exam were given. Since some students with a certain grade average were not required to take the final exam, it is omitted from the present consideration. Four quizzes and nine homework assignments corresponded to the material in the first midterm exam, with another four quizzes and nine homework assignment corresponding to the second.

To test the predictive power of homework grades, homework averages corresponding to each exam were fitted to the exam grades using a linear regression. The data sets for both exams were combined to find a single regression line. While grades are not plotted in the interest of privacy, the slope of the fit and the coefficient of determination are both given for the regression in Table 4. The homework and exams were both graded on a 100 point scale, so a slope of 1 might be considered "ideal" in some sense. Instead, the slope was 0.0648, or very nearly zero. The coefficient of determination, which is ideally unity for a perfect model fit, is also an extremely low value of 0.0096. These numbers indicate that there is essentially no correlation between homework and exam grades.

A similar analysis was performed for quiz averages. In this case the slope was normalized by dividing the regression slope by 25 (since there is a 4 point range between 1 and 5 for quizzes) so that the regression slope can be directly compared to that of the homework. Here the slope is a much larger 0.2903, and the coefficient of determination, while not large, is still an order of magnitude larger at 0.1659. This means that there is at least some correlation between quiz grades and exam grades, which could be helpful. However, most of this correlation occurs at the extremes. When the quiz averages of less than 2 and greater than 4 are removed (about 15% of the data set), the middle quiz grades form an even worse correlation to exam averages than the homework data, with a normalized slope of 0.0498 and coefficient of determination of 0.0024. Thus, while the students who rate their quizzes either very high or very low generally perform comparably on the exams, the quiz grades of those who score themselves in the middle 50% of the grade range are again completely uncorrelated to exam performance.

Table 4. Grade correlation results using linear regression.

Comparison	*Normalized slope*	*Coefficient of Determination (R^2)*
Homework	0.0648	0.0096
Quiz	0.2903	0.1659
Quiz (reduced set)	0.0498	0.0024

Conclusions and Future Plans

Based on the student surveys, the new quizzes were an extremely popular teaching/evaluation tool, and should be continued into the future. The self-evaluated quiz grades correlated somewhat with exam grades, but only on the extremes of the grade scale. It may be interesting to see if using a larger quiz grade scale will improve the correlation; further study may indicate if the quizzes can be made more useful as learning evaluation tools. With the online homework, student perceptions were more mixed but were still positive overall. The homework grades effectively were not correlated to exam performance, so in that sense the homework is not a very useful learning evaluation tool. In spite of their limitations as learning evaluation tools, it should not be assumed that they are not effective teaching tools; it would be ideal to be able to quantify this quality as well. Possibly teaching future classes with different permutations of quizzes and homework options will help to determine their efficacy as teaching tools.

References

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Kenneth Marek

Kenneth Marek is an Instructor in the Department of Mechanical Engineering at Mercer University. He earned a Ph.D. in Mechanical Engineering from the Georgia Institute of Technology in 2014. In addition to striving to be a better teacher, he has research interests in the areas of acoustics and dynamics.