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Study of Pre- and Post-Course Knowledge Surveys in an Engineering Economy Course

Dr. Simon Thomas Ghanat P.E., The Citadel

Dr. Simon Ghanat is an Assistant Professor of Civil and Environmental Engineering at The Citadel (Charleston, S.C.). He received his Ph.D., M.S., and B.S. degrees in Civil and Environmental Engineering from Arizona State University. His research interests are in Engineering Education and Geotechnical Earthquake Engineering. He previously taught at Bucknell University and Arizona State University.

Dr. Dimitra Michalaka, The Citadel

Dr. Dimitra Michalaka is an Assistant Professor at the department of civil and environmental engineering at The Citadel. Dr. Michalaka received her undergraduate diploma in civil engineering from the National Technical University of Athens (NTUA), after which she entered into the transportation engineering graduate program at UF. She graduated with a Master's of Science in May 2009 and with a Ph.D. in August 2012. Her research is primarily focused on traffic operations, congestion pricing, traffic simulation, and engineering education.

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Introduction

Formal assessment is required in most educational programs as it is a tool to evaluate or promote students' learning and guide the instruction process. There are many different ways to assess student knowledge[1]. The methods used depend on what the instructor wants to accomplish and when/how often, the assessment takes place. The question types used in assessment methods can be multiple-choice, short answer, open-ended, essays, matching, and true or false and can be incorporated in written reflections, quizzes, assignments, and others[2]. A commonly accepted assessment instrument used for both diagnostic and formative purposes is concept inventories[3], which refer to any kind of research-based assessment techniques that measure conceptual understanding[4]. Using concept inventories helps instructors measure the effectiveness of their teaching[4] and determines if students have the correct understanding of important concepts on a topic. This is particularly important and effective when students come to learn a subject with an established commonsense of the material[5] because that commonsense may not always be the right knowledge and it is better if the instructor is aware about the misconceptions from the start of the course. It has been shown that concept inventories provide reliable data and can positively influence pedagogical practices[3]. When the same set of questions is used, concept inventories help in evaluating students' pre and post knowledge on a subject. Pretests establish the prior knowledge on a subject and posttests measure the learning at the end of a learning experience. Those types of tests also help distinguishing between learning and performance[6]. In addition, monitoring the results of pre and post concept inventories allows instructors to make comparisons among the effectiveness of their teaching over time and possibly in different environments and across different institutions[4]. Even though concept inventory tests are a good tool, it is suggested to not be used to replace exams, homework assignments or other assignments that demonstrate students' math skills[4]. However, it is shown that students who do well in concept inventories tend to do well in problem-solving exercises too but the opposite is not necessarily true[7].

In STEM fields and specifically in engineering, concept inventories are used in a variety of courses such as Chemistry, Physics, Math, Fluid mechanics, Materials, Circuits. Statics and others[3]. However, there are not any studies on using concept inventories to assess pre and post knowledge in engineering economy courses. Therefore, this paper focuses on assessing students' pre and post conceptual learning in an engineering economy course using the widely used and accepted assessment technique of concept inventories. During the course, numerous learning techniques were used to help and guide students in learning and understanding of the course material. The concept inventory questions and the learning techniques used in several sections of engineering economy taught by three different professors are presented in the following sections.

As a requirement for graduation, Civil Engineering majors at The Citadel, a teaching focused institution in the Southern United States, must take an engineering economy course in their junior year. The course focuses on basic principles of engineering economy as applied to the economic analysis of the costs of construction and operation of various engineering works. The objectives of this study were to (1) assess the amount of exposure engineering majors have to engineering economy prior to this course and (2) to assess student learning as a result of various pedagogical techniques used. A pre-test and post-test were developed based on key concepts in engineering economy. The pre-test was administered to measure student's prior engineering economy knowledge at the beginning of the term. The same short-answer test was administered on the last day of semester to assess knowledge gained as a result of the course experience. Data were collected over the span of three years (2014-2016). Each summer two sections of engineering economy are offered at The Citadel. For this study, one section was used as treatment and the other as control. This paper discusses the instructional techniques employed, the analyses of pre and post-test results, and suggestions for future research.

Learning Tools Used in Engineering Economy

In the first section of the engineering economy (treatment section), various instructional pedagogies were employed to improve the student-learning environment in 2014-2016. Prior to each lesson, web-based pre-class reading responses[8] were used to motivate students to prepare for class regularly. Students were required to respond to one open-ended question (i.e., how does depreciation affect company's cash flow? how does frequency of compounding affect the future worth of an investment?) on the course website. Student responses were examined, and the in-class activities were tailored to meet their actual needs[9]. Also prior to each lesson, a song about money was played from a list of all- time greatest hits (i.e., “Money” by Pink Floyd, “Money For Nothing” by Dire Straits, “Take the Money and Run” by Steve Miller Band, etc.) to stimulate learning and get the students excited about engineering economy. Cash flow diagrams were drawn on the board using real money and magnets to demonstrate the applications of engineering economy factors before each lesson. In addition, learning objectives were written on the board and were referred to frequently to assist students as to where the content fit into the knowledge they were assembling[10].

At the beginning of each lesson, the Think-Pair-Share[11] strategy was used to help students organize prior knowledge, brainstorm questions and engage with the engineering economy concepts individually, in pairs, and as a whole class. An example of a Think-Pair-Share student activity from one of the lessons is illustrated[10] in Figure 1. Next, a mini lecture was conducted to introduce students to new key concepts and allow them to fill in the blanks in their Power Point lecture notes. The presented material was always linked to previous and future material in the course and to the students' personal experiences. After the mini lecture, hands-on small group problem solving was employed to assist students with the engineering economy concepts. The time value of money concept was applied to both real-life engineering projects and student's personal finance decisions such as student loans, car loans, credit cards, etc. Daily individual and team quizzes were administered on the assigned readings and the homework assignments and students were provided with quick feedback. On one occasion, students were asked to take a position for or against ethically oriented challenges confronted during benefit cost analyses and debate the issues. This activity not only assisted the students by providing relevancy of the course material to real-life issues, but also actively engaged students in thinking, analyzing, and interacting intellectually with one another.

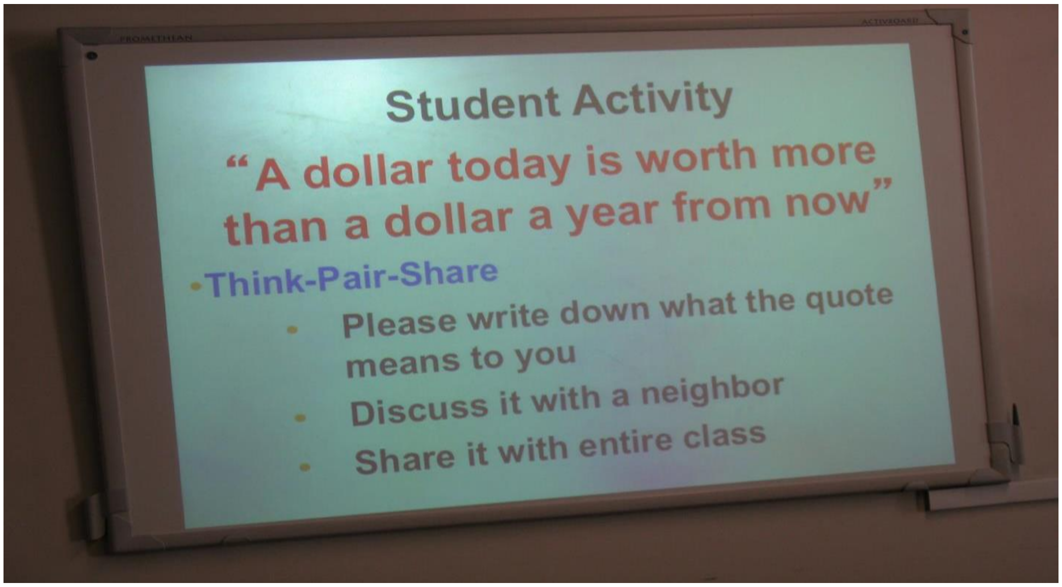

Figure 1. An example of "Think-Pair Share" activity used in engineering economy course.

At the end of each lesson, the One-Minute paper[9,12] or Muddiest point paper[9, 13] was used to monitor student learning and address students' misconceptions and preconceptions. Students were typically asked to write a concise summary of the presented topic, write an exam question for the topic, or answer a big-picture question from the material that was presented in the current or previous lesson in 60 seconds.

To review for the mid-term exams, Jeopardy-style questions were used, which required students to display mastery of key engineering economy concepts that goes beyond simple memorization. Category topics for the Jeopardy game included: time value of money, capitalized costs, depreciation, internal rate of return, and benefit-cost ratio. To review for the final exam, students were asked to create engineering economy crossword puzzles in their collaborative groups. Once constructed, the puzzles had to be solved by other groups in the class. The use of the games in the course truly encouraged students to take a greater degree of responsibility for their learning [14, 15]. Students were also asked to write a test question related to one of the learning objectives with correct answer key (open response or multiple choice formats) that could appear on the final exam. The best question was included on the final exam and student whose question was chosen also earned extra credit.

Traditional lectures with power points were employed in the second section of the engineering economy (control section) in 2014-15. The instructor taught the sections using a traditional passive learning pedagogy where students received a standard lecture presenting the material theory followed by a short example that implemented this theory. In the second section of the engineering economy course in summer 2016 (control), students were given the pre concept inventory test during the first day of class as part of a longer questionnaire that also included questions about themselves and their expectations for the course. Later, students introduced to course materials through several learning techniques which helped (based on the pre and post survey results that will be presented later) to have helped students understand the course material.

At the beginning of each class, students were given a set of learning objectives, which guided them to focus on what they were expected to know. Some examples of learning objectives are: "Apply the arithmetic gradient present worth factor (P/G) to convert an arithmetic gradient G for n years into a present worth at Year Zero, Find the rate of return of an investment, Compare projects using the Benefit/Cost Ratio, and Draw cash flow diagrams." Two-to-five objectives were given per class period. The concept of presenting learning objectives was adopted from the ExCEEd teaching model [16](X) because it has been proven that they facilitate the appropriate level of student achievement.

Simple examples were used to introduce the new concepts. For example, "time value of money" was presented using two different situations of depositing money to a financial account and withdrawing that amount of money after a number of years. Going through the solution of the given problem, the economic concept was related to student's own real life scenarios. Short definitions and equations were written on the board so students had complete notes to study after class. After the introduction of a new concept through one or more examples, students were asked to solve problems with the help from their peers and professor. The majority of the class time was spent in solving problems.

Complicated concepts and methods were taught not only by examples, but also by giving students step-by-step implementation of the concept/method and fill-in-the- blank exercises. Students were exposed to real life applications of Engineering Economy on a day-to-day basis; however, they did not have a deep understanding of the concepts which was determined from the results of their pretest). For instance, the professor gave students several loan examples with different amortization time periods and interest rates and students were asked to select which of them they would have chosen based on their financial situation at the moment. It should be noted that students did not have to share personal information about their finances if they were not willing to. No PowerPoint presentation was used in the course. Homework assignments were given to the students regularly, as well. Students had to solve 8-10 problems per week. In addition, students were given quizzes regularly in the class. Since the successful execution of this interactive and active learning class depended significantly on student participation, 10% of the student grade was attributed to class attendance, participation and professionalism and 10% to in-class quizzes to encourage students to participate and pay attention.

Assessment Measure

A six-question pre- and post-test was developed based upon the six learning objectives in the course (see Table 1). The pre-tests were administered to measure students' prior engineering economy knowledge and to identify student misconceptions at the beginning of the semester. The same short-answer test was administered on the last day of the semester to assess knowledge gained as a result of the course experience. It is important to note that neither the pre-test nor post-test counted toward the course grade.

Table 1. The short-answer questions on the pre- and post-test

Question 1	How do time and interest affect money?
Question 2	What is the meaning of the rate of return?
Question 3	What is the difference between Annual Percentage Rate (APR) and Annual Percentage Yield (APY)?
Question 4	What evaluation method is used to select between public sector alternatives with unequal lives?
Question 5	What is capitalized cost?
Question 6	What is the difference between tax depreciation and book depreciation?

Results and Discussion

Figure 2 illustrates the mean scores on the pre- and post-test for the treatment and control sections in this study. For the treatment section, the pre-test and post-test means range from 12.7% to 20.5% and 80% to 88.5%, respectively. For the control section, the pre-test and post-test means range from 18% to 30.3% and 72.8% to 81.3%, respectively. For the treatment sections, the pre-test and post-test standard deviations range from 7.6% to 14.3% and 9.1% to 16%, respectively. For the control sections, the pre-test and post-test standard deviations range from 7.5% to 14.2% and 14.6% to 17%, respectively.

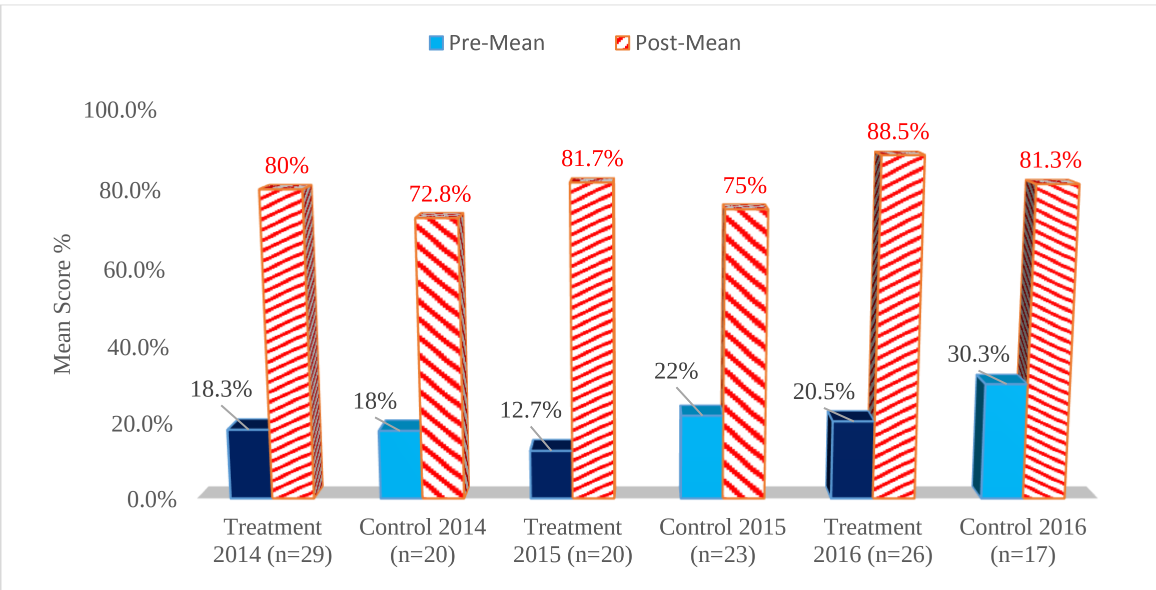

Figure 2. Pre-test and post-test mean for treatment and control sections in this study

Figures 3 shows a comparison of students' pre-test and post-test scores for treatment and control sections. The overall (three-year period) pre-test means for the treatment and control sections were 17.6% and 23.1%, respectively. For the treatment and control sections, the overall post-test means were 82.3% and 76.1%, respectively. It can be seen from Figure 3 that students in the control section performed slightly better on the pre-test than students in treatment section. However, the students in the treatment section performed slightly better on the post-test than students in the control section. When analyzing the results of the pre-tests and post-tests as a whole, there are relatively small differences between treatment and control sections.

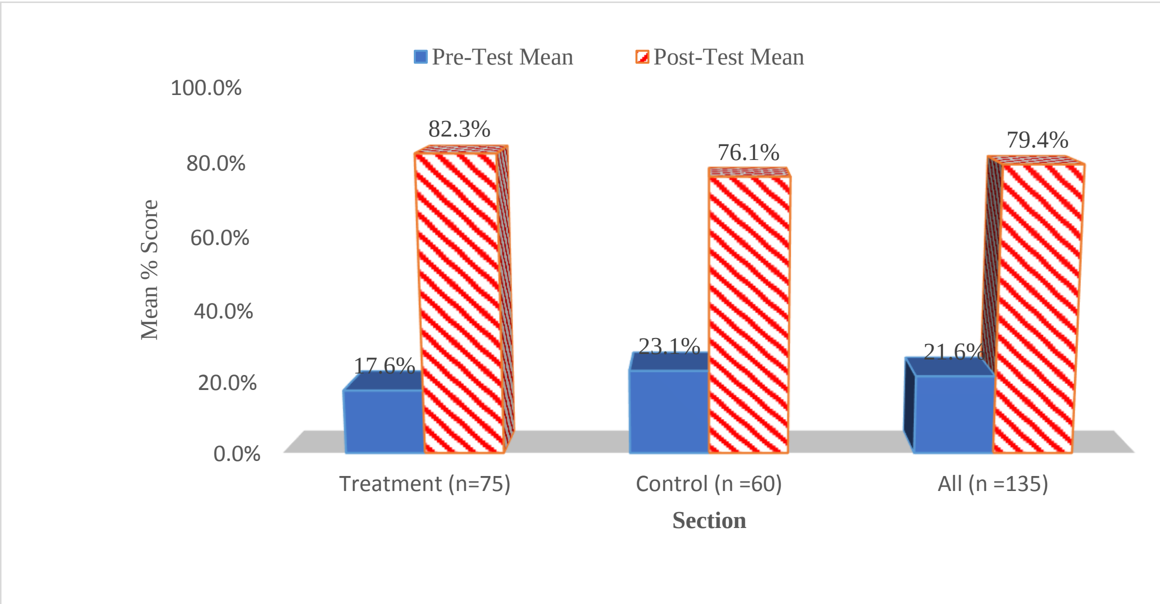

Figure 3. Pre- and post-test mean for treatment, control and all sections combined in this study

Figures 4-9 illustrate the students' performances on each question on the pre- and post-test across sections in this study. The pre-test means for Questions 1, 2, 3, 4, 5, and 6 range from 76% to 94%, 0 to 64%, 0 to 16%, zero, 0 to 12%, and 0 to 5%, respectively. The post-test means for Questions 1, 2, 3, 4, 5, and 6 range from 94% to 100%, 68% to 100%, 68% to 100%, 76% to 96%, 64% to 100%, and 39% to 68%, respectively.

Figures 4-9 further analyze students' performance on each question on the pre-test and post-test in years 2014-16. Student performance (at below 50% level) on Questions 2-6 of the pre-test is an extremely poor performance, indicating little to no prior experience with these concepts. The strongest score on the pre-test was Question 1 (concept of time value of money), which is an important theme in the engineering economy course that the students successfully mastered. Student's high pre-test performance on Question 1 suggests that they are sufficiently able to apply their prior knowledge to certain aspects of engineering economy. The weakest scores on the pre-test were Question 3 (difference between APR and APY); Question 4 (evaluation method used to select between public sector alternatives with unequal lives); Question 5 (concept of capitalized cost); and Question 6 (difference between tax and book depreciation). The scores increased on all of these questions for the post-test, although the scores for Question 6 were still slightly low. The strongest scores on the post-test were Questions 1, 2, 3, 4, and 5; these questions were all fundamental course concepts that are highly emphasized throughout the semester. The weakest score on the post-test was Question 6 (tax versus book depreciation). Students in the treatment section showed more growth from pre-test to post-test in Questions 3 and 5 (Figures 6 and 8) than the students in control section.

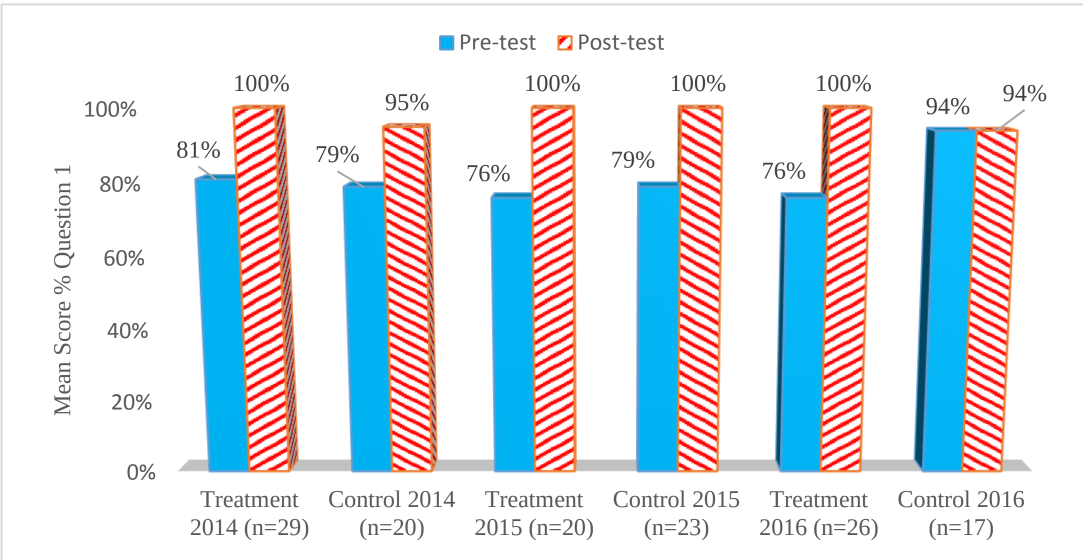

Figure 4. Results of pre- and post-test for Question 1 (How time and interest affect money)

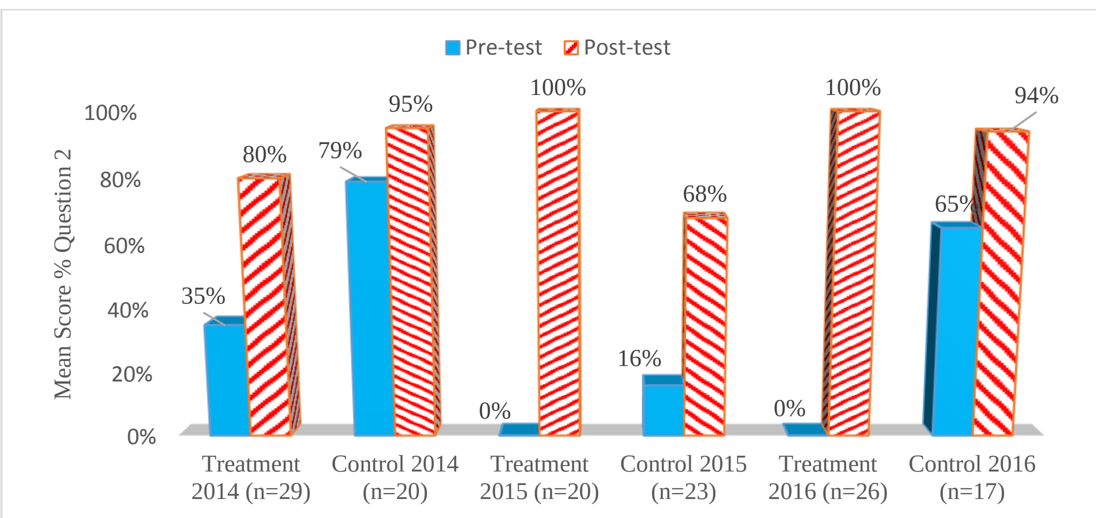

Figure 5. Results of pre- and post-test for Question 2 (Meaning of the rate of return)

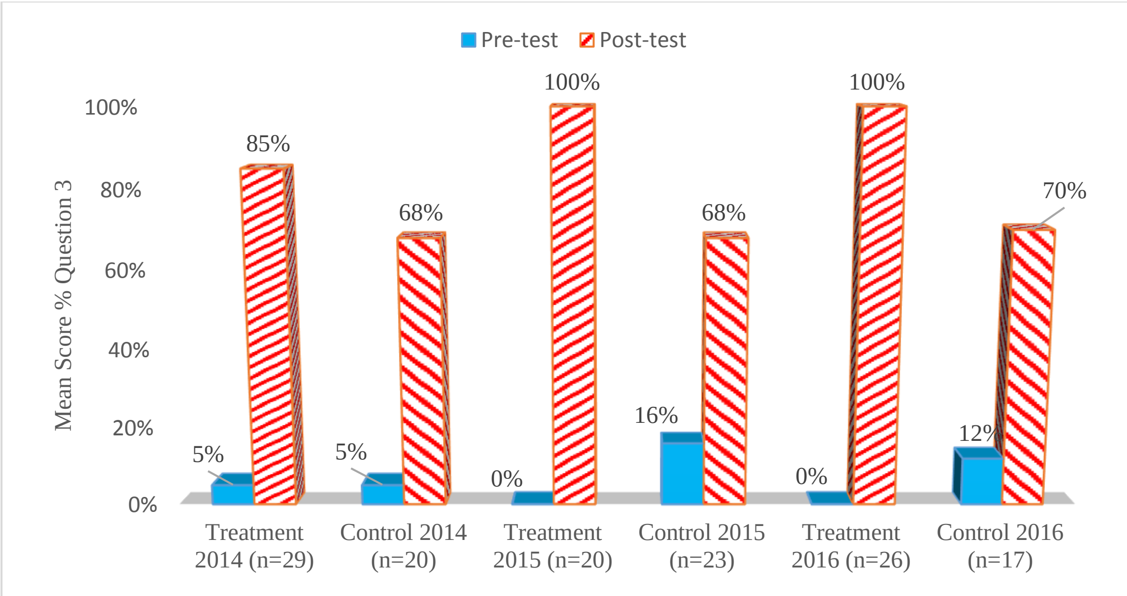

Figure 6. Results of pre- and post-test for Question 3 (Difference between APR and APY)

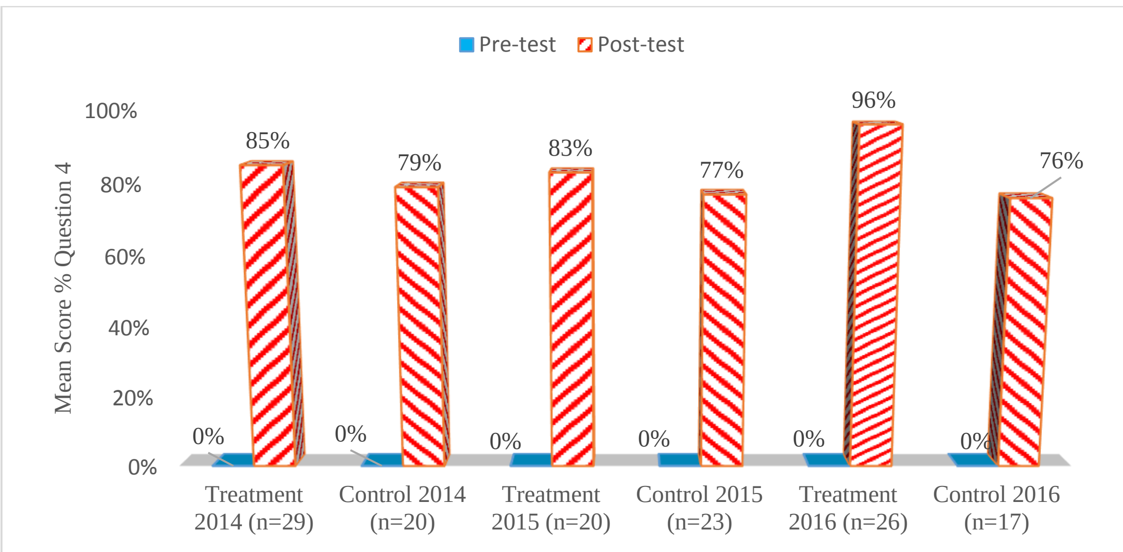

Figure 7. Results of pre- and post-test for Question 4 (Evaluation method used to select between public sector alternatives with unequal lives)

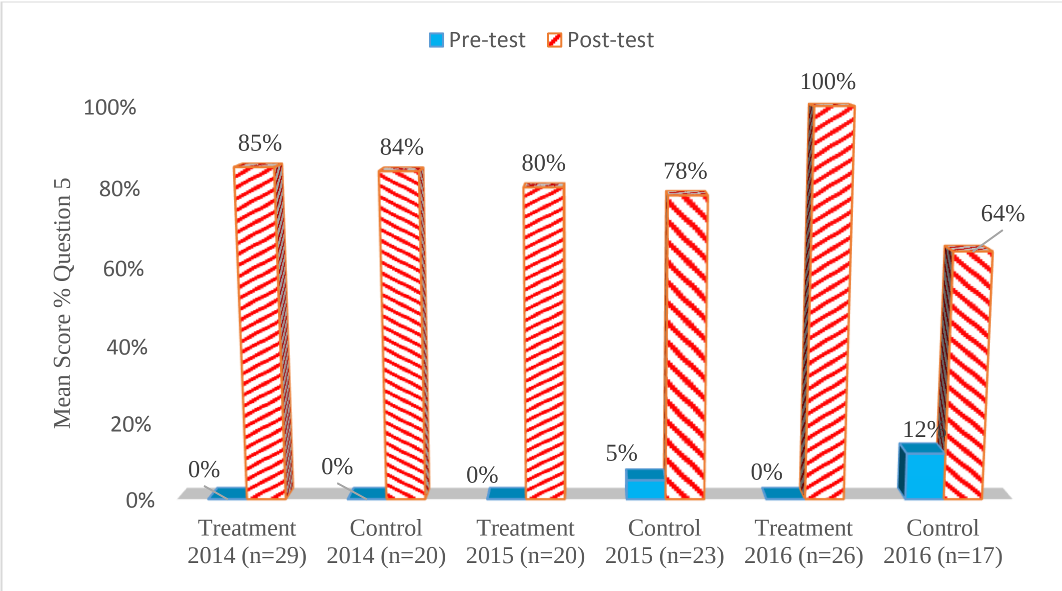

Figure 8. Results of pre-test and post-test for Question 5 (Concept of capitalized cost)

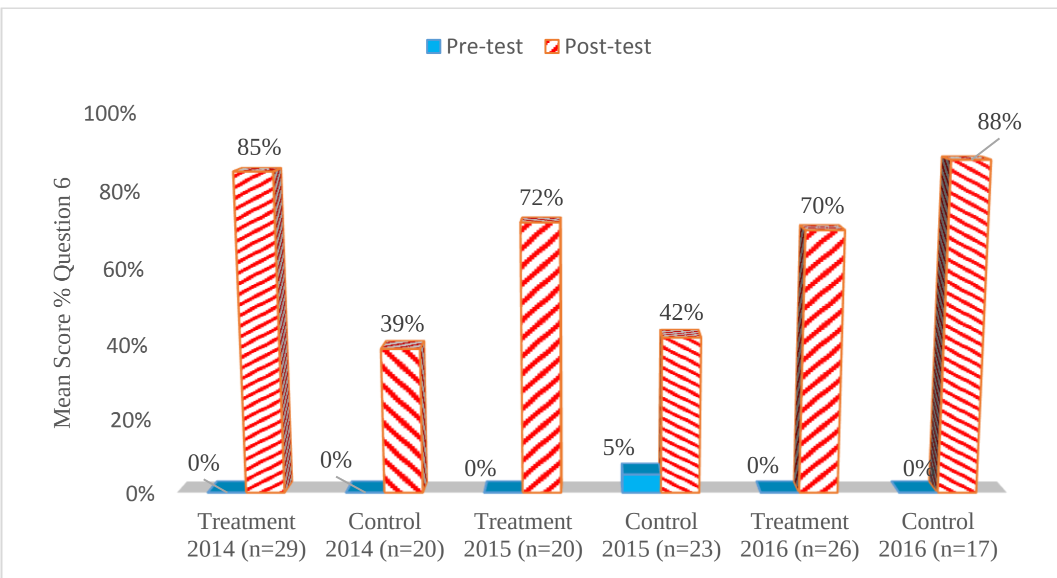

Figure 9. Results of pre-test and post-test for Question 6 (Difference between tax depreciation and book depreciation)

A statistical analysis was conducted on all pre-test and post-test data to detect if the changes in students' understanding of the engineering economy concepts over the course of the semester were significant. Comparison of the pre- and post-test scores was completed using the paired t-test at five percent level of significance, and the results are shown in Table 2. The difference between the means was statistically significant for each section and all sections combined, showing substantial improvement from pre-test to post-test at five percent level of significance.

The results showed that there was a significant difference in scores for pre-test and post-test. There was an increase from an average score of 21.6% on the pre-test to an average score of 74.9% on the post-test (mean paired diff = 53.3, t = 29.6, p-value < 0.001) across all sections (see Table 2).

Table 2. Pre-test-post-test means, standard deviations, differences of sections in this study

		Pre-Test		Post-Test				
Section	n	Mean (%)	St Dev (%)	Mean (%)	St Dev (%)	Mean Diff (%)	t	p-value
2014-Treatment	29	18.3	5.0	80.0	16.3	61.7	21.4	<0.001
2014-Control	20	18.0	5.8	72.8	17.7	54.8	15.5	<0.001
2015-Treatment	20	12.7	7.3	81.7	6.8	69	19.9	<0.001
2015-Control	23	22	8.0	75.0	17.8	53	13.8	<0.001
2016-Treatment	26	20.5	14.3	88.5	9.2	68	23.3	<0.001
2016-Control	17	30.3	13.5	81.3	19.5	51	9.7	<0.001
All	135	21.6	13.1	74.9	16.7	53.3	29.6	<0.001

The paired sample t-test was also conducted for each question to test for statistically significant differences between pre- and post-test scores. Comparison of the student's performances showed that all students performed similarly on each question and overall score when measuring conceptual understanding from pre-test to post-test. All six questions showed a statistically significant difference between the pre- and post-tests (all p < 0.001).

Conclusions:

Using data from two sections of engineering economy over a span of three years, this study assessed the amount of exposure engineering majors have to engineering economy prior to this course and the amount of gains in conceptual understanding of engineering economy concepts because of various pedagogical techniques used. The following conclusions can be made based on the study results:

- The difference between the means of pre-test and post-test was statistically significant for each section and all sections combined, showing improvements from pre-test to post-test. There was an increase from an average percentage correct of 22 on the pre-test to an average percentage correct of 75 on the post-test across all sections. The pre-test to post-test changes in overall scores was influenced by the various pedagogical techniques used in all sections in this study.
- Students are entering engineering economy course with little prior knowledge. The low performance on several of the pre-test questions is not surprising, as students are not expected to have wide exposure to these concepts prior to completing a course in engineering economy.

- Regardless of the pedagogical techniques, students experience significant improvement in conceptual understanding of economy concepts during the course.

This research provides a necessary first step towards identifying capabilities and limitations in our capacity in teaching engineering economy and can provide important feedback with regards to what works and what does not work for improving student's conceptual understanding of fundamental concepts.

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