AC 2012-4397: IMPROVING STUDENT RETENTION AND ENGAGEMENT IN STATICS THROUGH ONLINE FORMATIVE ASSESSMENTS AND RECITATIONS

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Improving Student Retention and Engagement in Statics through Online Formative Assessments and Recitations

Abstract

Statics is one of the first fundamental engineering courses in almost all engineering fields; it is a challenging course prerequisite for several engineering mechanics and design courses. Students in Statics need to acquire a strong foundation of long-lasting knowledge and deep understanding of concepts, while mastering adequate techniques and procedures that are essential to analyze and solve engineering problems. However, many engineering programs are facing serious difficulties in promoting student academic success in Statics. In the Mechanical Engineering Department at the University of Texas-Pan American (UTPA), the average passing rate in Statics during the past ten regular semesters is 60.7%, with about 14.3% students dropping the course, and about 25.0% getting D or F grades. Students drop or quit the course due to different circumstances at several stages along the semester. Some common documented reasons for students to drop the course are: deficiency in math (algebra and trigonometry), poor study skills and habits, work to support themselves and their families, taking too many courses, and lack of commitment and discipline, among other. For students that stay in the course until the end of the semester, there is a strong correlation among exam and course grades and the quality time and work dedicated to complete and submit homework. Hence, online formative assessments were developed and implemented to promote student knowledge retention and integration. Online assessments motivate students to use what they learn in one part of the course in subsequent topics to reinforce and integrate knowledge. Furthermore, the formative assessments provide quick feedback to students in topics being studied and alert them about the need to seek additional assistance. In addition, the Mechanical Engineering department has recently implemented voluntary weekly recitation sessions for undergraduate courses having high failure rates. Recitation sessions in Statics are about 3 hours a week and they engage students to work in teams of two or three members to solve homework problems that are completed and submitted by the end of the recitation session. The recitation sessions are recommended to all students in the course; but, currently, they are not mandatory because of scheduling difficulties. They might become mandatory for students that are repeating the course, students that did not pass the course pretest at the beginning of the semester, and for students that fail course exams. A teaching assistant coordinates efforts with the course instructor to help students during the recitation sessions. It is argued that the described activities have increased and will continue to increase student engagement in learning and their persistence to pass the course. Preliminary assessment results show promising accomplishments in addressing knowledge and student retention and engagement in Statics.

Introduction

Statics is traditionally taught by delivering material from a textbook on the board, computer presentations, handouts and/or any other similar means. Usually, the instructor solves several example problems in class involving different systems and loading conditions and, after that, students are assigned homework problems that they are expected to analyze and solve by studying the textbook and lecture notes. In addition, in case students need help out of the classroom, the instructor is available during several office hours each week to offer guidance.

Nonetheless, the Statics course becomes difficult for some students just at the beginning because of reasons such as having weak preparation or poor knowledge retention and deficient skills in algebra and trigonometry, and sometimes students lack the dedication and enthusiasm to take responsibility and ownership of their learning process. As the course progresses, most students usually figure out that the concepts in Statics are not very difficult to understand and they can follow the instructor's explanation in class[1]. However, difficulties arise for some students when solving problems on their own, mainly due to the decisions needed to be made to adapt and apply the acquired knowledge, especially when solving different and more complicated problems involving the application and integration of multiple concepts[1].

There have been numerous developments implemented and tested in Statics courses to engage and motivate students, to make real-life connections of the material delivered in the course, to improve the depth of concept understanding, and to improve passing rates and retention. In recent years, challenges, hands-on activities, online assessments, and engaging collaborative learning activities during recitation sessions and in class have been added to the Statics course in the Mechanical Engineering Department at UTPA through implementation of challenge-based instruction[2] and guided discovery modules[3]. In this paper, a description of online assessments and recitation sessions developed for the Statics course are presented including promising preliminary results; additional results will be presented in the future because this project is in progress. The purpose of this work is to increase passing rates, reduce the number of students that drop, and increase the average grade of the students that pass Statics; consequently, improving retention of engineering students. The online assessments intend to engage students in solving problems about fundamental concepts throughout the semester involving not only recently studied concepts but also integrating previously learned concepts to promote knowledge retention and emphasize its relevance in subsequent parts of the course. There is great satisfaction when students in Statics are able to analyze and solve a variety of machine, frame, and truss problems applying and integrating the fundamental concepts and procedures they learn in the course. The recitation sessions are intended to be collaborative learning activities in which students interact with classmates, a graduate assistant, and the instructor to clarify class or textbook content and to solve homework problems. Summarizing, online assessments and recitations are being implemented to enhance traditional face-to-face Statics instruction.

At the beginning of the Statics course, students learn about units and unit conversions, position, force, and unit vectors; immediately after that, students study equilibrium of particles in two and three dimensions. Some students start having difficulty making decisions integrating knowledge and following fundamental problem solving steps required in Statics, mainly because they mistakenly expect to learn a straightforward procedure that could be repeated to solve all sort of Statics problems. For instance, some students fail to clearly recognize the known and unknown parameters and the information needed to solve a problem; they might also fail identifying what could be modeled and simplified as a particle and thus be able to draw its corresponding complete free body diagram. As another example, some students might be unsuccessful in using correct sign conventions and trigonometry to determine the equilibrium equations and to recognize if algebra or an iterative numerical method is required to solve the equations. All of these decisions are what make problem solving in Statics difficult for some students and mastering problem solving skills is possible through good understanding of concepts and perseverance to overcome frustrating times when making mistakes and not getting correct problem solutions[1].

Dannenhoffer[1] mentioned that several approaches and techniques to teach Statics do not help students improving problem solving skills and setting up and solving problems; however, they might be useful for dissemination, demonstration, and evaluation of concepts. Based on that, Dannenhoffer[1] developed a new computerized learning system for Statics with immediate feedback, in which students indicate the forces acting on the free body diagrams and write the equilibrium equations. Also, Saad et al.[4] developed a lecture-recitation system for core engineering mechanics courses in order to increase retention rate in engineering, consisting of two one-hour lectures and a two-hour recitation session per week. The purpose of the recitation sessions was to create an active learning environment useful to address different student learning styles. Such recitation sessions were implemented to make Statics learning easier by encouraging students to get a deeper understanding of the material, complete homework on time, and review the lectures; besides that, they help students improving skills and abilities to take notes, they also create opportunities for the instructor to get feedback and to help students understanding the lecture content and identifying the most important parts of the textbook that need to be studied[4]. Rais-Rohani et al.[5] redesigned a Statics course as an emporium (classroom) model similar to an inverted classroom approach, in which the course content is delivered online outside of class. During the class time, students solve problems and work on hands-on activities with the help of the instructor and learning assistants. Hence, the class becomes an active and collaborative learning experience to work on assignments and experiments. Students complete online assessments, with several opportunities to respond each question, but, with limited online feedback depending on the restrictions of the online assessment environment being used (i.e. feedback is mainly obtained during class time). Therefore, before attending classes, students need to complete readings, watch videos, study examples, and do problems[5]. The instructor coordinates online delivery of the material and all the emporium activities and responds to students' questions. One major criticism by some students of this teaching method was that they expect the professor teaching the material in class rather than delivering it through videos. The latter, is supported by Mackey et al.[6] who also determined that even though students are less satisfied with the educational experience in an online course, it can generate similar results to the face-to-face course. Sorby and Vilmann[7] implemented an online version of the Statics course consisting of several modules developed through the Open Learning Initiative and it was compared to a traditional classroom course; at the end, it was determined that even though the online course could be useful to help students understand fundamental concepts in Statics, it becomes less effective than the face-to-face course when teaching students to solve a diversity of practical problems[7]. Kim et al.[8] developed a hands-on mechanics laboratory, with online access to some experimental setups. The laboratory was a co-requisite for ME students in the Statics course, but, it was optional for other majors. Such mechanics laboratory allowed students to understand Statics concepts better through instructor demonstrations and cooperative learning hands-on activities, group projects, and discussions; as a result, the failure and repeat rate of ME students in Statics was 32% compare to 52% of other majors. In another study, Mehta and Zhifeng[9] developed several activities for a Statics course expecting students to take ownership of their learning through studying the textbook sections and notes provided before attending class. Therefore, the class time started with a reading quiz and a discussion of real-life applications followed in order to enhance the relevance of the material. A concept quiz was implemented next; after that, student groups actively and collaboratively worked on problems to test their knowledge and provide useful feedback to other students and the instructor. At the end of the class period, additional questions that require simple calculations are given to the students. Consequently, students getting C or better grades were 92.6% using such new approach compared to 59.2% in a simultaneously taught traditional Statics course[9]. Being aware of these interventions in Statics courses at different institutions, this project presents a description of online formative assessments to integrate knowledge and recitation sessions developed for the Statics courses which are expected to enhance traditional face-to-face Statics instruction.

Statics Course Difficulties and Opportunities

Figure 1 indicates the main topics that are associated with student learning outcomes in the Statics course in the Mechanical Engineering department at UTPA, shown in the order that they are covered in class. One of the main difficulties students face in Statics is integrating knowledge in all these topics and develop adaptive expertise skills in order to apply the learned concepts and procedures to set up and solve a variety of engineering mechanics problems and situations.

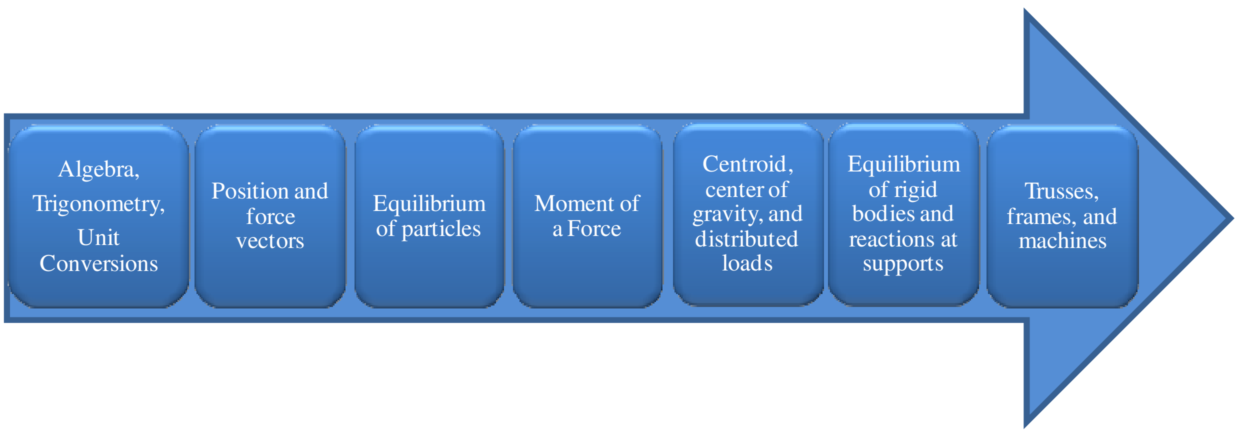

Figure 1. Main topics studied in Statics course at UTPA.

Figure 2 presents the passing and failing rates of students that took Statics taught by the same instructor in the regular semesters during 5 years, from the Fall 2006 to Fall 2011 semesters. Students that passed the course got A, B, and C grades, and the ones that failed were those that drop or got D or F grades. Considering the results up to the Spring 2011 semester, the average passing rate in Statics during such time was 60.7%. That is, the average failing rate was 39.3%; students that dropped were about 14.3% and 25% of students got D or F grades. Students drop the course due to different circumstances at several stages along the semester, some common reasons to drop the course are: deficiency in algebra and trigonometry, having too much work, taking too many courses, missing many homework and classes, and lack of commitment to be persistent and overcome frustrating experiences. As can be seen in Figure 2, critical situations happened in the Spring 2010 and Spring 2011 semesters, when 55.4% and 58.7% of students passed the course; 23.2% and 26% dropped it, and 21.4% and 15% failed it with D or F grades, respectively. One of the main reasons for the higher percentages of students dropping the course in recent semesters is the lack of determination and initiative to find help and/or assistance. Students make this decision on their own without talking or getting the approval of the course instructor or advisor and during the time that goes up to the first ¾ portion of the semester. Some students quit coming to class even though it has been the instructor's recommendation to students to stay in the course all the way to the final exam unless they have special reasons to drop it.

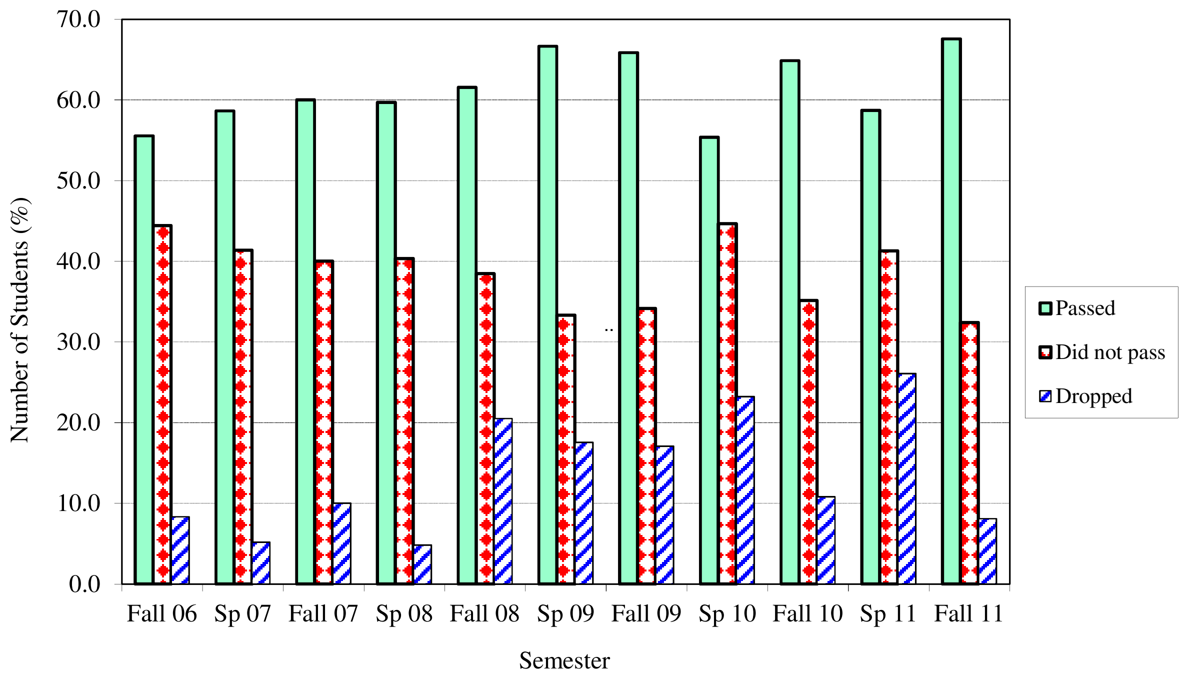

Figure 2. Passing and failing rates of students in Statics during Fall 2006 - Fall 2011 (percentage of students passing with C or better, and failing with D, F, or dropped grades).

Concerned with the high dropping and failing rate of students in Statics, the Mechanical Engineering department decided to start offering recitation sessions on Friday afternoons at 1:10-4:00 pm, in the Spring 2011 semester. The sessions are for students that voluntarily wanted to attend them but particularly recommended to students that are repeating the course or fail the pre-test or the first course exam (which is schedule at about 4 weeks from the beginning of the semester). Additionally, the Statics instructor has been developing online assessments for students to persistently study the course material and to retain and integrate knowledge and apply it to solve diverse problems. Consequently, it is expected that by combining online assessments and recitation sessions student performance and passing rates in Statics will be improved, and some improvement was obtained in the Fall 2011 semester as can be seen in Figure 2.

Online Formative Assessments to Integrate Knowledge

The purpose of this section is to present examples and a description of the online assessments developed to provide quick feedback or to test and improve student knowledge in topics being studied in class as well as to integrate knowledge as the course progresses. The main goal of the online assessments is to encourage students to study out of class time and apply what they learn in one part of the course in subsequent parts to reinforce knowledge retention and at the same time to emphasize the importance of such knowledge. It is expected that the perception and the interest of the students about what they are learning will improve through the online assessments; then, increasing the engagement in learning and perseverance to pass the class. Online assessments are graded automatically and provide immediate feedback to the students. Nevertheless, preparing online assessments is a complex task that requires developing, testing, and implementing the assessments, ideally involving relevant real-life applications to make a positive impact on the students' understanding of Statics related concepts.

Figures 3 and 4 show example questions used in the online assessments that are given to the students at the beginning of the semester to review algebra, trigonometry, and unit conversions. In these questions, students get random values from a range previously determined by the instructor to generate 100 or less possible answers to each question; therefore, it is usually the case that all students get different values. Also, not all students get exactly the same questions, because once they are prepared, it is relatively easy to modify them to create other similar questions. The answers, not provided to students, are shown in Figures 3 and 4 just for verification purposes.

Determine the value of x that is a solution to the following three equations:

x +(-1y) + z = 4
-2x + y - 4z= 10
-10x + 3y + z = -1

Answer:

Correct Answer
-3.56

What is the pressure inside a tire in (N/mm^2) if a pressure gauge indicates 24.77 psi?

Answer:

Correct Answer
0.171

Figure 3. Example online questions and answers about algebra and unit conversions.

Furthermore, Figure 4 shows the feedback that students receive when answering either correctly or incorrectly. As the online assessments are improved, it is expected that the feedback becomes more elaborated so that students might be directed to study specific sections of the textbook, study information from a web page, watch a video, or take another remedial action.

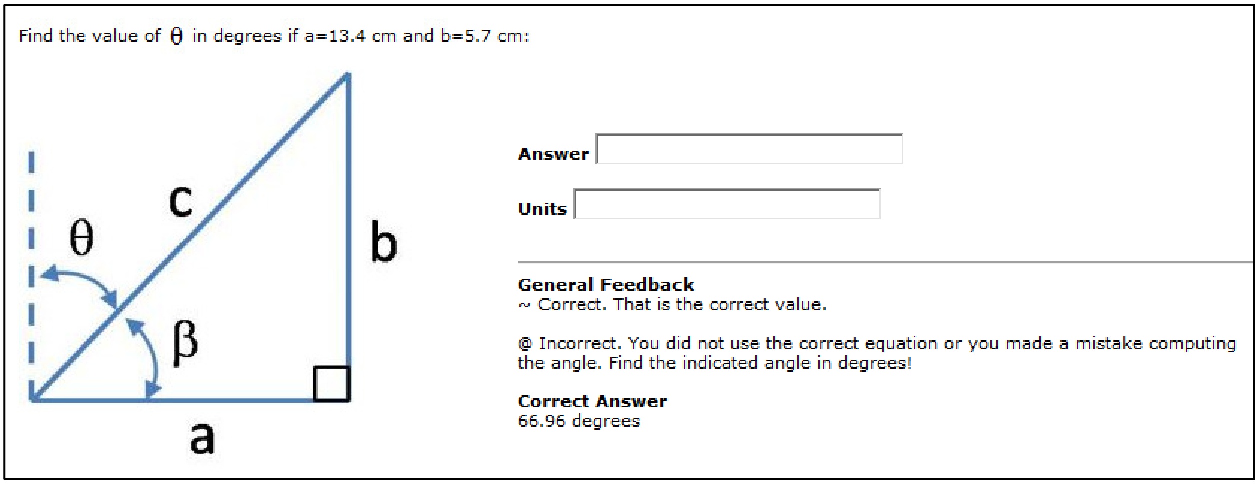

Figure 4. Online question with feedback about trigonometry.

Figure 5 is an online example problem about addition of vector forces. Students are provided a diagram with important geometric parameters and labels, the statement of the problem provides several random values, and the question being asked evaluates understanding of several concepts required to solve the problem. In this example, students might use the Cartesian components of the forces or use a graphical way to find the resultant force; either way, they need to correctly use trigonometry, unit conversions, and understand addition of forces in order to find the solution to the problem. Notice that the same diagram could be used to ask additional questions; for instance, finding the magnitude and/or the orientation of the resultant force acting at A given the forces T_1 and T_2 and the angles θ_1 and θ_2.

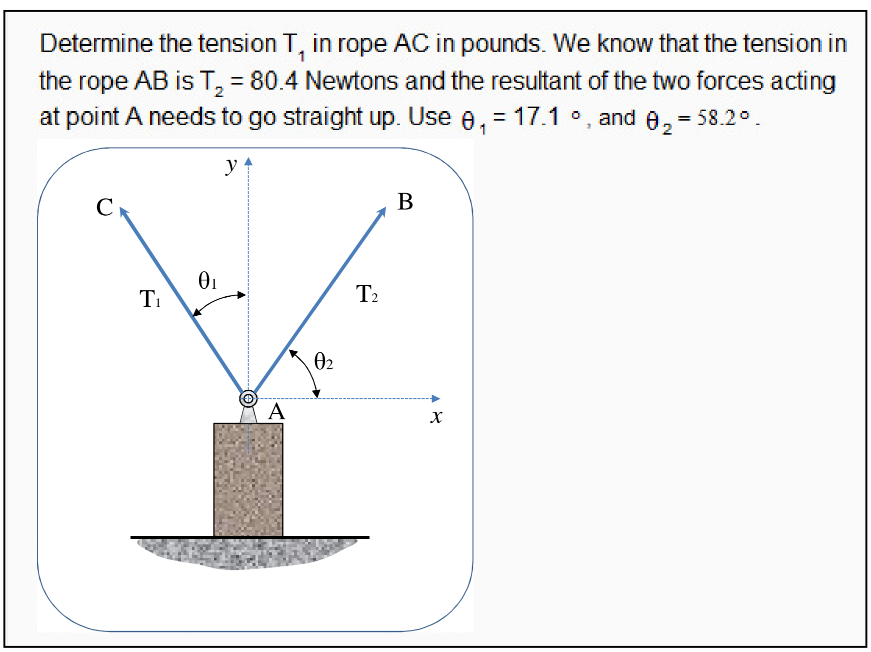

Figure 5. Online question about adding vector forces.

Figure 6 is an online example problem about equilibrium of particles in 2D. Students are given a diagram of a support system with the corresponding dimensions and labels; the statement of the problem generates random values for the mass of the box and some dimensions. To find the correct solution to this problem, students need to integrate knowledge of trigonometry, algebra, unit conversions, and equilibrium of particles in 2D (free body diagrams and equilibrium equations). Notice that the same diagram could be used to ask more or less complicated additional questions; for example, finding the maximum mass in kilograms that could be hanged at point A if ropes AC and AB would fail when any of them is subjected to a specified maximum random tension in pounds.

The mass m hanging at point A is 3.6 slugs.
Use the following dimensions and determine the tension in rope AB in Newtons:
h = 19.7 in., d_1 = 14.4 in., and d_2 = 11.4 in.

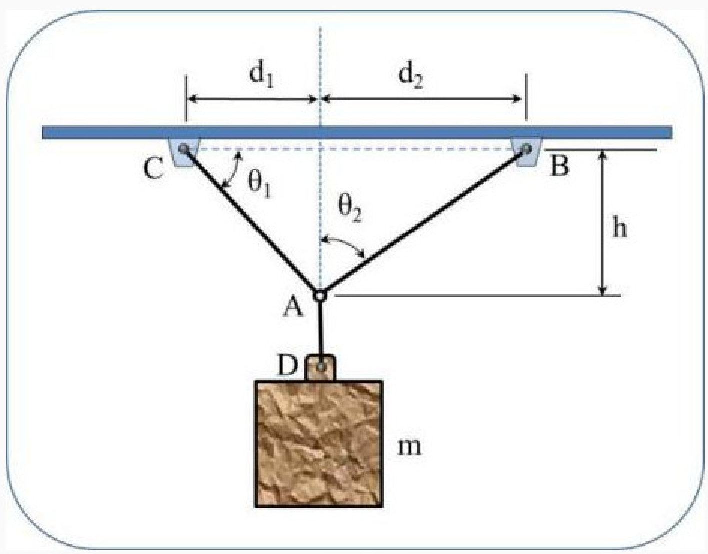

Figure 6. Online question about equilibrium of particles in 2D.

Figure 7 is an online example problem about equilibrium of rigid bodies in 2D. Students are provided with a diagram of a frame that is carrying several loads, including a distributed load; again the statement of the problem generates random values for several of the parameters in the diagram and asks a specific question. To find the correct solution to this problem, students need to know about simplification of a distributed load, centroids, trigonometry, algebra, unit conversions, two-force members, and equilibrium of rigid bodies in 2D (reactions at supports, free body diagrams, and equilibrium equations). The same diagram could be used to ask more or less complicated additional questions; for example, determine the value of the distributed load ω_1 (in lb/ft) required to make the force acting in link CA equal to zero.

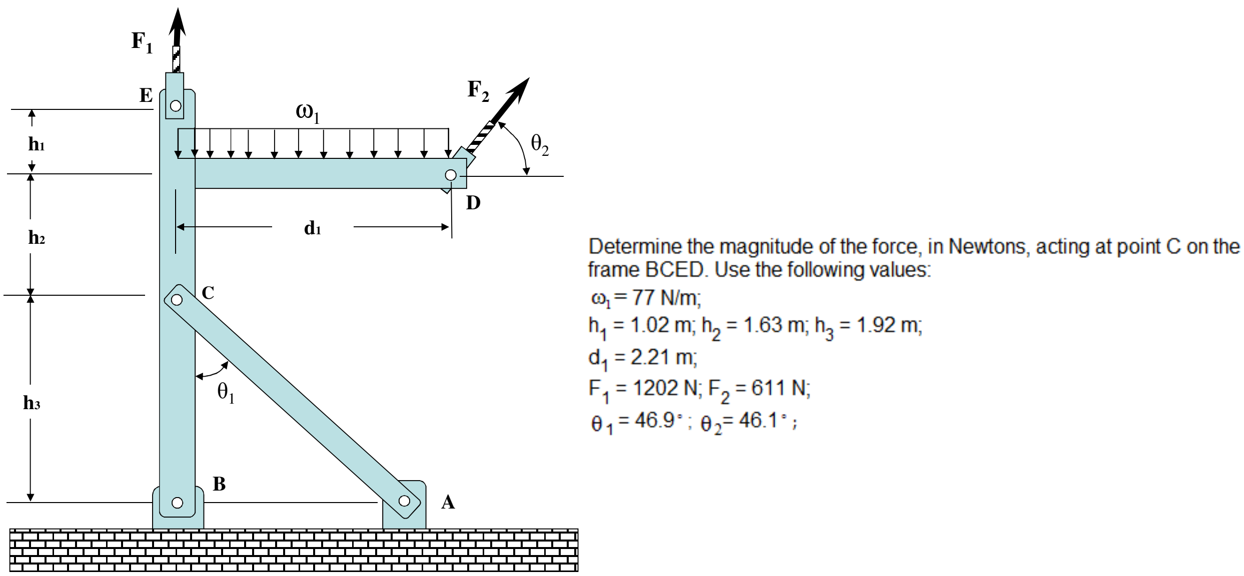

Figure 7. Online question about distributed loads, equilibrium of rigid bodies, and equilibrium equations.

As the Statics course progresses, it is important that students integrate concepts as presented in the questions in Figures 3 to 7 not only to evaluate new concepts but also to apply concepts previously studied to solve the problems (i.e. spiral learning). Many of these problems are already included in a similar fashion in textbooks, but, having them online as formative assessments present numerous advantages. For instance, they involve randomly generated parameters allowing assigning different problems or system conditions to each student. One important fact that might become a disadvantage of online assessments in comparison to in class or recitation session assessments is that students' work to set up and solve the problems is not revised by a grader. Therefore, the steps in the procedure to solve the online problem, such as drawing complete free body diagrams and finding the equilibrium equations are not directly being evaluated. It is expected that if a student fails getting the correct answer to an online assessment question, the student could ask for help during office hours or during recitation sessions. Consequently, it is important that the students take ownership of their learning process and actively seek to learn and improve their understanding of concepts.

During the Spring and Fall semesters in 2011 and Spring semester in 2012, the first online assessment in Statics consisted of 10 questions about unit conversions, similar to the one at the bottom of Figure 3. The questions were prepared using Respondus and they were published to the corresponding course in Blackboard. The assessment was set up to be delivered one question at the time until the students completed it. A second attempt was allow if the student decided to try to improve the grade obtained in the first attempt, and the higher of the two grades was assigned as the final grade of the assessment. During the second attempts the values of the parameters change and the entire assessment has to be completed again. The results obtained with this first online assessment are presented in Table 1.

Table 1. Unit conversions online assessment results.

	Spring 2011	Fall 2011	Spring 2012
Students in Statics	44	37	49
Average grade in assessment in first attempt	87.2%	77.6%	84.4%
Number of students that did a second attempt	11 (25%)	14 (37.8%)	16 (32.7%)
Average grade in assessments after including the second attempt	93.4%	84.5%	91.0%
Assessment grade improvement after including the results of the second attempts	6.2%	6.9%	6.7%
Assessment grade improvement for only the students that did the second attempt	15.5%	16.4%	17.5%

Notice that the results obtained with the online assessment about unit conversions in Table 1 are consistent during the 3 regular semesters in which it has been implemented. Most recently, six online assessments have been implemented in the Spring 2012 semester and the results are presented in Table 2. The number of students in the course is 49. So far, the topics in the assessments have been: pretest review (algebra, trigonometry, and calculus), unit conversion, vector forces, equilibrium of particles, centroids, and moment of a force about a point.

Table 2. Results of six online assessments during Spring 2012 semester.

	Value, % (Standard Deviation, %)
Average grade in assessments in first attempt	63.9 (15.9)
Number on students in second attempt	39.8 (9.9)
Average grade in assessments after including the second attempts	79.6 (11.3)
Assessment grade improvements after including the results of the second attempts	15.7 (8.4)
Assessment grade improvements for only the students that did the second attempts	34.5 (18.3)
Students that did not complete the assessments	7.8 (4.5)

It can be concluded up to the middle of the Spring 2012 semester that in average about 40% of the students that take any of the online assessments attempt each one of them a second time which in average improve their grades in 34.5%. This shows good results and also a significant degree of persistence and desire of some students for improving the assessment grades in a second attempt. About 8% of the students do not take the online assessments. Comparing the results during the first attempt and the final results in the assessments after including the second attempts, it is determined that the average class improvement was 15.7%, from 63.9% to 79.6%.

The results in the first exam, which occurs during week 5 after the beginning of the semester, were in average 80.0% during the Spring 2012 semester, while the averages on exam 1 in the Spring 2011 and Fall 2011 semesters were 64.6% and 76.9%, respectively. Thus, it seems that there is a tendency to improve test grades as more online assessments are implemented in Statics. More results will be analyzed at the end of the semester to determine the impact on the passing rates and the final average grades in the course.

Recitation Sessions

The Mechanical Engineering department has recently implemented voluntary weekly recitation sessions for undergraduate courses having low passing rates. The recitation sessions in Statics have been offered during the Spring and Fall semesters in 2011; they are about 3 hours a week and they are prepared to engage students to collaborate in teams of two or three members to solve homework problems that need to be completed and submitted by the end of the recitation session. The recitation sessions are recommended to all students in the course; but, currently, they are not mandatory because of scheduling difficulties. Some students might not need to attend the recitation sessions because they can do the homework on their own. The recitation sessions might become mandatory for some students that are repeating the course, students that did not pass the pretest about algebra, trigonometry, and calculus at the beginning of the semester, and for students that fail course exams. The instructor makes a selection of problems that might be similar to ones in the textbook or somehow similar to the online assessment problems, but, most of the time problems directly from the textbook are avoided to be used in the recitation sessions because sometimes students have access to solution manuals. A teaching assistant coordinates efforts with the course instructor to help students during the recitation sessions.

Unfortunately, some students that need to attend the recitation sessions do not attend them or only go a few times. Among the multiple reasons that students give not to attend recitations, the most common ones are that they have a job or need to attend other classes or recitations on Friday afternoons; other students consider that they do not need help to complete the homework; and others are indifferent about the recitation sessions.

Table 3 presents a summary of the results obtained with the recitation sessions in Statics during the Spring and Fall semesters in 2011. During the Spring 2011 semester, 10 out of 44 students attended most of 11 recitation sessions; at the end of the semester their grades were 3 students with A, B, and C respectively, and one with D. The average grade in three tests and the final exam of the 10 students that attended the recitation sessions in the Spring 2011 semester was 78.8% compared to 81.0% of the other 22 students in the class, a difference of -2.2%. However, a pretest was given to the students at the beginning of the semester to evaluate their knowledge of math topics required in Statics (algebra, trigonometry, differentiation, and integration), and the 10 students in recitation got an average of 60.0% while the other 22 students got 79.2% on the pretest, a difference of -19.2%. Out of the 44 students that started taking Statics in the Spring 2011 semester, 61.4% (27 students) passed with C or better grade; 11.4% (5 students) failed with D or F grades, and 27.3% (12 students) dropped the course. Then, the relative difference in improved performance on the exams of the students in recitation sessions with respect to the students that did not attend recitation is about 17.0% using the pretest as a reference.

Table 3. Average pretest and exam grades of students attending and not attending the recitation sessions.

	Spring 2011	Fall 2011
Students in Statics	44	37
Students voluntarily attending recitation	10 (22.7%)	9 (24.3%)
Students that passed with A, B, or C	27 (61.4%)	25 (67.6%)
Students that failed with D or F	5 (11.4%)	9 (32.4%)
Students that dropped	12 (27.3%)	3 (8.1%)
Average exam grade of students in recitation	78.8%	86.0%
Average exam grade of students without recitation	81.0%	70.8%
Average grade on pretest of students in recitation	60.0%	77.7%
Average grade on pretest of students without recitation	79.2%	71.1%

During the Fall 2011 semester, there were 11 recitation sessions and 9 (24%) students attended 6 or more times (a total of 18 students attended 1 or more recitations); 4 of these students got a B and 5 got an A grade in the course. The average grade in three tests and the final exam of the 9 students that attended the recitation sessions was 86.0% compared to 70.8% of the other 25 students, a difference of 15.2%. A pretest was given to the students at the beginning of the semester to evaluate their knowledge of math topics required in Statics (algebra, trigonometry, differentiation, and integration), and the 9 students in recitation got an average of 77.7% while the other 25 students got 71.1% on the pretest, a difference of 6.6%. Out of the 37 students that started taking Statics in the Fall 2011 semester, 67.6% (25 students) passed with C or better grade; 32.4% (9 students) failed with D or F grades, and 8.1% (3 students) dropped the course. During this semester, the relative difference in improved performance on the exams of the students in recitation sessions with respect to the students that did not attend recitation is about 8.6% using the pretest as a reference. This comparison is only fair if the same proportion of students that need to attend recitation session are actually in the recitation and in the no recitation groups. This is work in progress that is expected to generate more useful and conclusive results in the Spring 2012 and subsequent semesters.

A Statics concept inventory such as the one developed by Steif and Dantzler[10] will be implemented in the following semesters to determine student learning of concepts in Statics and the impact of the online assessment and recitations on the inventory results.

Conclusions

Online assessments were developed in Statics in an attempt to engage students in solving problems concerning fundamental concepts throughout the semester. These assessments involve not only recently studied concepts but also integrate previously learned concepts in an effort to promote knowledge retention and emphasize its relevance in subsequent parts of the course (i.e. spiral learning). Recitation sessions are also being implemented to get students to collaborate in learning activities and to solve problems and complete homework. In these sessions they interact with classmates as well as a graduate assistant and/or the instructor. During the recitation sessions, students practice and acquire better understanding of Statics concepts and they can clarify class or textbook content by asking questions. In summary, online assessments to integrate and reinforce knowledge and recitation sessions to motivate and engage students by solving practical problems have been implemented in Statics and have been described in this paper along with some preliminary results. These activities are expected to enhance traditional face-to-face Statics instruction. The preliminary results show promising accomplishments in addressing the need to improve student engagement, student retention, student knowledge retention, student adaptive expertise, and overall performance in Statics. Recitation sessions are being implemented again in the Spring 2012 semester together with the developed online assessments, which for the first time are part of the Statics course during the entire semester.

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