EVALUATING STUDENTS WITH ONLINE TESTING MODULES IN ENGINEERING ECONOMICS: A COMPARISION OF STUDENT PERFORMANCE WITH ONLINE TESTING AND WITH TRADITIONAL ASSESSMENTS

Abstract

Engineering economics courses often require students to take time-constrained, in-class exams in which they solve problems by hand, possibly referring to interest rate tables. Many students rely on partial credit to successfully pass exams. Outside of the classroom, professionals rely on computers to solve engineering economics problems, which raises the question of whether engineering economics courses are correctly assessing student performance. This article describes the study of a large engineering economics class using a non-conventional testing method. Student performance was evaluated using online testing modules with a stringent passing criterion, and the tests could be taken multiple times. The questions for each testing attempt were pulled from a huge database so that students received a new question every time. We compare the performance of students who were assessed using traditional methods with the performance of students assessed with these online testing modules. Our analysis shows that overall students who were assessed using the online testing modules earned better grades than students who were assessed via traditional methods. The analysis also discusses several benefits and drawbacks to using online assessments compared with traditional methods. The online assessment method could be useful in the large engineering courses that are formula-based.

Keywords: engineering education, online testing, examinations, student assessment

1. Introduction

Education has progressed from the chalkboard to learning through the Internet. Thanks to technological advancement, teaching and learning has reached a point where hundreds of books can be downloaded on a small device, lectures can be viewed on personal computers or phones thousands of miles away from the instructor, research groups can discuss material and projects from different parts of the world, and assignments can be submitted via email or web-portals.

The Internet is emerging as a teaching and learning tool rather than simply facilitating distance education. The Internet can help students learn material on their own and give students confidence in their ability to act as independent learners (Kian-Sam, Abang Ahmad, & Ming-Koon, 2003). Online instructional and assessment methods were introduced since at least 2002 to conduct many online experiments in science and engineering (Ammari & Slama, 2006; Salzmann, Gillet, & Huguenin, 2000; Gillet, Ngoc, & Rekik, 2005). The Internet has assisted engineering education by providing e-journals, documents, and references which can be shared and stored in large numbers for references. The enrollment in online engineering courses has risen quickly in the United States (Allen & Seaman, 2008).

As technology and the Internet have created new methods for students to learn and for instructors to teach, this phenomenon has raised new questions about the best methods to help students learn course material. The use of well-designed online modules can help students better understand course material (Henson, Fridley, Pollock, & Brahler, 2002). Instructors put a lot of thought and time in developing coursework and lessons that will help students in their future careers, but students often do not retain lecture material (Lyle & Crawford, 2011). Recognizing a student’s shortcoming in understanding course material, providing constructive feedback to students, allowing students to practice the material, and assessing student learning can all help bolster student learning. Designing the curriculum based on the learners' characteristics and modifying the existing instructional design can help students learn more effectively (Passerini & Granger, 2000; Zacharis, 2010). Traditional in-class exams may not be the best way to assess students or to help students learn, especially in the Internet age. For more than a century, research has investigated the use of tests to help students learn rather than just to assess students (Gates, 1917; Jones, 1923; Lyle & Crawford, 2011).

Utilizing computers and other technology in teaching and learning domains can be effective. Students in a psychology class performed significantly better using online quizzes than students who took traditional paper-and-pencil quizzes (Desouza & Fleming, 2003). A first-year course in geographical data analysis that used computer-based assessment showed that students were more content with the computer-based assessment and enjoyed the course more (Charman & Elmes, 1998). The students also reported that they were "very satisfied" with online quizzes. Online tests allow students to determine when and where to take their exams, which provides flexibility for the students. Regular online testing in two large introductory psychology classes demonstrated that student performance improved more than the performance of students in a traditional class taught by the same instructor (Pennebaker, Gosling, & Ferrell, 2013).

Practicing is an effective method of learning. Butler & Roediger III (2007) discover that tests after approximately a month of teaching and short answer tests can help students retain more material for longer intervals. Students earned better scores on the Graduate Record Examination when they took it the second time (Kingston & Turner, 1984). Students can receive immediate feedback with online exams, which is usually not possible with traditional exams. Online tests can be used for practicing and providing quick feedback to the students so that they learn from their mistakes. When students practice multiple times with the same or similar versions of a test, their scores improve. Possible reasons could be familiarity with the testing format due to repetition (Terry, 2015; Wolkowitz, 2011).

Anxiety can contribute to poor academic performance. Anxiety among students can include panicking, going blank before an exam, feeling helpless while studying, and a quickened pulse. Engineering students may be particularly susceptible to anxiety (Ruffins, 2007; Vitasari, Wahab, Othman, Herawan, & Sinnadurai, 2010). Traditional in-class exams can increase student anxiety because most engineering courses only have 3-4 exams during the semester and much of the student's grade depends on performing well on each exam. Eliminating worry can help treat test anxiety (Tryon, 1980). Students reported feeling less anxious about taking online tests than in-class tests (Stowell & Bennett, 2010). Self-regulation helps students to assess their own work, and feedback increases a student's ability to self-study (Nicol & Macfarlane-Dick, 2006). One challenge with online exams is it makes it easier for students to cheat. Kennedy, Nowak, Raghuraman, Thomas, & Davis (2000) report that academic dishonesty will increase as web-based learning and online exams increase.

This article analyzes how the assessment procedure impacts the performance of students in a large-enrollment engineering economics course at a large public university. The article compares and contrasts students who were assessed via online testing modules with students who were primarily assessed with traditional homework and in-class examinations. Students in the engineering economics course during the 2017 spring semester were assessed via weekly homework assignments, a group project, and three in-class exams. The final exam for the spring course was structured as an online testing module as a precursor to the fall semester. Students in the same engineering economics course in fall 2017 were assessed with online testing modules. These online testing modules contained randomized questions. A student could take a testing module multiple times and never encounter the exact same problem. This article compares the difference in student performance between students in the fall who were assessed via online testing modules and students in the spring assessed via traditional methods. This article also compares student performance in the spring on the traditional exams and on the online final exam.

To the authors' knowledge, little research has examined the effectiveness of using online exams with multiple attempts for learning in engineering classes, and even less research has compared the performance of engineering students with online exams and with traditional in-class exams. The article compares how the same students performed on traditional assignments and exams versus an online final exam. The grades of students who were assessed via online testing modules in fall are statistically compared to the grades of students in the spring. Since some of the same questions were used in the in-class exams in the spring and in the online testing modules in the fall, a unique element of this article compares how students performed on specific questions based on whether the question was asked in an online or in-class test. The fall students may have attempted the same question multiple times, and this article compares the ability of the students to correctly answer a question that they see multiple times with students who see the question one time during an in-class examination. The results from this study and the analysis provide important qualitative and quantitative insights into the benefits and drawbacks of relying on online assessments of students in engineering economics.

The rest of the article is structured as follows. Section 2 describes the traditional methods of assessing students in the spring 2017 semester and the online testing modules for fall 2017. Section 3 presents and analyzes the data on student performance, to include comparing the grades between the two classes and comparing course evaluations between the two semesters. Section 4 discusses the results and makes qualitative comparisons between the two assessment procedures. Concluding remarks appear in Section 5.

2. Methodology

The engineering economics courses at this large, public university typically enroll about 1000 engineering students a year and have multiple sections each semester. Some sections are online classes only, and some sections are in-class sections only. The main learning outcome of this course is for students to correctly apply economic principles to engineering problems. We compare two sets of students with different assessment methods to evaluate their performance. Students in spring 2017 were evaluated based on their scores on homework, a class project, three in-class tests, and an online final exam. Students in fall 2017 had all of their grading based on the online testing modules. This research attempts to analyze the benefits and drawbacks of this new assessment method in a high-enrollment engineering-course.

2.1 Spring 2017

The instructor taught engineering economics in spring 2017. This section had 162 students, and they were exclusively in-class students. This semester largely had traditional assessments for students: three 50 minutes exams, a final exam, a group project, and eight homework assignments with 5-7 problems each. The second exam had two parts: an in-class part and a take-home part due 48 hours later. Each of the three in-class exams had between 4 and 6 questions. Each question usually required a numerical answer, and some questions also required students to briefly interpret their numerical answer. Students were awarded partial credit for incorrect answers. Appendix A provides the questions used for the first exam. Students generally performed poorly on the third exam, and scores were curved on the third exam.

The grading scale used for the spring 2017 course is shown in Table 1. Each exam was worth 18% of the semester grade, the homework assignments were worth a total of 18% of the semester grade, and the project was worth 10% of the semester grade.

Table 1 Grading scale of spring semester

Grade	Percentage range	Grade	Percentage range
A	92.5 – 100	C	72.5 - 76.49
A-	89.5 - 92.49	C-	69.5 - 72.49
B+	86.5 - 89.45	D+	66.5 - 69.49
B	82.5 - 86.49	D	62.5 - 66.49
B-	79.5 - 82.49	D-	59.5 - 62.49
C+	76.5 - 79.49	F	59.49 or below

The final exam in this course was an online exam available for 10 days. The instructor used the final exam to evaluate if testing modules could be used in the following (fall 2017) semester. The online final exam was very similar to the online testing modules used in the fall 2017 class, which will be discussed in Subsection 2.2. The final exam had 7 questions, and students could take the final exam as many times as they wanted in order to improve their grades. Each of the 7 questions randomly chose from among 4-6 problems, and each problem had 100 different versions. The best score for a student on the final exam was recorded as the final exam score. Table 2 depicts the grading scale for the final exam.

Table 2 Grading scale for the final exam in spring

Correct answers	Score	Correct answer	Score
7	100%	3	65%
6	95%	2	55%
5	85%	1	45%
4	75%	0	0%

2.2 Fall 2017

The engineering economics course in fall 2017 had 242 students, which included both in-class and distant-learning students. The class was taught in the classroom, and recordings of each lecture were made available to both the distance-learning and in-class students. Each student's performance was evaluated based on the results of the online testing modules which could be taken multiple times. The online testing modules encouraged students to use Excel. Consequently, many of the classroom lectures focused on teaching students how to use Excel and an Excel-based simulation software in order to solve engineering economics problems. Students were encouraged to use Excel because the use of Excel reflects how these problems are usually solved in practice. Further discussion on the use of Excel appears in Section 4.

The grades for this course depended on passing the seven online testing modules with two additional testing modules. Each testing module contained a certain number of questions (usually 7 or 8). All the questions required applying engineering economics formulas, and students entered their numerical answers for each question. Passing a testing module usually required the students to correctly answer all but one question. The instructions for each testing module specified the number of correctly answered questions required to pass. The solutions allowed an answer to be within $\pm$1% of the correct answer in order to account for rounding error. Partial credit was not given for any question. Each testing module also required the student to state on his or her honor that he or she had not cheated while taking the testing module. Although students were allowed to use their own computers and could refer to notes and the Internet during these testing modules, they were not allowed to discuss questions with other students while they were taking a testing module. Each testing module had a time limit between 90-120 minutes to prevent students from keeping a testing module open indefinitely.

Questions for the testing modules were randomly selected for each student so that it was very unlikely that a student ever received the exact same version of a question during his or her multiple attempts. For each attempt on a testing module, a question randomly chose one problem from among 3-6 different problems. The problems in a question usually covered the same topic and were roughly equivalent in difficulty. For example, the problems in a question might all be questions related to calculating annuities. Each problem had 100 different versions. All versions of the same problem had identical text, but each version had different or randomly selected numbers. For example, if a problem asks a student to calculate the present value of an annuity, one version might have an annuity of $2,000 each year for 25 years with an interest rate of 6%, and another version might have an annuity of $3,400 each year for 28 years with an interest rate of 4%. Thus, each question on a testing module had 300-600 unique versions and answers. Having so many different versions ensured that a student could not simply memorize and regurgitate an answer and made cheating more difficult.

Since the standard for passing a testing module was relatively high and students could take each testing module as many times as they needed to in order pass it, this format helped students practice with the goal that they would retain information in their long-term memory

(Willingham, 2004). Testing students with exams may be more effective than other teaching techniques (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). Students received the results from a testing module immediately and could practice the problems they missed offline. Well-designed repetition is also an effective learning practice (Thalheimer, 2006). The first four testing modules only told the students which questions they answered incorrectly but did not provide students with the correct answers. Based on student feedback, the instruction team changed the testing modules beginning with the fifth module so that students would also receive the correct answers after taking a testing module. Students could resolve the problems and check to see if their new solutions were correct.

No deadline was imposed for students on these testing modules until the end of the semester, which occurred on the last day of the final exam schedule. Theoretically, a student could procrastinate and pass all of the testing modules on the final day. However, the testing modules were difficult enough that students were unable to complete all of the testing modules in a single day or even a single week although a couple of students seemed to try. To discourage students from procrastinating, the professor gave advice throughout the semester on which testing modules should be completed based on the timeline for lectures in the course.

Students were allowed to use textbooks, class notes, the Internet, and Excel while taking a testing module. They were not allowed to talk with other students or receive help from any individual while taking a testing module. After a student took a testing module, he or she could discuss the questions with other students and receive help from the professor or teaching assistant. Referring to textbooks, practicing the problems with peers, and receiving help from the instruction team allowed students to learn through a method that suited them the best. These resources combined with repetition may help students master difficult content (Chickering & Gamson, 1987). The motivation behind this type of online testing module was to allow students to study the material, understand and apply the concepts to the questions, learn from their mistakes, retake the testing modules, and improve their performance. Students were highly encouraged to interact with the teaching assistants and the professor for help on questions.

Grades were assigned according to the number of modules passed during the semester (Table 3). The seven required testing modules tested material covered in the classroom lectures, and a testing module usually covered about 2-3 weeks of class lecture. Students who wanted to earn an A in the course were required to successfully pass two bonus testing modules. The bonus testing modules asked questions on material that was in the textbook but that was not covered in classroom lectures. Although students could ask the instruction team about questions in the bonus testing modules, the goal of the bonus testing modules was for students to learn material independently of classroom lectures. The bonus modules did not help a student's grade unless he or she successfully passed the seven required testing modules.

Table 3 Grading scale in fall 2017

Grade	Number of testing modules
A	Pass 7 required testing modules + 2 additional testing modules
A-	Pass 7 required testing modules + 1 additional testing module
B+	Pass 7 out of 7 required testing modules
B-	Pass 6 out of 7 required testing modules
C	Pass 5 out of 7 required testing modules
D	Pass 4 out of 7 required testing modules
F	Pass fewer than 4 out of 7 required testing modules

Although the ideal way to compare which group of students learned better may be to give each group of students the exact same set of questions and have each group answer the questions in the same environment, the nature of these classes and the semester prevented such a comparison. However, we can still compare student performance in the two different assessment procedures. This article uses this comparison to make conclusions about the benefits and the drawbacks of using online testing modules.

3. Results

Results from comparing between spring and fall consist of: (i) comparing student performance on traditional assignments with their performance on the online final exam in the spring; (ii) comparing students in the spring semester with students in the fall semester; and (iii) comparing the course evaluations in the spring and fall. The spring students' performance on the in-class exams and the online final exam enables us to compare the performances of the same students on two different assessment procedures. Comparing students in the spring with students in the fall is a between-group design, and we compare the overall grades and performances on individual questions. Comparing the students' course evaluations enables us to analyze if students seemed to prefer one assessment method over the other method.

3.1 Spring 2017 traditional exams and online final exam

Students in spring 2017 were assessed via traditional assessments and an online final exam. We compare those percentage grades from the traditional assessments to the percentage grades of students on the online final exam (as shown in Table 2). The students knew their percentage grade based on eight homework assignments, one group project, and three in-class exams before taking the final. Students could calculate their letter grade based on their percentage using Table 1. The students could calculate exactly how their percentage grade on the final exam would be combined with their prior grade to result in a semester letter grade.

Figure 1 compares the performance of students on the online final exam and their performance in their other assignments. Figure 1(a) compares the final online exam to the students' percentage score before taking the final, and Figure 1(b) compares the final online exam to the average of their three in-class exams. The different shapes represent the students' semester percentage grades. The data points above the dotted line show the number of students who performed better on the final exam, and the data points below the dotted line show the number of students who performed worse on the final exam. Both figures suggest that about half the students performed better on the online final exam and half the students performed worse on the online final exam. This seems to be true regardless of the semester grade for the student. The average difference between the students' percentage on the online final exam and their percentage score before taking the final was -0.123%. The average difference between the students' percentages on the online final exam and the in-class exams was 1.71%. According to a matched-pairs t-test with a 10% confidence level, the difference between either of these averages and 0 is not statistically significant.

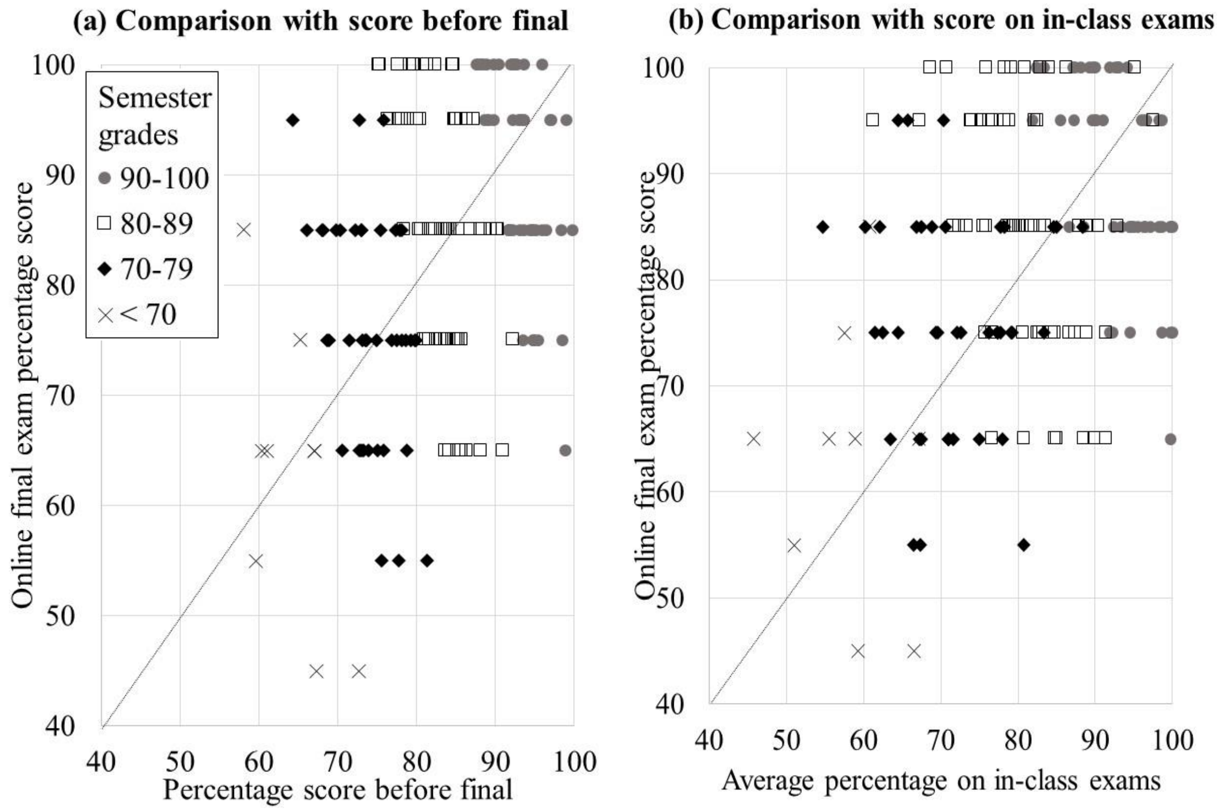

Figure 1. Comparison of online final exam with (a) student percentage scores on all graded work before the final and (b) student's average percentage on in-class exams. The different shapes represent the student's final semester grade.

On average, no significant difference in performance exists between the online final exam and the traditional assessments. Some students performed better on the online final exam than they had on their previous work and in-class exams, and other students performed worse on the online final exam. A number of reasons could explain this lack of difference. First, high-performing students do well on both types of assessments, and lower-performing students struggle on both types of assessments. Second, finals week can be a busy and stressful time for many students, and this may impact student performance for the online final exam. Finally, many students who had an A or A- before the final exam only needed an 85% (or in some cases a 75%) on the final exam to maintain their A or A- for the semester grade, so they were not incentivized to continue to take the final exam to earn a 95% or 100%. Several students who were earning a D or C before the final did take advantage of repeating the final multiple times in order to improve their semester grade to a C or B, respectively. Before the final exam, 13 students were earning a D+, D, or D-, and 5 of those students did well enough on the final to improve their grade to a C- or better.

The final exam remained open for 10 days. Students were allowed to discuss questions on the final exam with each other and with the teaching team as long as they were not taking the final exam. Keeping the exam open for 10 days perhaps offered opportunities for cheating, and some students likely received unauthorized help while they were taking the final exam. If rampant cheating occurred on the final exam, the results would likely demonstrate that students performed much better on the final exam than they did on the three in-class exams. Figure 1(b) indicates that average difference between the final exam and the three in-class exams was only 1.71%. Approximately half of the students performed better on the final, and approximately half of the students performed worse on the final. Based on these results, it does not appear cheating was widespread on the final exam, or the cheating was not very effective. Section 3.5 returns to this subject of cheating for these online assessments.

3.2 Spring 2017 and fall 2017 letter grades

To compare the performance of students assessed with in-class exams and with online exams over the entire semester, we compare the pre-final grades of 162 students in spring 2017 to the semester grades of 242 students in fall 2017. The spring and fall courses covered the same material in the course with the same instructor. We chose the pre-final grades for students in spring 2017 because the final for the spring was an online examination.

As shown in Figure 1, the percentage of students in the fall semester who earned an A is more than twice the percentage of students in the spring semester. The largest percentages for the fall semester grades occur at A, B-, C, and F. The spring semester grades are more evenly distributed across the 12 grades. Students in the fall were required to take two surveys, and their grade suffered if they failed to take a survey. Students in the fall who earned a B, C+, C-, and a D- are those students who did not take one of the two surveys, which negatively impacted their semester grades. The average grade in the spring was a B-, and the average grade in the fall was a B. Our results echo a study at Texas Tech University where students in an online psychology course outperformed students in the traditional test environment (Maki, Maki, Patterson, & Whittaker, 2000).

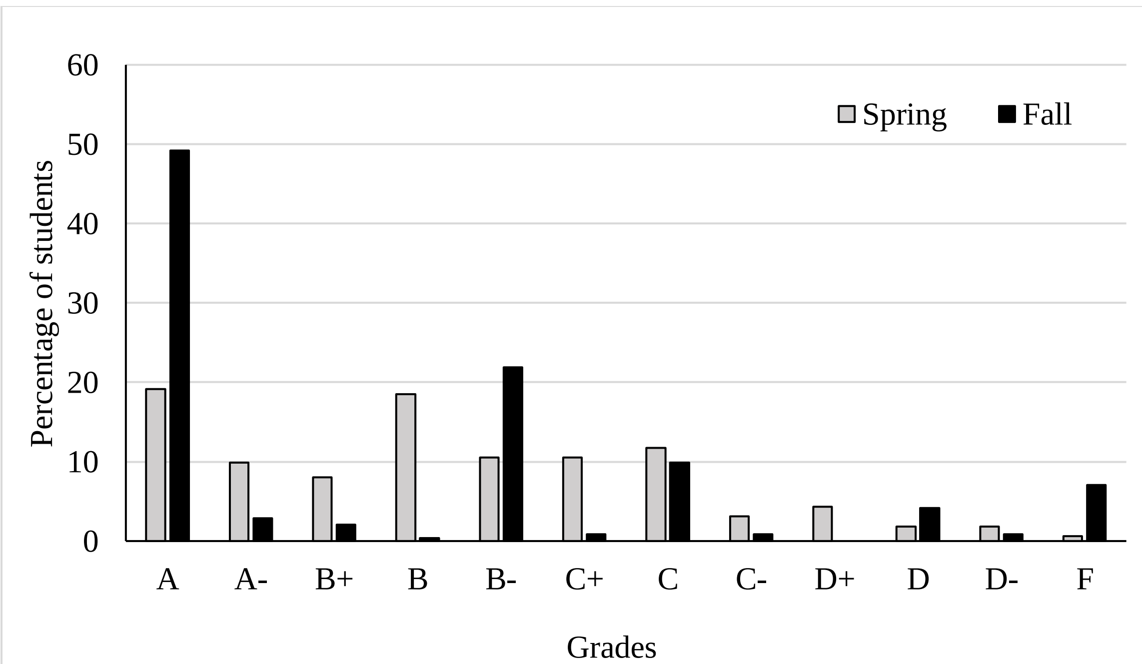

Figure 1 Distribution of grades for spring '17 (traditional assessment) and fall '17 (online assessment)

We test to see if the distributions of grades in the fall and spring are significantly different from each other. We test if the grades divided into the 12 categories (e.g., A, A-, B+, B) as depicted in Figure 2 are significantly different and if the grades divided into 5 categories (i.e., A, B, C, D, and F) are significantly different. We conduct a Pearson chi-squared test to evaluate if the difference in grades between the two semesters occurred by chance. Since the expected value in some of the categories is very small (less than 5) we also conduct a Fisher's exact test. Both the Pearson's chi-squared test and Fisher's exact test returned small p-values (less than 0.01) for the grades divided into 12 categories and for the grades divided into 5 categories. We conclude that the distributions of grades between the spring and fall semesters are significantly different from each other.

More than 50% of students in the fall earned an A or A-, compared with almost 30% of students in the spring. Many students who might normally earn a B+ or B through traditional assessment procedures seemed to take advantage of being able to retake the online testing modules in order to earn an A. Many more students in the fall earned an A than those who earned an A- or B+. Since students could improve their grade from a B+ to an A by passing the two additional modules on material not covered in class, this suggests that students were motivated to learn material on their own to attempt the additional testing modules. The percentage of students who earned a B- or C+ in the spring was approximately equal to the percentage of students who earned a B- or C+ in the fall. The percentage of students who earned a C in each semester was also roughly equivalent.

The fall 2017 course was offered both as an in-class section and a distance-learning section. Lectures in the in-class section were recorded and posted online where both in-class and distance-learning students could watch. Thus, a student who was registered for the in-class section could decide not to attend any of the lectures in person and watch the recorded lectures. Similarly, a student registered for the distance-learning section could attend the class in person. The in-class and distance-learning sections were graded exactly the same. Students registered for the in-class section earned better grades on average than students registered for the distance-learning section. However, the ratio of industrial engineering (IE) students to non-IE students was larger in the in-class section than in the distance-learning section, and IE students earned better grades than non-IE students on average. Results are inconclusive about whether students in the distance learning section earned worse grades because they were registered for the distance-learning section or because they were not majoring in IE.

3.3 Spring 2017 and fall 2017 question comparison

Eleven problems from the three in-class exams in the spring also appeared in the online testing modules in the fall. Appendix B lists these eleven problems. These eleven problems were distributed among the seven required testing modules. Students in the spring received their exams and may have given these exam questions to students in the fall. Each online testing module had approximately 35-40 different problems, and each problem had 100 different versions. If a student in the fall received a question from the spring semester, the student would have had about a 15-20% chance of getting that problem during any given attempt in the online testing module. The problem the student would have received would also have had different numbers than the exam question from the spring semester.

Students in the fall were required to enter a numerical answer that was within 1% of the correct answer in order to have the question correct on the testing module. We compare the percentage of students who solved these problems correctly with the percentage of students in the spring who solved the same problems correctly on the in-class exams.

As discussed earlier, even though the problem in the fall online testing module had the same words, the numbers were varied each time since there were 100 versions of each problem. Since students in the fall could take a testing module as many times as they needed to until they passed and suffered no penalty for failing to pass a testing module, many students opened a testing module to look at the questions and submitted the module without answering any question. They got a score of 0 on that particular attempt, but they could work on the problems offline. They would attempt the testing module again. Thus, when we count the number of attempts on a question, we only count attempts for which a student provided an answer. If a student did not enter a number for the question, this attempt was excluded from the count in this comparison.

Table 4 shows the difference in the proportions of students who answered questions correctly between the spring in-class exams and the different attempts in the fall testing modules. Several students enrolled in the spring semester dropped the course by the middle of the spring, and 168 students answered the first six problems in the spring and 161 students answered the last five problems. The third column in the table shows the proportion of students in the spring who answered each question correctly. The fourth through eighth columns in the table depict the difference in the proportion of students in the fall who answered a problem correctly on a given attempt and the proportion of students in the spring who answered the same problem correctly. Attempts 1-4 indicate the first, second, third, and fourth time the student sees the problem on the testing module. The best attempt represents the proportion of students who solved the problem correctly on the attempt in which they received their best score on that testing module. The best attempt was often the attempt during which a student passed the testing module. Due to the randomness in the online testing modules, a student may not have received that problem during his on her best attempt. Those students are not included in the data for best attempt. The table also depicts if the differences between the proportions in the fall and the spring are statistically significantly different from 0. Two-tailed tests for population proportions were performed, where the null hypothesis is that the difference between the proportions of students equals 0, and the alternative hypothesis is that the difference does not equal 0.

Table 4 Difference in success rate between the spring and fall on the same problem

Pro-blem	Number of students in spring course	Proportion of students in spring who solved problem correctly	Proportion in fall who solved problem correctly for a given attempt minus proportion in spring who solved problem correctly *Number in italics represents the number of students in fall course who attempted a question*				
			1st attempt	2nd attempt	3rd attempt	4th attempt	Best attempt
1	168	0.393	-0.049 (ns) *131*	-0.037 (ns) *45*	0.062 (ns) *22*	0.107 (ns) *6*	0.376 *** *39*
2	168	0.405	-0.087 (ns) *88*	0.60 (ns) *28*	0.095 (ns) *4*	0.095 (ns) *2*	0.323 *** *22*
3	168	0.512	0.143 ** *139*	0.171 ** *63*	0.176 * *32*	0.088 (ns) *15*	0.399 *** *45*
4	168	0.399	0.040 (ns) *123*	0.101 (ns) *54*	0.140 (ns) *26*	0.046 (ns) *9*	0.469 *** *44*
5	168	0.393	0.219 *** *157*	0.205 *** *82*	0.357 *** *32*	0.321 ** *14*	0.477 *** *77*
6	168	0.500	0.020 (ns) *98*	0.033 (ns) *30*	0.167 (ns) *6*	-0.167 (ns) *3*	0.256 *** *45*
7	161	0.267	-0.132 *** *126*	-0.106 ** *56*	-0.147 *** *25*	0.150 (ns) *12*	-0.023 (ns) *74*
8	161	0.379	0.295 *** *132*	0.162 ** *61*	0.431 *** *21*	0.177 (ns) *9*	0.447 *** *46*

9	161	0.689	-0.010 * *144*	0.053 (ns) *70*	0.159 * *33*	0.168 (ns) *14*	0.240 *** *71*
10	161	0.702	-0.465 *** *118*	-0.408 *** *51*	-0.342 *** *25*	-0.369 *** *15*	-0.309 *** *79*
11	161	0.398	-0.181 *** *83*	-0.136 *** *42*	-0.093 (ns) *23*	-0.013 (ns) *13*	-0.050 (ns) *46*

Note: (ns): non-significant, *: <0.1, **: <0.05, ***: <0.01

Table 4 depicts the differences in proportion, and Figure 2 displays the proportion of correct answers for students in the spring and fall for these eleven problems. The four column bars in the graph show the proportion of students in the fall who solved the problem correctly on attempts 1-4. The bold line with squares (best attempt) represents the proportion of students who solved the problem correctly on the attempt in which they received their best score on that testing module. The grey data line with circles depicts the proportion of students in the spring who solved the problem correctly during the in-class exam.

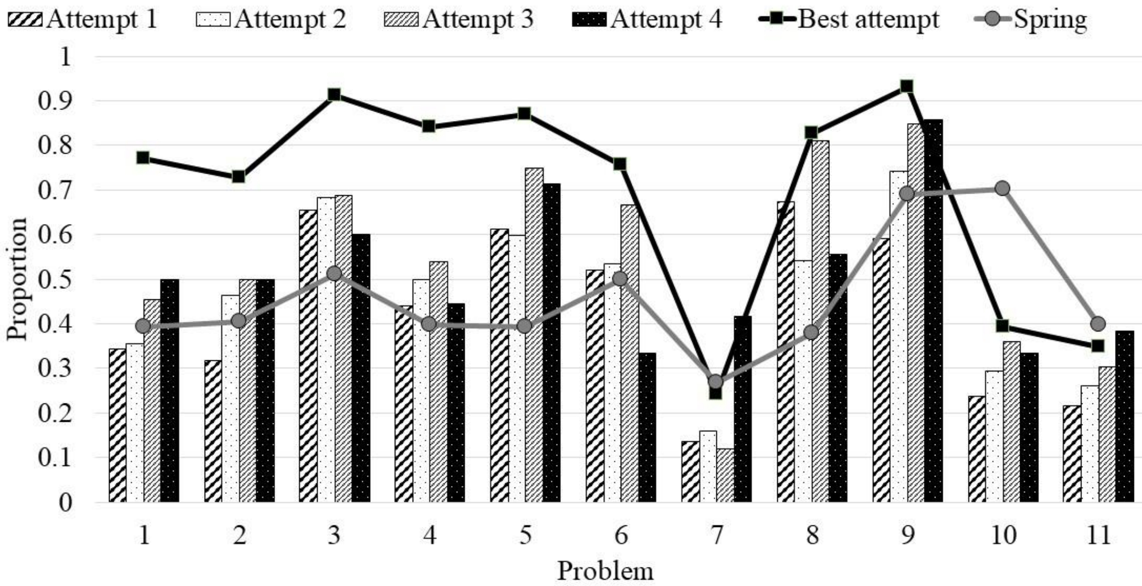

Figure 2 Proportion of students who answer a question correctly in the fall and the spring. Attempts 1-4 and Best attempt correspond to the fall online testing modules.

The average percentage of correct solutions to these problems is 46% for the spring, 43% for the first attempt in the fall, 47% for the second attempt, 55% for the third attempt, 51% for the fourth attempt, and 69% for the best attempt in the fall. A larger proportion of students answered five of the eleven problems (3, 4, 5, 6, and 8) correctly on their first attempt in the online testing modules compared to those students in the in-class exams. The difference between the spring and the first attempt is significant at the 5% level for three of those five problems.

A larger proportion of students in the fall answered a problem correctly on their best attempt in the testing module in eight of eleven problems compared to those students in the in-class exam. Table 4 indicates that this difference is significant at the 1% level for all eight of those problems. This result suggests that on average, students in the fall were able to learn how to solve engineering economics problems and demonstrated that they were able to solve these problems. Students in the spring were not provided the opportunity to learn from their mistakes for these problems.

A larger proportion of students answered three problems correctly in the spring compared to students in the best attempt in the fall, but the difference is only significant for problem 10. Problem 7 was very difficult, and only 27% of students in the spring solved problem 7 correctly. Students in the fall also thought problem 7 was difficult, and it appears that many students in the fall strategically decided not to learn how to correctly solve the problem because they could still pass the testing module by correctly answering other questions. Problem 11 was also challenging and was part of testing module 7 in the fall. Testing module 7 covered material at the end of the semester and resulted in the fewest number of students who passed this testing module because students had less time to improve their performance. Determining why students in the fall performed badly on problem 10 compared to students in the spring is more challenging. One possible explanation is that the answer to the problem was a negative number, and many students in the fall entered a positive number, which was marked incorrectly by the online testing module.

A larger proportion of students answered nine out of eleven questions correctly in their second attempt compared to students in their first attempt in the fall. A larger proportion of students answered ten out of eleven questions correctly in their third attempt compared to students in their second attempt. A larger proportion of students answered four out of eleven questions correctly in their fourth attempt compared to students in their third attempt. These results suggest that allowing students to take more attempts and see the same problem with different numbers helped them learn how to solve the problem at least for the first three attempts. One reason why the improvement does not continue for the fourth attempt may be that the number of students who attempted one of these eleven problems three or four times is fairly small, especially compared to the total number of students in the class. The best students might have only attempted a problem a few times because they might have passed the testing module before seeing the same problem three or four times.

A different study of these online testing modules in the fall semester analyzes if the students' likelihood of answering questions correctly and of passing a testing module improved with each attempt. On average, 10% of students passed a testing module for each attempt through the first five attempts. After the first five attempts, that percentage decreased to approximately 5%. The difficulty of a question had a large impact on whether the odds of a student answering a question correctly increased with each attempt. On average, for each time a student saw a question during the student's first three attempts, the student's odds of answering the question correctly increased by approximately 20%.

3.4 Course evaluations

Students in the engineering economics course had the opportunity to fill out course evaluations at the end of the semester. The professor encouraged the students to fill out the course evaluation and provide feedback in order to improve the course the future, but filling out the course evaluations was optional. The students' responses were anonymized. In spring 2017, 19 IE students and 50 non-IE students out of a total of 161 completed a course evaluation. In fall 2017, 20 in-class IE students, 48 in-class non-IE students, and 35 distance-learning students completed a course evaluation.

The students answered 15 Likert-response questions and were invited to provide open-ended comments on the course and the instructor. The course evaluations did not attempt to calibrate students, and one student's interpretation of a response of 4 may not be equivalent to another student's response of 4. Table 5 depicts the student responses to three of the questions that are most applicable to the assessment procedures. Since the spring course did not have any distance-learning students, it might be fairer to compare the evaluations of only those students in the fall who were registered for the in-class version. Statistical significance is tested to see if a response in fall is different from a response in the spring.

Table 5 Course evaluations for spring and fall 2017 courses

The objectives of the course were:	**Spring 2017**	**Fall 2017 (in class and distance learning)**	**Fall 2017 (in class only)**
Not stated	1	1	1
Not attained	0	11	6
Attained	68	91	61
Percentage of students who answered attained	98.6	88.3***	89.7**
The exams were fair			
1 (Strongly Disagree)	1	3	1
2	3	6	4
3	13	30	19
4	24	25	17
5 (Strongly Agree)	27	39	27
Percentage of students who answered 4 or 5	75.0	62.1**	64.7*
Percentage of students who answered 5	39.7	37.9 (n.s.)	39.7 (n.s.)
The overall teaching effectiveness of the instructor was:			
1 (Poor)	2	0	0
2	0	3	1
3	4	12	9
4	22	37	23
5 (Excellent)	41	51	35
Percentage of students who answered 4 or 5	91.3	85.4 (n.s.)	85.3 (n.s.)
Percentage of students who answered 5	59.4	49.5 (n.s.)	51.5 (n.s.)

Note: (ns): non-significant, *: <0.1, **: <0.05, ***: <0.01

Students in the spring responded slightly more favorably to the course than students in the fall. A greater percentage of students in the spring believed that the course objectives were obtained, that the exams were fair, and the teaching effectiveness of the instructor was good or excellent compared to students in the fall. This is true whether the course evaluation for fall includes both in-class students and distance-learning students or only in-class students. The differences in percentages are statistically significant at the 1% level for whether course objectives were obtained. The percentage differences of students who answered with a 4 or 5 are statistically significant at the 10% level for the question if the exams were fair. The percentage differences are not statistically significant for the question about the teaching effectiveness of the instructor.

These results suggest that students may slightly prefer traditional course assessments rather than the online testing modules. Perhaps a larger percentage of students in the fall course did not think the exams were fair because students found the online testing modules difficult to pass. Some of the open-ended comments indicated that some students in the fall found the testing modules very frustrating. Although some of the differences in percentages may be statistically significant, those differences are approximately 10%, which does not seem to indicate that students overwhelmingly preferred traditional course assessment. Students in the spring may also have been reflecting on the online final exam when they responded to this course evaluation.

3.5 Cheating

Online testing may provide greater opportunity for students to cheat and get other students to answer questions on their behalf. The instructions that the students received about resources they could use on the online testing modules consisted of the following:

> You are allowed to use the textbook, notes, the Internet, any other books, and a calculator to answer questions on the testing module. You are strongly encouraged to use Excel to answer questions. During the time you are taking a testing module, you are not allowed to discuss the testing module with any other individual by any means of communication. When you submit your answers, you must verify that you have not discussed the testing module when you submit your answers. If you are caught discussing the testing module while you take the testing module, you will fail that testing module and not be allowed to retake it.
>
> When you are <u>not</u> taking a testing module, you are allowed to discuss the testing module and questions with other people, including other students (as long as they are not taking a testing module), and post questions via Blackboard [the learning management system].

Experimental studies have found that less cheating occurs if a strong honor code exists (McCabe & Trevino, 1993), students sign an honor code (Dickerson et al., 1992; LoSchiavo & Shatz, 2011), or people are reminded of their own moral or honesty standards (Mazar, Amir, & Ariely, 2008). In order to remind students of their honor in the online testing modules in the engineering economics course, a student was required to answer the following question at the end of each testing module: "Do you state on your honor that you have not received any unauthorized aid while taking this exam and that you did not discuss this exam during the time it took you to take this exam? After clicking on submit, you can talk about this exam with other people."

Since each question in the testing module was randomized among different problems and each problem had different versions where the numbers changed, students could not simply get the answer to a question and enter the answer. They were allowed to receive information from other students on how to solve a particular problem—as long as they did not receive that information during the time that they were taking an online testing module.

Despite these safeguards to discourage cheating on the online testing modules, it would be naïve to assume that no student received help from another student while taking an online testing module. A student may have even taken an entire testing module in place of another student. Unfortunately, no data was collected about student cheating for the course in fall 2017. However, the engineering economics course in spring 2018 and in fall 2018 was conducted in the same manner as fall 2017 with online testing modules. Surveys of the spring and fall 2018 courses were conducted at the conclusion of the semesters and asked students about cheating. These surveys were anonymous, and students were told that the instructor would make no effort to determine how a student responded in these surveys. Table 6 displays the survey and the results.

Table 6 Survey of students in spring and fall 2018 courses on cheating

	Spring 2018	**Fall 2018**
Number of respondents	172	226
Question 1: This question asks you about help that you receive on the testing modules. I promise that I won't know what you answered. Please mark the best answer.		
I NEVER discussed how to solve questions during the time that I was taking a testing module.	149 (87%)	184 (81%)
I received help from an individual one or two times while I was taking a testing module.	18 (10%)	36 (16%)
I received help from another individual more than two times while I was taking a testing module.	4 (2%)	6 (3%)
No answer	1 (1%)	0 (0%)
Question 2: This question asks you about help that you may have given to another student. I promise that I won't know what you answered. Please mark the best answer.		
I NEVER helped another student during the time that	152 (88%)	185 (82%)

student was taking a testing module.		
I helped a student one or two times while a student was taking a testing module.	17 (10%)	36 (16%)
I helped another student more than two times while the student was taking a testing module.	1 (1%)	5 (2%)
No answer	1 (1%)	0 (0%)
Question 3: How many students (not including yourself) do you know received help while taking an online testing module?		
I don't know of any students who received help while taking a testing module.	139 (81%)	177 (78%)
I know of 1-4 students who received help during the time they were taking a testing module	28 (16%)	47 (21%)
I know of more than 4 students who received help during the time they were taking a testing modules.	4 (2%)	2 (1%)
No answer	1 (1%)	0 (%)

Table 6 indicates that cheating on the online testing modules did occur. Ten to twenty percent of the students admitted to helping or receiving illicit help from other students while taking an online testing module. However, only 2-3% of the students admitted to cheating more than two times. Many students were aware that other students were cheating, but the percentage of students who were aware of other students cheating was still a minority of the class. On the positive side, 82-87% of the students declared that they never cheated. Approximately 80% of the students across spring and fall 2018 did not know of students who were cheating.

4. Discussion

The different assessment procedures have slightly different goals. The goal of spring 2017 assessment was to test if students knew the material. The fall 2017 students were allowed to take multiple attempts of tests so that they could improve by learning from their mistakes. The repeated online testing modules focuses on improving through repetition, which is different than the assessment process in the traditional in-class examinations. Since the assessment methods have slightly different goals, making a straightforward comparison between the two classes is challenging.

Comparing the performance of students in the spring on their homework and in-class exams with their performance on the online final exam shows a wide disparity. Some students performed better on the traditional work, and other students performed better on the online exam. Since the best students did not need an A on the final exam to earn an A for the semester, these students were not incentivized to perform their very best on the final. This may skew the results. Many students who performed mediocrely on the traditional assignments took advantage of the online final with multiple attempts to improve their grade. Students were being strategic while taking the online final exams in spring semester because they knew their in-class assessment grades beforehand.

Charman & Elmes (1998) argue that the introduction of computer-based assessment can improve student performance and consequently student learning. We compare the performance of students in the spring and fall semesters based on their semester grades. Comparing performance based on letter grades is problematic because mapping the numerical results of student performance on homework and exams to letter grades is arbitrary. Since students generally care about the grades they receive and work to earn better grades, comparing grades between the classes does provide insight into how students perform during the semester. Students in the online testing course earned higher grades overall than students assessed with in-class exams, and more students in the online testing course eventually answered the same question correctly than the students taking in-class exams. The results are not uniform across all the students, however. The course evaluations suggest that students in the traditional assessment course had a slightly more favorable opinion of the course than students in the online testing course.

Prior results show that if the student assessment interface is well created, students can do better with online tests (Ricketts & Wilks, 2002). Students in the fall had flexibility because they did not have time constraints or deadlines on the testing modules to submit their tests. The availability of practicing the tests multiple times might have comforted the students and reduced the anxiety by regularity in studying (Leeming, 2002; Stowell & Bennett, 2010). The possibility of retaking a testing module could have reduced student anxiety and helped them perform better (Sarason & Mandler, 1952; Sarason, Mandler, & Craighill, 1952).

Seven percent of students in the fall failed the course compared with less than 1% of the class who failed the class in the spring. More students failed the course with the online testing modules because they procrastinated too much and failed to take advantage of the multiple attempts. Often, engineering students who barely pass engineering courses are able to take advantage of receiving partial credit on examinations. Since the online testing modules offered no partial credit and the standard for passing a testing module was relatively high, this type of student was unable to demonstrate sufficient mastery of the subject to pass the course.

We observed that many students who failed the course in the fall or barely passed the course in the fall procrastinated in taking the online testing modules. Implementing deadlines for testing modules could help motivate students to complete the testing modules more quickly rather than solving all the testing modules towards the end of the semester and getting frustrated due to its repetitive structure. Although we did not specifically measure student strategies, we observed that students who were more proactive in taking testing modules frequently during the semester and who asked for help with questions that they answered incorrectly were more successful in the class. Subsequent versions of this course included deadlines for the testing modules.

Eleven problems were asked of students in the spring and in the fall. On average, the fraction of students who answered these questions correctly on the online testing modules in their first attempt was smaller than the fraction of students who answered these questions correctly in the in-class exams. Students in the fall likely did not spend time studying the material before attempting the online testing modules. Students in the spring studied for the in-class exams and appeared to be a little more prepared to solve these problems correctly. The spring course also provided practice exams with similar types of problems so the students in the spring could practice solving similar problems before encountering these eleven problems on the exam.

Having automatically graded assessments as in the online testing modules in the fall limited the types of questions that could be asked. Questions did not really focus on whether students interpreted their answers correctly. A typical question in an engineering economics course asks students to choose the best project perhaps on the basis of net present value (NPV), annual equivalent worth (AEW), or internal rate of return (IRR). Rather than asking the student to choose the best project, which a student could answer correctly by guessing—a 50-50 chance—the online testing module either asked the student to enter the NPV of the best project or asked the student to enter the AEW of the best project. A drawback to the automatically graded testing modules is that students were not asked to interpret their answers in a meaningful way, such as asking why one project might be better or by asking students what would need to change with a project in order to make it acceptable. Methods such as incremental IRR analysis are more challenging to test in this environment. Questions that asked students for the rate of return that would make them indifferent between two projects was one way to assess if they could perform incremental IRR analysis.

Many questions in the online testing modules involved several steps, and students were required to enter the final answer. Testing students with multistep questions based on the final answer is justified because students have multiple attempts and had the opportunity to ask about questions they might have missed. Students did get frustrated when they made a single mistake on a cash flow statement (such as not dividing depreciation by 2 in the final year) and then were required to retake an entire testing module. However, this assessment procedure also encouraged students to work to calculate the correct answer rather than relying on partial credit.

The spring course required a group project, and the fall course did not have a group project. The project in the spring required the students to compare the cash flows of two different stocks. Students were required to use simulation to assess the future cash flow of one of the stocks and compute the NPVs of purchasing each stock. Students needed to compare the two stocks and decide which one they wanted to purchase and explain why. One stock had a greater expected NPV but more risk and variance. Some students preferred the stock with the greater expected NPV, and other students preferred the stock with the deterministic but smaller NPV. Students seemed to enjoy this project, and learning how to trade off between risk and return was a useful learning objective of this project. The fall version of the course included part of this project—the part about calculating the expected NPV for an uncertain stock using simulation—within one of the online testing modules, but students in the fall were not required to compare stocks or determine which one they preferred. Subsequent versions of the engineering economics course have continued the online testing modules but also incorporated course projects in which student groups need to submit memoranda outlining their answers to the project statements.

One of the main differences between the fall and spring versions of the course was the students' use of Excel. Students in the spring could use a calculator on the in-class exams but not Excel. (They were encouraged to use Excel on their homework, for the take-home portion of exam 2, and for the final exam which was conducted similarly to the course assessments in Fall.) Students in the fall were encouraged to use Excel to pass the online testing modules. Engineering economic problems in the real world are frequently solved using Excel, and the online testing modules encouraged students to use tools and software that are used in business. The use of Excel allows for more complex problems that cannot be solved with a calculator. For example, SIPmath is a free simulation software that is integrated with Excel, and one testing module required students to use the software to analyze engineering economic problems with uncertainty. Finally, the use of Excel helped students avoid silly mathematic mistakes. The principal drawback of allowing students to use Excel is that they rely on the Excel formulas like NPV or IRR to make their calculations. Students may never really learn or understand what these formulas are doing. The use of Excel on the testing modules may have also helped students to share solution methods. One student could solve the problem in Excel and email the Excel file to another student who could have inputted his or her own values without actually knowing how to answer the question.

Overall, we believe the benefits of allowing students to use Excel outweigh the drawbacks, principally because it reflects more closely how engineering economics problems are solved in the real world. It is doubtful that anybody working on engineering economics problems for a company consults interest tables. Requiring students to use interest tables to answer questions on an exam seems unproductive to us.

5. Conclusion

Online testing modules as described in this article could be a method to assess students in large engineering classes. It saves the instructors and the teaching assistants time, and more importantly, the repetition and multiple attempts encourage students to continued to work on the material. Students who feel anxious during in-class exams may benefit from online testing modules because the students know they can always retake a testing module. Students earned a better overall grade in the fall semester than the students who took in-class exams in spring. Attempting a question with similar concepts multiple times on the testing modules helped in students to improve their performance. Hence, the authors believe that online testing modules could be an option for courses where student needs to continually practice applying mathematical formulas.

A limitation of this study is that there is no direct comparison of whether students who are evaluated via repeated attempts of online tests retain course material better or worse than students who are evaluated via traditional methods. Future research can explore how much material students retain after a course with each type of assessment method. According to the course evaluations, a greater percentage of students in the traditional assessment with the online final exam believed the course was effective compared to the percentage of students in the online testing module course. The difference in percentage was not large, however, and students were not asked to compare between the two types of assessment methods.

The survey of students in the fall revealed that a substantial minority of students cheated on the online testing modules. Future research could study if proctored settings allowing multiple attempts of exams help students learn better while limiting the possibility of cheating. Having so many proctored online exams could be logistically challenging, however. It would be interesting to understand if cheating on online testing modules occurs more frequently than cheating on other types of assignments and in-class examinations.

This new method of online assessment with multiple attempts could be beneficial for large classes and could especially be fruitful for courses that are delivered online. Future research could analyze data on how much time students spend with the testing modules and when they take the testing modules in order to develop strategies that may be best for succeeding with online testing modules. Studies could also be conducted that combine online testing with more conventional methods of assessment in engineering education to explore the effectiveness of such an approach.

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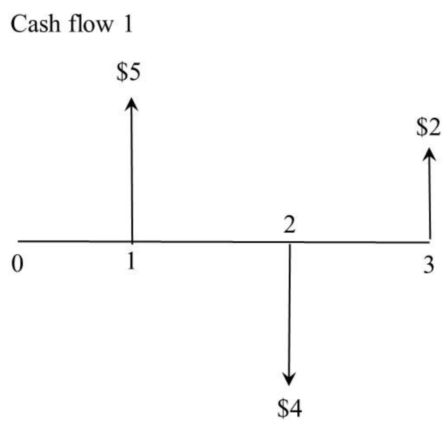
Appendix A

Exam 1 for Spring 2017

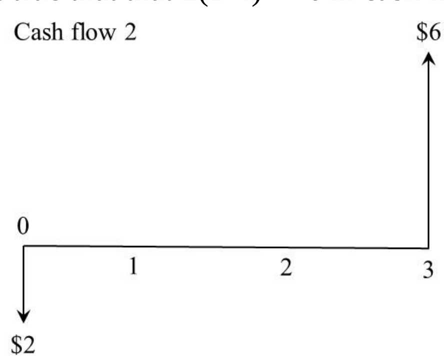
1) You receive a loan for $74.13 where the APR is 6%, compounded monthly. You make a payment of $5 on this loan every 6 months (i.e., 2 payments per year), which will enable

you pay off the loan in exactly 10 years. Immediately after making your regular payment at the end of 6 years, you desire to pay the remainder of the loan in a single payment. Compute the amount you must pay for the remainder of the loan.

2) You deposit \$10 into a savings account that is **compounded daily**. At the end of 3 years, you have \$12 in the account. Assuming you only made that single deposit and you made no withdrawals, what is the **nominal interest rate** for this savings account? Assume 365 days per year.
3) You establish an Individual Retirement Account (IRA) with an interest rate of 5%, compounded annually. You plan to deposit \$30 at the end of each year for a total of 30 years. However, you only deposit \$10 at the end of year 5. If you deposit \$30 in the other 29 years (i.e., years 1-4 and years 6-30), how much do you have in the IRA at the end of 30 years?
4) A city is considering building a new multi-purpose sports and entertainment complex. The city would spend \$400 million immediately to construct the complex. Annual revenue from this complex would be \$40 million and annual operations and maintenance costs would be \$10 million. Assuming the annual revenue and costs will remain the same under these conditions for an infinite amount of time, should the city build the sports and entertainment complex and why? The city's MARR is 10% compounded annually.
5) Cash flow 1 has an interest rate of 5%.



What is the interest rate for cash flow 2 such that cash flows 1 and 2 are **economically equivalent**? Note: It is not true that that $2(1+i)^3 = 6$ in cash flow 2.

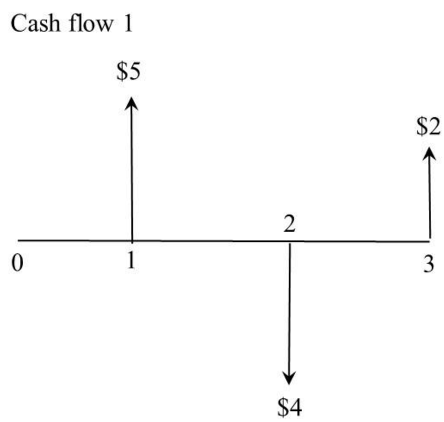


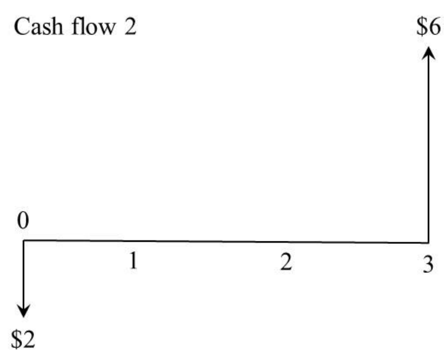
6) You plan to operate the same type of machine for 21 years. Machine A lasts 3 years and Machine B lasts 7 years. Machine A costs $8 and Machine B costs $10. The salvage value of Machine A is $5 and the salvage value of Machine B is $2. Annual operation and maintenance costs $3 for Machine A and $2 for Machine B. Both machines can be purchased in the future at the same price as today, and their salvage values and annual costs will remain as they are now. Your MARR is 15% annual rate compounded annually. Which machine should be purchased and why?

Appendix B

Common problems between spring 2017 and fall 2017

1) You establish an Individual Retirement Account (IRA) with an interest rate of 5%, compounded annually. You plan to deposit $30 at the end of each year for a total of 30 years. However, you only deposit $10 at the end of year 5. If you deposit $30 in the other 29 years (i.e., years 1-4 and years 6-30), how much do you have in the IRA at the end of 30 years?
2) Cash flow 1 has an interest rate of 5%.





What is the interest rate for cash flow 2 such that cash flows 1 and 2 have the same present value?

3) You deposit \$10 into a savings account that is **compounded daily**. At the end of 3 years, you have \$12 in the account. Assuming you only made that single deposit and you made no withdrawals, what is the **nominal interest rate** for this savings account? Assume 365 days per year.
4) You receive a loan for \$74.13 where the APR is 6%, compounded monthly. You make a payment of \$5 on this loan every 6 months (i.e., 2 payments per year), which will enable you pay off the loan in exactly 10 years. Immediately after making your regular payment at the end of 6 years, you desire to pay the remainder of the loan in a single payment. Compute the amount you must pay for the remainder of the loan.
5) A city is considering building a new multi-purpose sports and entertainment complex. The city would spend \$400 million immediately to construct the complex. Annual revenue from this complex would be \$40 million and annual operations and maintenance costs would be \$10 million. Assuming the annual revenue and costs will remain the same under these conditions for an infinite amount of time, what is the present worth of the entertainment complex? The city's MARR is 10% compounded annually.
6) You plan to operate the same type of machine for 21 years. Machine A lasts 3 years and Machine B lasts 7 years. Machine A costs \$8 and Machine B costs \$10. The salvage value of Machine A is \$5 and the salvage value of Machine B is \$2. Annual operation and maintenance costs \$3 for Machine A and \$2 for Machine B. Both machines can be purchased in the future at the same price as today, and their salvage values and annual costs will remain as they are now. Your MARR is 15% annual rate compounded annually. Enter the Annual Equivalent Cost (AEC) for the machine that should be selected.
7) A contributing factor to an airplane's fuel consumption is the bypass ratio of the engine system. The bypass ratio is the amount of air passing around the engine core relative to the amount of air passing through the core. An airplane manufacturer is designing a new airplane and wants to determine the bypass ratio for the airplane's engine system. The airplane will fly 3,500 hours per year and average 500 miles per hour. The amount of fuel that an airplane consumes can be expressed as:

$$z = 0.0549 - 7.64 \times 10^{-4} * y \quad \text{for } 4 \leq y \leq 12$$

where y is the bypass ratio (a unitless number) and z is the number of gallons of fuel consumed per mile flown by the airplane. The cost of fuel remains constant at \$4.18 per gallon.

The initial cost of the engine system as a function of the bypass ratio is $\$280{,}000 + \$2400y^2$. The engine system will be used for 10 years. At the end of 10 years, the salvage value of the engine system as a function of the bypass ratio is $\$10{,}000y$. The airplane manufacturer wants to minimize the annual equivalent cost (AEC) of the engine system (which includes the initial cost, the annual cost of fuel, and the salvage value). The manufacturer's MARR is 13%. What is the optimal bypass ratio that minimizes the AEC of the engine system? (The optimal answer for the bypass ratio is between 4 and 12, but it should not be necessary to consider that constraint in your calculations.)

8) A firm is considering two projects with the following cash flows and internal rates of return. If the firm's MARR is 19%, should it select project A, project B, or neither? It cannot select both projects. What is the net present worth of the preferred project?

n	A	B
0	-10	X
1	0	0
2	15	28
IRR	22.47%	20.00%

9) A firm's total cost (TC) function follows a cubic function

$$TC(x) = 1 + 30x - 9x^2 + x^3$$

where $x > 0$ is the number of units the firm produces. The firm can sell each unit that it produces at a price of 51. How many units should the firm produce if it wants to maximize its profit where profit is total revenue minus total cost?

10) A firm purchases a new machine for $200,000. It borrows $80,000 at 10% annual interest to be repaid in 3 years. The machine is depreciated using a 5-year MACRS. At the end of 3 years, the firm sells the machine for $50,000. The firm's tax rate is 34%. How much does the firm pay or save in taxes from selling this machine at the end of 3 years? In other words, what is the gains taxes?

11) You are responsible for constructing a new building. The building will have 10 floors. You are considering modifying the design of the structure with extra steel, utilities, and elevator shafts so that it will be easier to double the height of the building to 20 floors (after the building is constructed). You need to decide whether to modify the design of the building before the building is constructed.

When the building is built with 10 floors, there will either be 10 occupants or 5 occupants. There is a 0.6 probability that there will be 10 occupants. If there are 5 occupants, your company will never choose to make the building taller.

If there are 10 occupants, your company may decide to double the height of the building. If your company doubles the height of the building (to 20 floors) there is a 0.3 probability the building will have 20 total occupants and a 0.7 probability the building will have 14 total occupants.

The revenue for the company depends on the number of occupants in the building:

Number of occupants	5	10	14	20
Revenue	$5	$10	$14	$20

Note: If there are originally 10 occupants and the building's height is doubled, assume the revenue for the company is either $14 or $20. Do not add $10+$14 or $10+$20.

The cost for the company depends on whether the design is modified and whether it chooses to double the height of the building:

Alternatives	Modify Double height	Modify Do not double height	Do not modify Double height	Do not modify Do not double height
Cost	$12	$7	$15	$5

Your company wants to maximize its expected profit (where profit is the revenue gained from the occupants minus the cost). What is the expected profit for the optimal option?