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Comparison of Direct and Indirect Assessment of a Summer Engineering Economy Course taught with Active Learning Techniques

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Abstract

The abbreviated summer class schedule, which results in longer class times, can present several barriers to learning. One significant factor is the lack of time needed for knowledge construction. As students stretch and reform their schemas to synthesize new material, they often generate inappropriate perceptions of critical class material. An effective strategy for addressing this is to provide a variety of active learning techniques that engage students and focus on their different learning styles.

In this paper, data from two class sections of engineering economy taught in a compressed summer term were examined to see how well the student's self-assessment of the course objectives compared to direct assessment measures. Teaching techniques used in these classes include incorporating learning objectives directly into the teaching of course material, both student and instructor-generated crossword puzzles, student-generated Pictionary, clickers, starting each class with a song about money, using real money and magnets to illustrate applications of different interest factors, Muddiest Point paper, think-pair-share, individual and group problem solving, brainstorming, case studies, debates, and a number of other useful techniques. The student's self-assessment of learning objectives was measured through a survey and the direct assessment was done through the use of mid-term and final exam questions. To assess the correlation between self-assessment and direct assessment, one-tailed tests at a level of significance of 0.05 with 50 degrees of freedom were performed. A correlation was found to be significant at the 0.01 level and so overall, it appears that the students had an accurate perception of their own course performance. The paper will discuss the student self-assessment of the course objectives, the direct assessment of course objectives, and some of the teaching and learning techniques used to enhance the course.

Introduction

To enhance the two engineering economy classes offered in the summer 2014 term and to improve the student learning environment, a wide variety of teaching techniques and activities were employed. These included incorporating learning objectives[1] directly into the teaching of course material, both student and instructor generated crossword puzzles, student generated Pictionary, clickers, questioning techniques[2], playing songs about money, using real money and magnets to illustrate applications of different interest factors, One Minute paper, Muddiest Point paper, think-pair-share, individual and group problem solving, assigned reading, daily individual and team quizzes, daily assignment, daily presentations of homework by the peers, exams linked to the learning objectives and a number of other techniques. Many of these ideas are derived from best practices presented as part of a Mini-ExCEEd Teaching Workshop at our institution conducted by our Dean for new faculty[3,4].

After the course learning objectives were articulated and assessment questions regarding the learning objectives were devised[5], it was decided to assess students' mastery of the learning objectives both directly and indirectly. Direct assessment of the learning objectives occurred in the form of student performances on the mid-term and final exam questions. Indirect assessment of learning came from a survey conducted at the end of the course. Using these data, the following research question was addressed: Is there a correlation between the student perceived survey on learning objectives scores and the corresponding direct assessment of student learning objective scores? SPSS software was employed to investigate the correlation between the direct and indirect assessment of the learning objectives.

Background Information

In order to maximize student learning, it is essential to incorporate teaching and learning methods that adequately address the different learning styles in the classroom, and to develop ways to promote student motivation[6] and engagement. As stated in the literature, engineering students are predominantly active, visual, and sensing learner types [6-9]. However, most teaching methods in engineering are geared toward reflective, verbal, and intuitive learner types[6]. This is the exact opposite of the suggestions made from multiple learning style studies stated in the literature [6-9]. Teaching in engineering is generally more focused on theory, verbal, and passive learning, as opposed to deductive learning supported by Felder as the preferred learning method using practical applications, visual, sequential/global, and active learning[6, 8, 9, 10]. It is known that educators often unconsciously prefer to teach in the same way they learn, or the way they were taught[6, 9]. It is also stated in the literature that when an educator's teaching style and students' learning styles match, students gain a better understanding of the course material [6, 8, 9, 10]. Felder noted this as teaching around the wheel[10]. Therefore, students retain the course material longer and leave the course with a deeper understanding of the material [6, 8, 9, 11, 12].

Motivated students strive to make the most of their education by acquiring new information and using it to further their knowledge[6, 13]. To increase the value that students place on a task, it is helpful to relate it to their interests [6, 11, 12, 13]. If students are able to work on a topic that has meaning or relevance to them, they are more likely to see the value and become more motivated[6, 14]. One way to increase students' motivation is to provide them with assignments that focus on real-world applications. Focusing on real-world problems helps students see the actual applications of the theories learned in class [6, 11, 12, 13]. The real-life examples and case studies help students see their classroom material come to life[6, 13].

The primary purposes of assessments are to evaluate student learning and to inform and improve teaching and learning. Student learning can be assessed using direct and indirect measures[14]. Best practices recommend the use of both direct and indirect measures when determining the degree of student learning that has taken place[14]. Direct measures are those that measure levels of achievement of student learning on specific outcomes[14]. On the other hand, indirect measures of assessment are those in which students judge their own ability to achieve the learning outcomes[14, 15]. Indirect measures are based on perception rather than direct demonstration[14, 15]. Indirect assessment provides insight into student learning and should be viewed as an augmentation to direct assessment[15].

Engineering Economy Summer Course

Students who take the summer course of engineering economy at our institution must learn course material during a compressed summer time frame. In addition, the student population of summer classes can differ significantly from those in the fall and spring since they can be composed of both cadet and evening, full and part-time, Civil and Electrical Engineering students and many have just transferred from a two-year technical college to a four-year institution. Historically, most of these student groups have been enrolled in different classes in the fall and spring and this is the first time they are together.

During the fall, engineering economy classes are taken primarily by members of the Corps of Cadets. A relatively small percentage of the classes are occupied by active duty or veteran students who take day classes with the Corps of Cadets. Evening classes are populated with students who live in the community, many of whom work full or part-time. Some veterans or active duty students may be included in the evening classes. Veterans that have been approved for Day status may also attend evening classes in the fall and spring.

Engineering economy is required of students in both the Civil and Electrical Engineering programs. Students in the evening program may only take engineering economy during the summer term. For the day program, engineering economy is offered during the fall semester, but these students may also register for the course in the summer.

Summer sections of engineering economy primarily have Civil and Electrical Engineering evening students, but may also have cadets, active duty students, and veteran students. Evening students who normally attend school in the day program may also have summer jobs. Finally, students in the summer engineering economy classes may have been taking courses at the university for two or more years, while other students may be students in a 2+2 program (first two years at a Technical college or other university and the last two years at our institution) who are taking engineering economy as their initial course to start their junior year at our institution.

Because summer engineering economy classes are taught during a shortened time frame, the class times are significantly longer than would be experienced in a fall or spring semester. Although a small number of other junior and senior-level engineering classes are taught in the summer, the compressed time frame does not represent the typical classroom experience for junior and senior engineering students in either the day or evening programs. This means that for most of these students, there is less time to learn course material, to evaluate how much and how well they have learned, and to catch up if they get behind (particularly considering there are fewer weekends). More information must be processed in a single class during a summer session. Exams may occur more frequently than in the fall or spring. Students do take fewer hours in the summer, but nonetheless, must make appropriate adjustments to offset the accelerated pace.

For such a diverse group of students, who have different learning styles, different working and academic experiences, it is imperative to design the course to address the needs of the different learning styles in the classroom that is generally a deductive learning style (active vs. reflective; sensing vs. intuitive; visual vs. verbal; sequential vs. global).

Active Learning Techniques Used

In an effort to maximize student learning, the instructors integrated and aligned course learning objectives, learning activities addressing various learning styles, and assessment tools. Real-life personal finance application problems (i.e., student loans, car loans, credit cards, mortgages, retirement, stocks and bonds) linked to the course learning objectives were developed for the in-class, hands-on group activities and homework assignments. Exams and quizzes linked directly to the learning objectives were composed to assess student mastery of engineering economy.

Prior to each lesson, a song about money was played from a list of all time greatest hits to stimulate learning and to get the students excited about engineering economy. For the visual learners, cash flow diagrams were drawn on the board using real money and magnets to demonstrate the applications of engineering economy factors (Figure 1). Learning objectives were written on the board and were referred to frequently during class to assist both sequential and global learners as to where the content fit into the knowledge they were assembling.

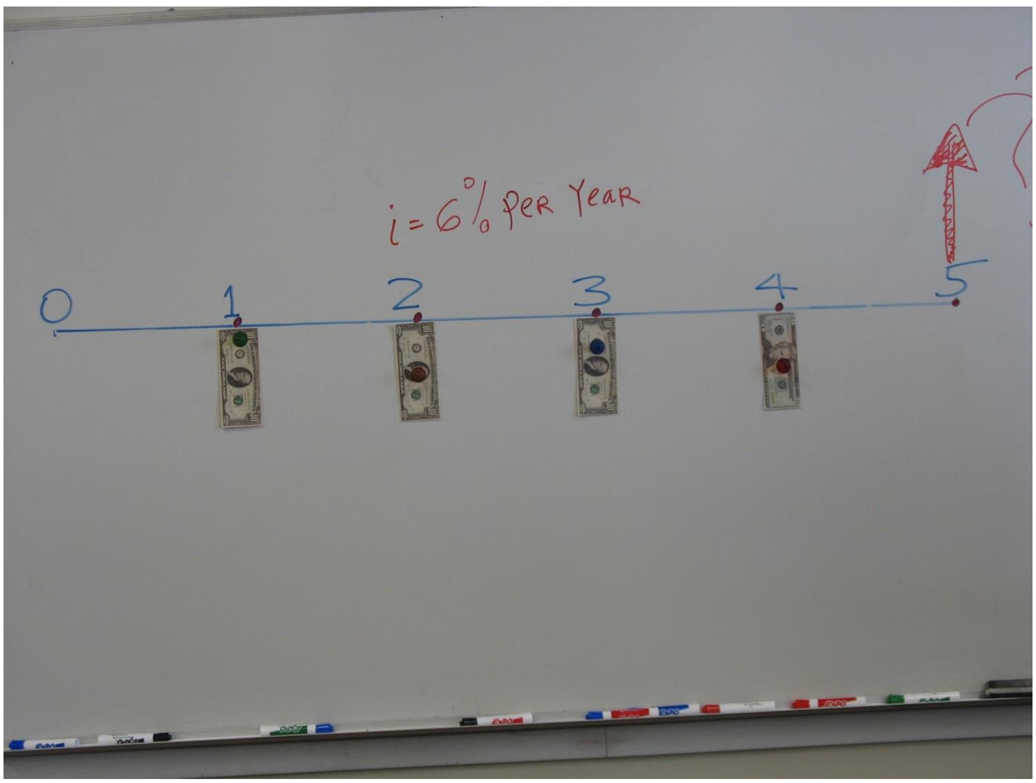

Figure 1. A cash flow diagram illustrating future worth calculations

For the reflective and active learners, the Think-Pair-Share strategy was employed at the beginning of the lessons 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 in Figure 2. 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 mini lectures assisted the intuitive learners with the conceptual information, the verbal learners with explanations and derivations of formulas, and the sequential learners with the logical flow of engineering economy topics. For the global learners, the presented material was always linked to previous and future material in the course and to the students' personal experiences. Following the mini lecture, hands-on small group problem solving was employed to assist both the active and sensing learners 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 quizzes (individual and team) were administered on the assigned readings and the homework assignments and students were provided with quick feedback. On occasion, clickers were employed to assess the understanding of concepts and create an environment to engage students and provide immediate feedback to both students and instructors. Students worked problems in teams and each team submitted responses using a clicker. On other occasions, 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 sensing and global learners by providing relevancy of the course material to real-life issues, but also engaged students actively in thinking, analyzing, and interacting intellectually with one another. Finally, after active learning opportunities, reflective assignments (i.e., write a concise summary of material presented in class and/or write the single most confusing point related to the topic) were administered at the end of the lesson. The purposes of these reflective assignments were to assist the reflective learners and to further assess the students' learning of the engineering economy concepts.

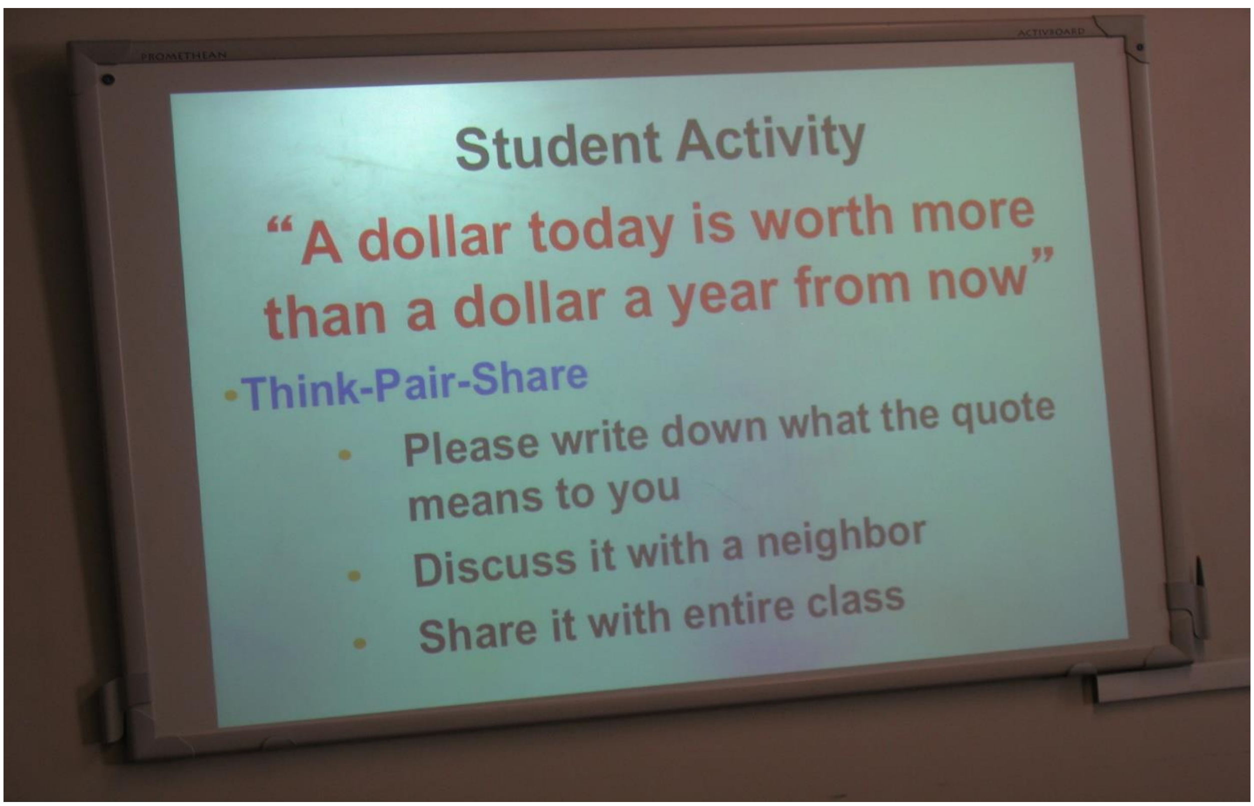

Figure 2. An example of "Think-Pair Share" activity used in engineering economy course

At the end of the course, Pictionary and Crossword puzzle games were employed to facilitate the review of the learning objectives for the final exam. When playing the game of Pictionary, students were asked to draw on the board to covey the meaning of words or phrases which benefited the visual learners. Student-generated crossword puzzles on engineering economy concepts were used to promote active learning, discourage memorization, and help students with the development of critical thinking skills. An instructor-generated crossword puzzle was also used with student teams to compete for bonus points.

Study Methods

Student mastery of the course learning objectives was measured directly through the use of mid-term and final exam questions. At the end of the course, students were also administered a self-perception survey of the course learning objectives. This indirect instrument was used to gauge student perception (on a five-point scale) anonymously in the areas of the five course learning objectives (Table 1).

A one-tailed test at an alpha level of significance of 0.05 with 52 data points and degrees of freedom = 50 was chosen. The null hypothesis was stated as: "there is no correlation between the direct and indirect assessment of the learning objective data;" and the alternate hypothesis was stated as: "there is a positive correlation between the direct and indirect assessment of the learning objective data."

Table 1. The survey of student perception of five learning objectives

1. How well are you able to solve basic Time Value of Money problems by applying P, F, A, G factors on a scale of 1 to 5 (**5 is most**)?   Least 1 2 3 4 5 Most
2. How well are you able to calculate rate of return analysis for alternative comparison, using minimum attractive rate of return (MARR) as a basis on a scale of 1 to 5 (**5 is most**)?   Least 1 2 3 4 5 Most
3. How well are you able to compute capitalized cost and equivalent uniform annual worth for alternative comparison on a scale of 1 to 5 (**5 is most**)?   Least 1 2 3 4 5 Most
4. How well are you able to calculate benefit cost ratio alternative comparison, including associated ethical considerations on a scale of 1 to 5 (**5 is most**)?   Least 1 2 3 4 5 Most
5. How well are you able to calculate depreciation calculations using straight line, double declining balance, and modified accelerated cost recovery system methods (**5 is most**)?   Least 1 2 3 4 5 Most

Student Perceived Survey on Course Learning Objectives

Students were asked to self assess their ability in the areas of the five learning objectives and the results are shown in Figure 3. The student self-assessment responses were converted to a percentage scale in the standard way, with a score of "5" being considered equivalent to 100. In this way, an equivalent mean percentage was obtained for the course learning objectives 1 through 5. Mean percentage scores for the indirect assessment of the learning objectives 1 through 5 are 94.62, 90.00, 90.38, 86.54, and 85.77, respectively as shown in Table 2. The standard deviations for the indirect assessment of the learning objectives range from 8.96 to 12.89.

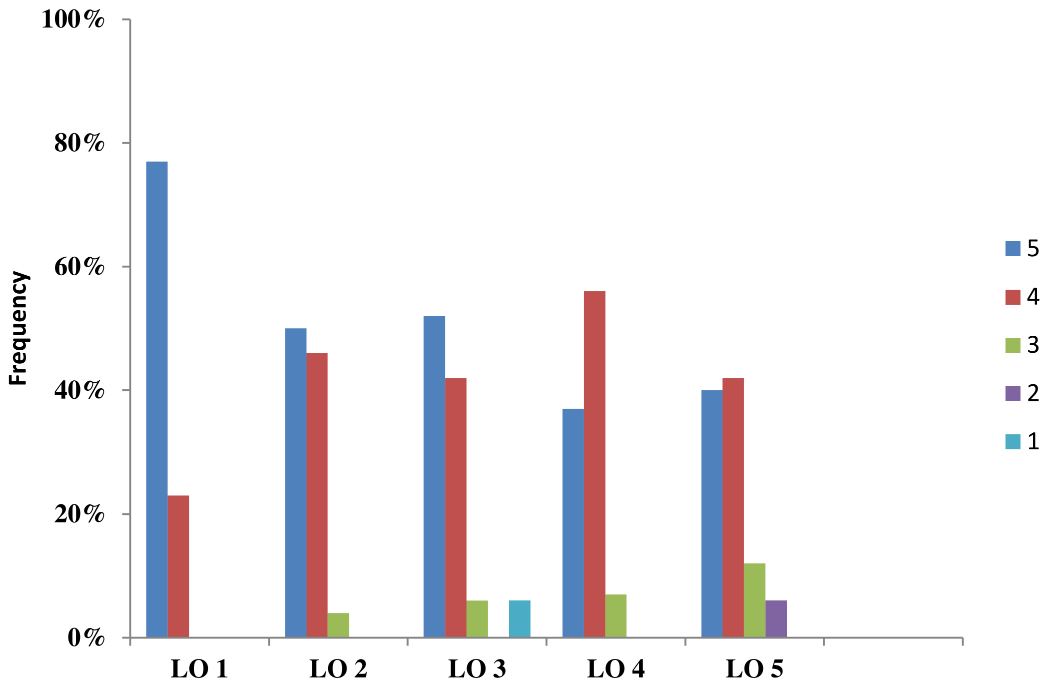

Figure 3. The results of student self-assessment of the learning objectives (LO)

Table 2. Mean and standard deviation of indirect assessment results in percentage form

Indirect Assessment		
Student Self Assessment of Course Learning Objectives	Mean Score (%)	Standard Deviation
1. How well are you able to solve basic Time Value of Money problems by applying P, F, A, G factors?	94.62	8.96
2. How well are you able to calculate rate of return analysis for alternative comparison, using minimum attraction rate of return (MARR) as a basis?	90.00	10.66
3. How well are you able to compute capitalized cost and equivalent uniform annual worth for alternative comparison?	90.38	10.66
4. How well are you able to calculate benefit cost ratio alternative comparison, including associated ethical considerations?	86.54	10.64
5. How well are you able to calculate depreciation using straight line, double declining balance and modified cost recovery system methods?	85.77	12.89

Students were also asked if the learning objectives add value to teaching and learning. It can be seen from Figure 4 that 90% of the students perceived that the learning objectives add value to teaching and learning, as well as add to their sense of ownership in the learning process.

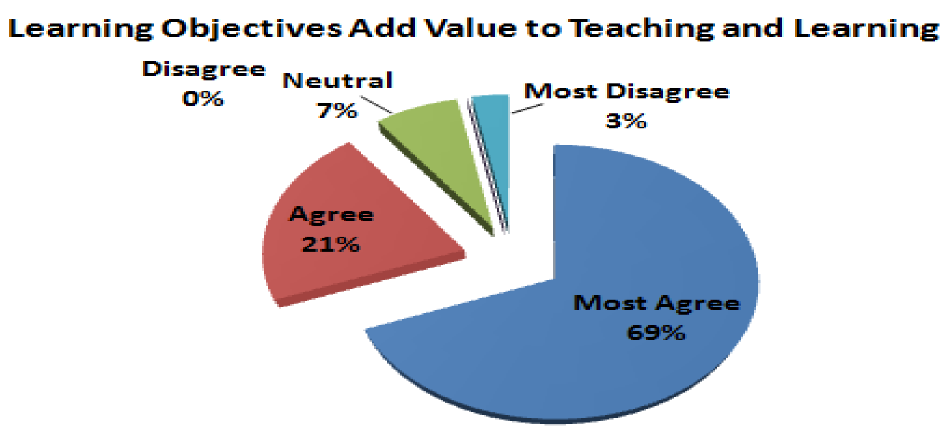

Figure 4. Students' self perceived attitude toward learning objectives

Direct Assessment of Learning Objectives Scores

Direct assessment of the learning objectives was accomplished through the use of mid-term and final exam questions and the results are shown in Table 3. Ratings of 80 percent or higher resulted from the direct assessment of the five course objectives. Mean and standard deviation score for the five learning objectives range from 80.10 % to 93.16% and 10.40% to 21.27%, respectively.

Table 3. Results of direct assessment of the learning objectives

Direct Assessment (Exams and Final Exam Questions)		
Direct Assessment of Course Learning Objectives	Mean Score (%)	Standard Deviation
1. Solve the time value of money problems by applying P, F, A, G factors.	89.53	15.52
2. Calculate rate of return for alternative comparison, using minimum attractive rate of return (MARR) as a basis.	92.25	12.29
3. Calculate capitalized cost and equivalent uniform annual worth for alternative comparison.	93.16	10.40
4. Calculate benefit cost ratio for alternative comparison, including associated ethical considerations.	80.10	21.27
5. Calculate depreciation using straight line, double declining balance and modified cost recovery system methods.	87.40	16.68

A comparison of the results for the direct and indirect assessment of the five learning objectives is shown in Figure 5. Average scores for the indirect assessments of learning objectives 2 and 3 are slightly lower than those of the direct assessments. It appears that students were slightly modest about their own capabilities with regard to learning objectives 2 and 3. However, the average scores for the indirect assessments of learning objectives 1, 4, and 5 are slightly higher than those of direct assessment. In regard to these three objectives, it appears that students had a slightly inflated view of their ability.

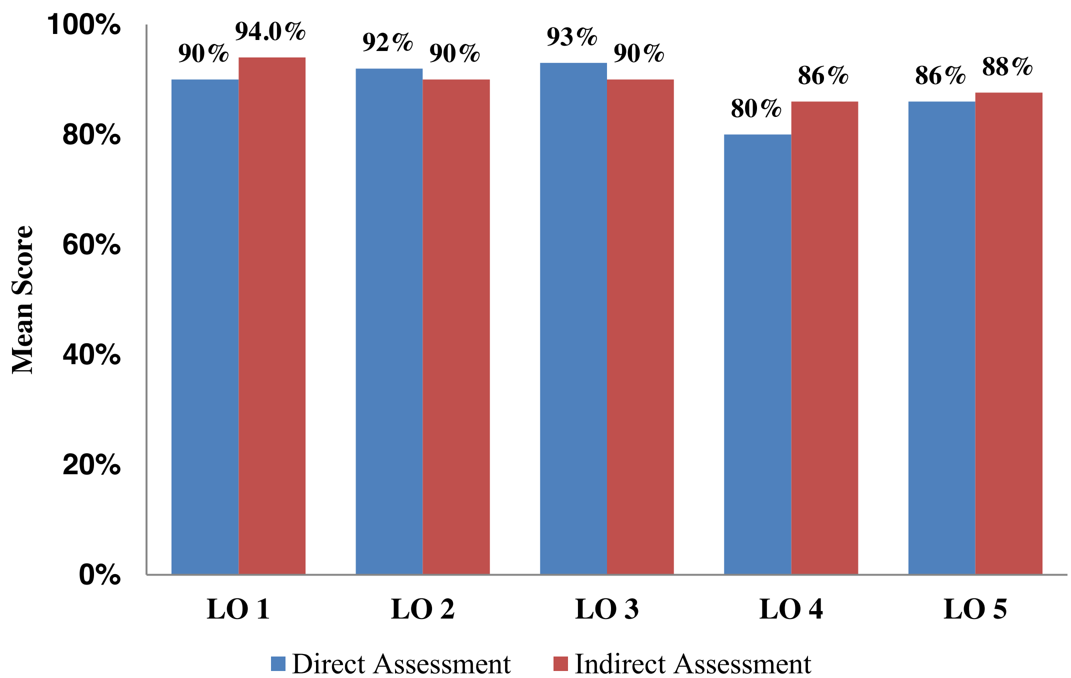

Figure 5. Comparison of the results of direct and indirect assessments of learning objectives

Results and Discussion

The SPSS software was employed to analyze the correlation between direct and indirect assessment data corresponding to learning objectives 1 through 5. The Pearson's correlation coefficients and corresponding p-value for each of the course learning objectives were determined and are shown in Table 4. The resulting correlation coefficients indicate that moderate to strong correlations exist between the direct and indirect assessment of the five learning objectives. The resulted p-values are all smaller than the level of significant of 5%. Therefore, the null hypotheses are rejected and statistically significant positive correlations exist between the direct and indirect assessment of the learning objectives 1 through 5. Correlations were found to be significant at the 0.01 level and so overall, it appears that the students had a fairly accurate perception of their own course performance.

The results appear to show that students learn most effectively when assignments, exams, and learning activities are directly linked to the course learning objectives. The results also indicate that effective learning requires an alignment between active learning techniques and students' learning styles. Implementing numerous active learning techniques and addressing the needs of the different learning styles in the engineering economy course has resulted in moderate-to-high positive correlations between direct and indirect assessment of the learning objectives.

Table 4. Results of correlation analysis

Null (H_o) and Alternative Hypothesis (H_1)	Pearson's Correlation	p-value
[H_0: $\rho = 0$ – there is no correlation between the direct and indirect assessment data for LO1] [H_1: $\rho > 0$ – there is a positive correlation between the direct and indirect assessment data for LO1]	0.854	< 0.00001
[H_0: $\rho = 0$ – there is no correlation between the direct and indirect assessment data for LO 2] [H_1: $\rho > 0$ – there is a positive correlation between the direct and indirect assessment data for LO 2]	0.464	0.000531
[H_0: $\rho = 0$ – there is no correlation between the direct and indirect assessment data for LO 3] [H_1: $\rho > 0$ – there is a positive correlation between the direct and indirect assessment data for LO 3]	0.544	0.000031
[H_0: $\rho = 0$ – there is no correlation between the direct and indirect assessment data for LO 4] [H_1: $\rho > 0$ – there is a positive correlation between the direct and indirect assessment data for LO 4]	0.469	0.000453
[H_0: $\rho = 0$ – there is no correlation between the direct and indirect assessment data for LO 5] [H_1: $\rho > 0$ – there is a positive correlation between the direct and indirect assessment data for LO 5]	0.775	<0.00001

Conclusions

A study was conducted to investigate the correlation between the student perceived survey on learning objectives scores and the corresponding direct assessment of student learning objective scores in two summer engineering economy courses at our institution. The following conclusions can be made based on the study results:

- Students learn most effectively when assignments, exams, and learning activities are directly linked to the course learning objectives.
- Students learned most effectively when the teaching techniques and their learning styles have been aligned.
- Implementing numerous teaching techniques which address the needs of the different learning styles can directly affect both direct and indirect assessment results.
- Integrating and aligning the learning objectives, learning activities, assessments, and student learning styles resulted in a moderate-to-strong positive correlation between students' self perception and direct assessments of the learning objectives.

Based on the results of our study and studies done in literature by Felder, we highly recommend that any educators teaching summer courses should consider using our approach as a model when designing their own courses.

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