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Comparison of Engineering Economics Learning Outcomes and Student Perception

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Abstract

Two growing trends in education are the increasing use of distance or on line delivered instructional materials and the struggle for improving the effectiveness of learning. There is a significant body of literature which examines both aspects of on line versus traditional instructional methods and the issues of effective teaching. This paper contributes to this literature by examining student perception and actual accomplishment of learning outcomes in engineering economics courses delivered in two universities and with different course delivery techniques: live face to face lectures compared to live distance delivered lectures. Three sections of engineering economics with three different instructors (two face to face and one distance delivered) participated in the study. All three sections used consistent exam questions, evaluated learning outcomes using shared rubrics, and compared student self-assessment of learning with actual results. The paper analyzes similarities and differences in student accomplishment based on these exam questions and student responses to related survey questions.

Introduction

One of the primary challenges for engineering education is the question of how to measure learning and how it is impacted by the mix of instructional techniques employed[1]. In this era of "educational effectiveness," it is important to match the best combination of teaching and delivery methods with students and with the range of different instructor personalities, student learning methods, and course delivery techniques[2, 3]. This is a complicated mix and is especially complex for a course such as engineering economics which also require a logical and real world orientation. This paper presents a first step in exploring these questions by examining methods to evaluate student perception of learning and actual accomplishment in engineering economics courses across differing course structures and university contexts. The immediate goal in this paper is to test comparative learning evaluation methodologies and explore, in a preliminary manner, what differences may or may not be evident or hinted in the results. Building on these results in the long term, the objective here is to address more fully the relationship of teaching methods, learning perceptions, and learning results in engineering economics. This was the primary focus of our literature search.

Literature Search

Previous papers [4, 5] explored broad areas of best practices in teaching characteristics and distance education effectiveness. To build on this past work and more fully address the focus of this paper, literature in the area of student perception and learning was explored. There is a significant body of literature involving the combined areas of teaching method effectiveness, how that relates to intelligence beliefs (e.g. survey responses) and actual learning. The following paragraphs provide an overview of this work.

Several studies we found had particular application to our work and addressed the relationships of personal beliefs / perception and actual learning. A recent example[6] studied engineering student intelligence beliefs and learning. This work found that in general there are two types of students: those who believe their intelligence is a fixed trait which cannot be changed and those who believe intelligence is incremental and they can increase their intelligence through their own efforts to learn. This paper referenced a prior work[7] that indicated the general population is split 40% in each of these areas with 20% undecided. Implications noted from this study are that there may be a component of the self-fulfilling prophecy in the student survey results for the proportion who believe that intelligence is a fixed trait. Overall students who displayed the incremental belief achieved higher performance improvement than the fixed trait believers.

A study by Orabi[8] is a typical example of work examining gender differences in perception of learning. This research studied performance and attitudes in an introduction to engineering course and did not find differences in the gender performance or learning perceptions.

Another segment of this literature addresses the question of whether student perception of learning is influenced by the teaching style. An example of these studies[9] involved inquiry based learning and found students were more prone to rate learning highly if a more open or inquiry based teaching approach was employed. Implications for the standard student response survey at many universities are seriously debated in this literature.

Key in general to our current work is the question of whether student perception relates to student learning. A common term in this literature is "constructive alignment"[10] which describes the concept that the curriculum is designed so that the learning and assessment are aligned. If this is effectively accomplished, students in turn attain the goals intended for the course. In this view, students are responsible for their own learning and the expectation is that there is consistency between student perceptions of learning and the actual results. Kunh and Rundle-Thiel[11] are an example of a study built on this premise and they found student perception of learning was correlated with actual student performance, as measured by grade. They also found that student perceptions of learning are suitable measures to provide an alternate means (to test results) to understand whether students are learning what was intended.

Overall, this literature provided a basis for several points in constructing our study. First, although there can be confounding issues, there is often a relationship between student perception of learning and actual learning. Second, gender does not appear to be a differentiator in this regard. Finally, it is important for constructive alignment to be carefully integrated into the instructional methodology. The next section describes how we applied these points in developing our experimental design.

Experimental Approach

Since we were not able to determine what type of students we had relative to intelligence belief[6], we focused on the results of Kunh and Rundle-Thiel[11] to assure our various course sections conformed as much as possible to the concept of constructive alignment. Consequently, the course material was organized based on identification of a set of common learning objectives contained in Table 1 and a common set of test questions, coupled with a shared student survey.

A common rubric and project assignment was used to evaluate the first objective. Objectives 2-8 had an exam question which was assessed using a common 1-4 point rubric / scoring system:

1. Student did not answer or showed minimal understanding of the problem.
2. Student response showed a degree of understanding of the problem.
3. Student clearly understood the problem but had a math error or similar simple mistake.
4. Student worked the problem correctly and had the correct answer.

This coordinated set of tools allowed consistent connection of student perception of learning with actual accomplishment across the three sections studied.

Table 1: Course Learning Objectives

1. I am able to describe and apply the principles of engineering economics to engineering design and/or engineering projects.
2. I am able to describe the concept of equivalence and calculate present and future worth of cash flows using nominal and effective interest rates and continuous compounding.
3. I am able to determine the equivalence of uniform series cash flows as a present or future value including using arithmetic and geometric series.
4. I am able to apply present worth to evaluate the cash flows of projects and select from alternatives.
5. I am able to convert cash flows into an equivalent uniform annual amount (such as A) and use this result to evaluate project alternatives.
6. I am able to evaluate the rate of return (IRR) of a cash flow and use the delta project method to evaluate multiple alternatives.
7. I am able to evaluate various methods of depreciation and the influence of depreciation on taxes and investment alternatives.
8. I am able to use real, market and inflation rates to analyze the impact of inflation (constant and actual dollars).

The Table 1 learning objectives were also presented in the student survey, which involved a self-assessment of the specific objective on a 1-5 scale (5= strongly agree, 1= strongly disagree). An example student survey question is presented below for outcome 1:

1. I am able to describe and apply the principles of engineering economics and structured decision steps.				
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

As previously mentioned, our goal in this initial research step is to test methods and comparative statistics, focusing on learning versus perception of learning. Although the three participating course sections shown in Table 2 represent a range of potential differentiators, we did not design our study to analyze these factors in this first step. As we continue our work and grow the data set in the future, we plan to define ways to better study the differentiators noted in Table 2. Consequently our results are reported based on the instructor (or section) noted in the first column of Table 2.

Table 2: Participating Course Characteristics

Instructor	Class size	Credits	Homework requirement	Class quizzes	Lecture style	Final exam
1	28	2	Weekly (By Lecture Unit) 4 to 12 Problems (not collected); however, an extensive Spreadsheet assignment due at end of semester was collected and graded.		Traditional In Class Format: Tablet PC PowerPoint Lecture	Cumulative
2	27	2	Weekly 4-5 problems-submitted on blackboard with excel file if applicable	Weekly on line quiz and in class	On line Saba Meeting, streamed live lecture	Cumulative
3	116	3	Weekly (By Lecture Unit) 4 to 12 Problems from the Textbook (not collected)	¾ of the quizzes are in class traditional format and ¼ are take home quizzes.	Traditional In Class Format: Tablet PC PowerPoint Lecture.	Non-cumulative

Results

The study data contained results for 171 students and with eight outcomes resulting in a total of 171*8= 1368 observations. The results are organized to answer a series of questions and the first question explores whether students saw their accomplishment of learning objectives consistently with how the instructors assessed the learning based on exam question results.

Do student survey perceptions of learning correspond with assessment results?

In general, the statistical comparisons in this section employ a basic paired t-test of means with variances assumed unequal. The significance level of $\alpha = 0.05$ was used. Table 3 provides the summary of student perception of learning compared to assessed accomplishment across all students in the study.

- Outcomes 1, 5, & 6: Student Survey = Student Achievement (Assessment of Student Work)
- Outcomes 2, 3, 4: Students overestimated their abilities on the survey when compared to achievement.
- Outcomes 7 & 8: Students underestimated their abilities on the survey when compared to achievement.

Table 3: Student Survey and Achievement Results by Learning Objective

Outcome	Overall (n = 171)	P value of test
1. apply engr. econ to design	Student Survey = Achievement	p = 0.253
2. equivalence	Student Survey > Achievement	p < 0.001
3. uniform cash flow	Student Survey > Achievement	p = 0.001
4. PW applied to projects	Student Survey > Achievement	p < 0.001
5. Convert cash flows into equiv. annual amounts	Student Survey = Achievement	p = 0.203
6. Rate of return	Student Survey = Achievement	p = 0.826
7. Depreciation and taxes	Student Survey < Achievement	p < 0.001
8. Inflation and real / market rates	Student Survey < Achievement	p < 0.001

These results may be related to timing of materials over the semester. Outcomes 7 and 8 are covered last; thus, the students may not feel as confident. Outcomes 2, 3, and 4 are covered early in the semester, so students may think they know this material better. However, they did not retain and/or overestimated how well they knew it. Outcomes 1, 5, and 6 results were consistent as noted.

Table 4 presents the results of Table 3 broken down by class section and showing the p value of the specific t test, $p < 0.05$ means a significant difference in the mean rating of the student and the result on the assessed question. The blocks highlighted in red are the sections which did not agree with the overall result and several points are worth noting:

- In general, 16 of 24 outcomes by sections had agreement with the overall result.
- All sections agreed with the overall result only for outcome 8. Outcome 4 may also be considered very close to uniform agreement since the one dissenting section had a p = 0.054, very close to 0.05.
- Outcome 3 illustrates the possible influence of a large section (such as 3) since both of the smaller sections (1 and 2) had equal results for student survey and assessment. The overall result, dictated by the larger section was that students over rated their proficiency.

Table 4: Student Survey and Achievement Results by Section

Outcome	Overall (n = 171)	Inst. 1 (n = 28)	Inst. 2 (n = 27)	Inst. 3 (n = 116)
1. Apply engr. econ to design	p = 0.253	p = 0.886	p = 0.860	**p = 0.035
2. Equivalence	p < 0.001	p < 0.001	**p = 0.199	p < 0.001
3. Uniform cash flow	p = 0.001	**p = 0.233	**p = 0.861	p < 0.001
4. PW applied to projects	p < 0.001	p = 0.024	p = 0.012	**p = 0.054
5. Convert cash flows into equiv. annual amounts	p = 0.203	p = 0.620	p = 0.051	**p = 0.008
6. Rate of return	p = 0.826	p = 0.338	**p = 0.006	p = 0.090
7. Depreciation and taxes	p < 0.001	p < 0.001	p < 0.001	**p = 0.555
8. Inflation and real / market rates	p < 0.001	p < 0.001	p < 0.001	p = 0.001
	In agreement with overall.		**In disagreement with overall.	

Table 5 breaks out the results of Table 4 to explore if there is any pattern of disagreement with the overall result:

- Outcomes 1, 5 and 6 overall had survey and achievement equal. In all cases of disagreement, the issue was students overestimated their capabilities.
- Outcomes 2, 3, and 4 overall had students overestimating their performance. In all cases of disagreement, students predicted their achievement.
- Outcomes 7 and 8 overall had students underestimating their performance. In the one case of disagreement students correctly predicted their performance.

Table 5: Student Survey and Achievement Results with Differences

	Overall (n = 171)	**Inst. 1 (n = 28)**	**Ist. 2 (n = 27)**	**Inst. 3 (n = 116)**
1. Apply engr. econ to design	Student Survey = Achievement			Student Survey > Achievement
2. Equivalence	Student Survey > Achievement		Student Survey = Achievement	
3. Uniform cash flow	Student Survey > Achievement	Student Survey = Achievement	Student Survey = Achievement	
4. PW applied to projects	Student Survey > Achievement			Student Survey = Achievement
5. Convert cash flows into equiv. annual amounts	Student Survey = Achievement			Student Survey > Achievement
6. Rate of return	Student Survey = Achievement		Student Survey > Achievement	
7. Depreciation and taxes	Student Survey < Achievement			Student Survey = Achievement
8. Inflation and real / market rates	Student Survey < Achievement			
		In agreement with overall.	In disagreement with overall.	

Do students who perform better self-assess better?

In general, the statistical comparisons in this section employ a basic paired t-test of means with variances assumed unequal. The significance level of $\alpha = 0.05$ was used.

To identify whether students who performed better did in fact generally assess their learning more accurately, student data points with a 3 or 4 assessment (correct answer or correct except for math or minor error) were aggregated together and the data points with a 1 or 2 assessment similarly. These two groups were then compared (achievement of 3 or 4 and achievement of 1 or 2) with the survey objective ratings from that student. Results are summarized in Table 6. Overall and in two of the three sections, students who performed better rated themselves higher compared to those who did not do well.

Table 6 Comparison of High Performers versus Low and Survey Self Report

	Assessed at 3 or 4	Assessed at 1 or 2	Conclusion
Overall	Survey rating=4.38, n= 1160	Survey rating =4.00, n= 208	Significant difference $p < 0.001$
Instructor 1	Survey rating=4.06, n= 177	Survey rating =4.00, n= 47	Not a significant difference
Instructor 2	Survey rating=4.09, n= 161	Survey rating =3.6, n= 55	Significant difference $p < 0.001$
Instructor 3	Survey rating=4.51, n= 822	Survey rating =4.21, n= 106	Significant difference $p < 0.001$

The results in Table 6 were divided based on outcome to determine if the results of Table 6 were consistent across outcomes. Table 7 presents those results and, considering p=0.091 for outcome 1 as close to a significant difference, shows that for all outcomes but outcome 8, higher performing students did rate their knowledge higher than low performing students. Outcome 8 did not represent a significant difference in student's perception of their achievement; however, their survey average of the higher assessed students was lower than that of the lower assessed student.

Table 7 Comparison of Exam Question Assessment with Survey Self Report by Outcome

Outcome	Assessed at 3 or 4	Assessed at 1 or 2	Conclusion
1. apply engr. econ to design	Survey rating=4.35, n= 151	Survey rating =4.05, n= 20	Not a significant difference, p= 0.091
2. equivalence	Survey rating=4.64, n= 138	Survey rating =4.18, n= 33	Significant difference, p = 0.002
3. uniform cash flow	Survey rating=4.47, n= 143	Survey rating =4.04, n= 28	Significant difference, p = 0.003
4. PW applied to projects	Survey rating=4.60, n= 144	Survey rating =4.26, n= 27	Significant difference, p = 0.024
5. Convert cash flows into equiv. annual amounts	Survey rating=4.56, n= 141	Survey rating =3.9, n= 30	Significant difference, p < 0.001
6. Rate of return	Survey rating=4.39, n= 135	Survey rating = 3.72, n= 36	Significant difference , p < 0.001
7. Depreciation and taxes	Survey rating=4.12, n= 155	Survey rating = 3.75, n= 16	Significant difference, p = 0.026
8. Inflation and real / market rates	Survey rating=4.0, n= 153	Survey rating =4.11, n= 18	Not a significant difference, p = 0.513

Comparison of Sections

Finally, we compared the various sections to determine if any patterns could be identified which might guide planning to examine instructional or course structure details. Two comparisons were conducted:

- The first comparison involved instructors 1 and 2 who were at the same university and both consisted of the two credit version of the course.
- The second comparison involved the two credit sections (1 and 2) compared to the three credit section. This also represents large classes (Instructor 3) versus small classes (Instructors 1 and 2).

Table 8 and 9 summarize these results. Instructors 1 and 2 differed in only one learning outcome for both assessment and student survey. On the other hand, we found that students did significantly better in the three credit section compared to the two credit sections in four outcomes. Similarly, students were more confident in all eight outcomes in the three credit section compared to the two credit sections.

Table 8: Comparison of exam question assessment results by Section

Comparison	Result	Discussion
Instructor 1 vs 2	Differed on outcome 6 (IRR) ($p < 0.001$), 1 higher than 2.	Compares the two credit sections and differences in instructional methods.
Instructor 1 and 2 vs 3	Differed on Outcome 2. ($p- < 0.001$) Differed on Outcome 3. ($p- = 0.036$) Differed on Outcome 4. ($p- < 0.001$) Differed on Outcome 6. ($p- < 0.001$) In all cases 3 higher than 1 and 2	Comparison focused on the two credit versus the three credit sections. In four of eight outcomes, students did significantly better in three credit section.

Table 9: Comparison of student survey question results by section

Comparison	Result	Discussion
Instructor 1 vs 2	Differed on outcome 7 (depreciation and taxes) ($p=< 0.005$). 2 higher than 1.	Compares the two credit sections and differences in instructional methods.
Instructor 1 and 2 vs 3	Instructor 3 students rated perception higher in all outcomes: Outcomes 1, 3, 4: p-value = 0.001 Outcomes 2, 5, 6, 7, 8: p-value < 0.001	Comparison focused on the two credit versus the three credit sections. In eight of eight outcomes, students rated themselves significantly better in three credit section.

To illustrate the results of Tables 8 and 9 graphically, Figures 1 (table 8) and Figure 2 (table 9) show the average student ratings for both assessment and student surveys based on outcome and section.

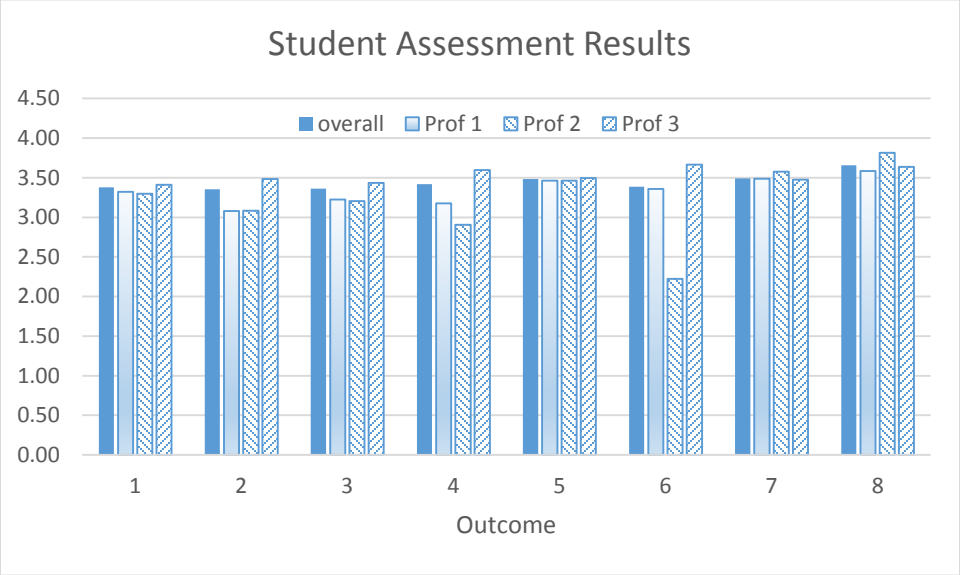

Figure 1 Student Assessment Results by Outcome by Section

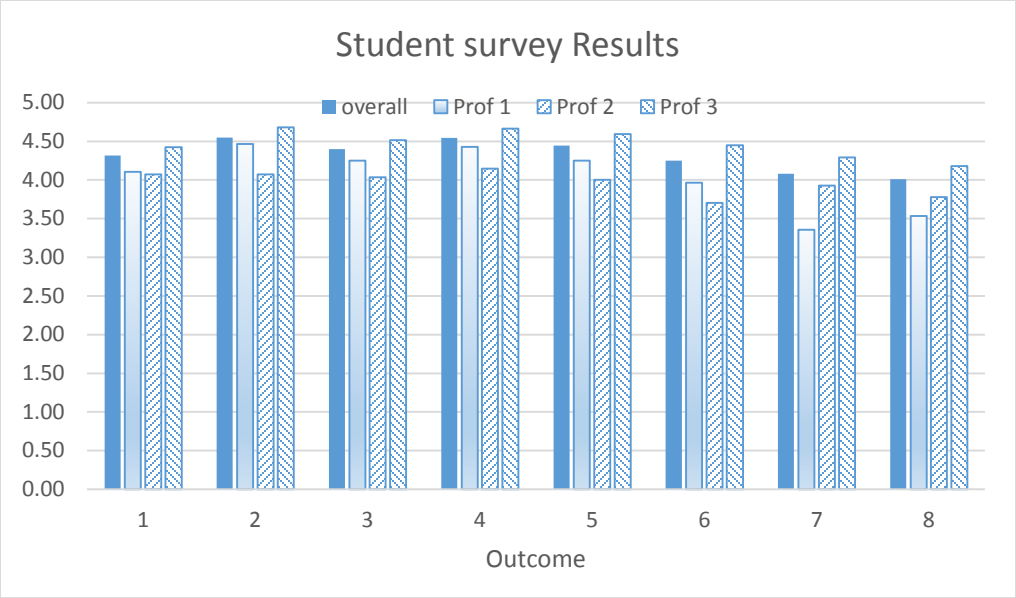

Figure 2: student Survey Results by Outcome by Section

Conclusions

The overall goal of this study was to explore and evaluate methods for assessing student learning which in the long term may help to evaluate the impact of teaching and instructional methods in assessing engineering economics course educational objectives. This study has demonstrated that with planning and coordination, it is possible to gather data from assessment and student surveys to accomplish this task:

- Student survey information correlated reasonably well with assessment results.
- Although the reasons are unclear at this point (since many variables are confounded; such as university, instructor, number of credit hours), the methodology used was able to differentiate learning between the sections.

More work is necessary to explore several areas which may have impacted the learning variation we found.

- The obvious issue is that two and three credit versions of the course should have shown differences and in fact they did.
- The prevailing thinking that smaller class size is better, if true, did not compensate for the credit differential.
- We were not able to adjust for or integrate into the study any consideration of student differences such as part time jobs or program selectivity.
- Cumulative versus non-cumulative final exams may be a factor. Instructor 3 students took the evaluated test questions when the material was fresh. For the other two sections, the cumulative final adds a larger burden of preparation and time constraints of final exam periods.
- It does appear that student survey responses are less confident of materials which they have recently learned.

We plan to continue our efforts and are working on an additional study in fall 2015.

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