A Hybrid Mastery-Conventional Assessment in Engineering Economy

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Introduction

For us, educators, student's learning is the most important aspect that we care about. Students' learning can be impacted by the effectiveness of teaching and assessment methods. Teaching is a closed-loop process where instructors prepare assignments and activities, such as homework assignments, and they expect that the students will try and apply what they have learned in the classroom to understand and address these activities. The instructors then use assessment techniques to evaluate student performance and identify students' weaknesses or strengths. Therefore, assessment technique should be informative, suggest opportunities for improvement, and provide guidance on the formulation of course objectives. Mastery learning and assessment can be used to evaluate individual learning weaknesses and suggest remediation actions[1].

Mastery learning and assessment is an approach that has existed in education for decades. There are two main approaches for mastery learning: Bloom's Learning for Mastery and Keller's Personalized System of Instruction[2-4]. Both approaches hinge on the idea of dividing the course material into basic modules. The students have to master each module before moving to the next module. Student's mastery is assessed via set of tests where each test is focused on a certain concept.

Mastery learning and assessment have been implemented for a number of years at Penn State Behrend within the School of Engineering. The implementation of mastery learning and assessment was solely focused on fundamental engineering courses (i.e., Statics, Strength of Materials, and Thermodynamics)[5-7]. The use of mastery approach in these fundamental courses showed clear evidence that students who passed these courses with at least a C could solve engineering problems successfully and were better prepared for advanced courses in engineering when compared to the conventional learning and assessment approach.

In this paper, mastery learning and concept assessment practices are applied to the Engineering Economy course in the Industrial Engineering Department at Penn State Behrend. The initial set of concepts in this course. i.e., time value of money and money management, are fundamental to understanding the remainder of the engineering economy concepts. The main hypothesis in this

study is that mastery learning and assessment motivate students to learn the fundamental concepts in Engineering Economy better than the conventional approach, resulting in more successful achievement of learning outcomes. Data have been collected and analyzed to test the effectiveness of the implementation of mastery learning and assessment in this course. The data analysis has shown that the implementation of the mastery learning practice led to a statistically significant increase in students' learning of the time value of money and money management concepts when compared to the traditional teaching approach. A two-sample t-test was performed. The two samples tested are statistically different. The average of grades on the first midterm exam were 88.00% and 75.90% for the mastery approach cohort and traditional approach cohort, respectively.

This paper discusses in detail the background of mastery learning and assessment approach that was implemented in the Engineering Economy course, data collection, analysis and results. Conclusions and future research suggestions are presented at the end of the paper.

Mastery Learning and Assessment in Engineering Economy Course

The Industrial Engineering (IE) Department at Penn State Behrend requires undergraduate students to complete a course in Engineering Economy. The course is offered in fall and spring semesters. The class hosts IE and non-IE students where most non-IE students are from the Mechanical Engineering (ME) major. The enrolled IE students are usually in their junior year while non-IE students are usually in their senior year. The objectives of the course are:

- To apply the theoretical and conceptual basis of financial project analysis which includes time value of money, cash flow approach, equivalence calculations, present worth analysis, annual worth analysis, benefit-cost analysis, rate-of-return, depreciation, and income taxes.
- To make informed financial decisions when selecting among several viable alternative projects.
- To identify how engineering decisions during product design, process selection, manufacturing system design, etc. affect the company's financial issues.
- To develop skills that extend the basic concepts to solve problems encountered in personal financial situations.

The class involves lectures, quizzes, homework assignments, two midterm exams, in-class problems, and a final exam. The course grade reflects the student performance in six quizzes (20%), two midterm exams (40%), in-class clicker questions (10%), and a final exam (30%). The instructor decided not to grade the homework assignments because these assignments proved to be ineffective in enhancing students' learning in previous semesters. The instructor noticed that students would receive a high or perfect grade in the homework assignments but would later struggle in the exams. This suggested that the students might be getting the homework solutions from either the textbook solution manual and/or from other students instead of attempting to solve the problems by themselves. Nevertheless, the homework assignments are still assigned on specific dates throughout the semester and solutions are provided after one week of their assignment date. The class size is between 25 and 45 each semester.

The manner in which engineering economy is taught and the content being taught is documented by numerous studies within the published literature. Some work makes futuristic predictions of engineering economy education[8] and suggestions for improvement[9] while other work discusses the importance of teaching engineering economics to cover financial mathematics, decision-making analysis, spreadsheet analysis, and the use of online educational tools[10, 11]. A whole host of work has been carried out since the turn of the century that provide either structure or experiences in teaching engineering economics at both the undergraduate and graduate levels, the inclusion of risk and uncertainty in engineering economics, active learning, flipping the engineering economy classroom, and teaching engineering economics online or in hybrid formats[12-21].

To the best of our knowledge, mastery learning and assessment approach has never been used in an engineering economy course. It also was never used before in the Engineering Economy course at Penn State Behrend until this semester (Fall 2016). Figure 1 shows a graphical representation of mastery learning and assessment. In this study, a variation of the mastery learning and assessment approach is implemented in this course. The Engineering Economy course is a hybrid in the sense that the mastery learning and assessment is used in the first third of the course where students are required to successfully solve problems before receiving credit for their work. The pace of the course is led by the instructor. The remaining two thirds of the course is taught using the traditional learning and assessment approach where grades are based

on partial credit and no retakes are allowed. Table 1 shows the topics of the Engineering Economy course and the portions where mastery and traditional approaches were used. The reasoning behind this division is that the first portion of the course is vital in understanding the remaining topics in the course. For example, understanding economic equivalence is important in performing present and annual worth analyses to evaluate engineering projects.

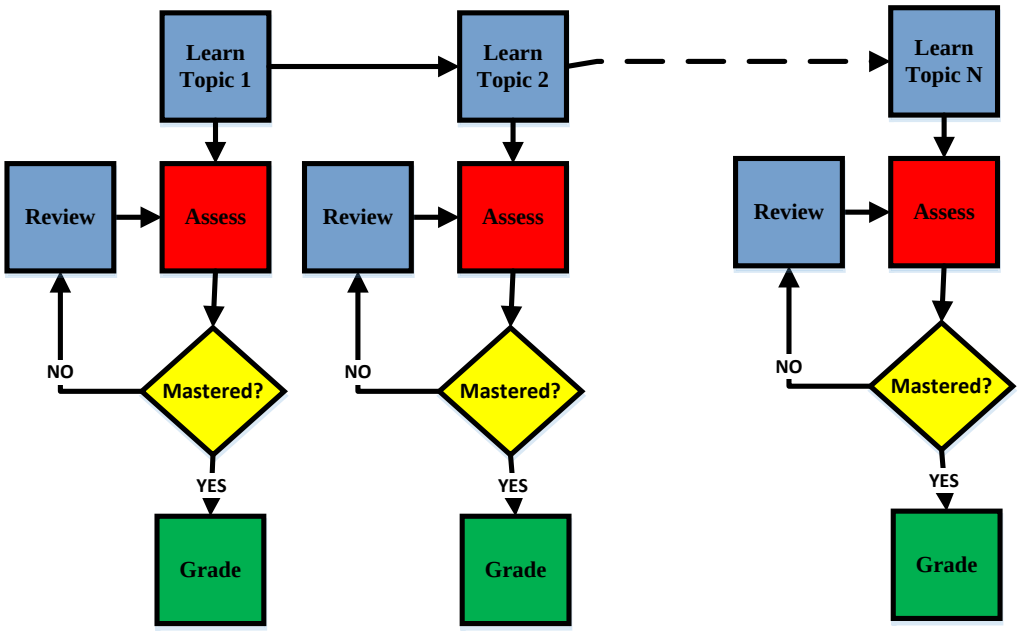

Figure 1. Mastery Learning and Assessment

Mastery learning and assessment can be applied to any activity or assignment. In this course, the students are required to take online quizzes multiple times prior to receiving credit for their work. Two quizzes are delivered in the mastery learning and assessment portion of the course, i.e., the first and second quizzes. Each quiz involves a first attempt, retake attempt, and final attempt. The retake and final attempts include new questions that have similar difficulty level to the first attempt questions while also testing the same concepts. Figure 2 shows an example of two questions from the first and second trial of the second quiz. The quizzes also involve qualitative questions. The student will not receive grade points for these quizzes until he/she successfully solves the quiz questions or finish the trials. Successfully solving a quiz is defined as achieving at least a B grade in any trial. After the initial attempt, students are awarded a reduced credit for successive retakes as shown in Table 2.

Table 1. Breakdown of Topics in the Engineering Economy Course

Topics	Teaching Approach
Interest and Time Value of Money, Cash Flow Diagrams, End-of-Period Convention, Common Time, Simple and Compound Interest Rates, Economic Equivalence, Single Cash Flows (Present Value, Future Worth), Factor Notation, Single-Payment Compound-Amount Factor (F/P, i, N), Present-Worth Factor (P/F, i, N), Solving for (i) and (N), Uneven-Payment Series, Equal Payment or Uniform Series, Compound-Amount Factor (F/A, i, N), Sinking-Fund Factor (A/F, i, N), Capital-Recovery Factor (A/P, i, N), Present-Worth Factor (P/A, i, N), Present Value of Perpetuities, Linear Gradient Series, Present Worth Factor: Linear Gradient Series (P/G, i, N), Gradient-to-Uniform Series Factor (A/G, i, N), Geometric Gradient Series, Geometric Present-Worth Factor (P/A_1, g, i, N), Composite Cash Flows	Mastery Learning and Assessment
Market Interest Rates, Nominal Interest Rates, Annual Effective Yields, Discrete Compounding, Continuous Compounding, Effective Interest Rate Per Payment Period, Equivalence Calculations with Effective Interest Rates, Borrowing with Credit Cards, Commercial Loans and Principal and Interest Payments, Comparing Different Financing Options	
First Midterm	
Measure of Inflation, Effect of inflation, Average Inflation Rate, Time Value of Money with Inflation, Actual Dollar Analysis, Constant Dollar Analysis	Traditional Teaching/No Retakes
Comparison of Engineering Projects, Payback Analysis (Conventional and Discounted), Present Worth Analysis, Capitalized-Equivalent Method, Perpetual Service Life, Service vs. Revenue Projects, Comparison of Mutually Exclusive Projects (Unequal and Equal Project Lives)	
Annual-Equivalent Worth Criterion, Comparing a Set of Projects, Finding Annual Equivalent Worth by Conversion From NPW, Capital (Ownership) Costs versus Operating Costs, Calculating Capital Recovery Cost, Unit-Profit or Unit-Cost Calculation, Make or Buy Decisions, Comparison of Mutually Exclusive Projects (Unequal and Equal Project Lives), Annual Equivalent Cost Comparisons	
Second Midterm	
Rate of Return, Return on Investment, Return on Invested Capital, Internal Rate of Return, Simple vs. Non-Simple Investments (Borrowing and Lending), Computational Methods (Direct-Solution, Trial-and-Error, Excel), Decision Rule for Simple Investments, Decision Rule for Non-Simple Investments, Flaws in Project Ranking by IRR, Incremental IRR Analysis for Comparing Mutually Exclusive Alternatives, Incremental Analysis for Cost-Only Projects, Handling Unequal Service Lives	
Benefit-Cost Analysis, Evaluation of Public Projects, Incremental Benefit-Cost Ratio Analysis for Comparing Mutually Exclusive Alternatives, Profitability Index, Incremental Profitability Index Ratio Analysis for Comparing Mutually Exclusive Alternatives	
Accounting for Depreciation and Income Taxes, Depreciable Property, Cost Basis, Useful Life and Salvage Value, Depreciation Methods: Book and Tax Depreciation, Straight Line Method, Declining Balance Method, Switching Policy, Units-of –Production Method, Book Value, Corporate Taxes, Taxable Income, Net Income, Marginal Tax Rate, Average Tax Rate, Tax Depreciation Methods, MACRS Recovery Periods, MACRS Depreciation of Personal Property, MACRS Depreciation of Real Property, Gain Taxes	
Project Cash Flow, Project Cost Elements, Break-Even Sales Volume, Contribution Margin, Income-Tax Rate to Be Used in Project Evaluation, Incremental Cash Flows from Undertaking a Project, Operating Activities, Investing Activities, Financing Activities	
Final Exam	

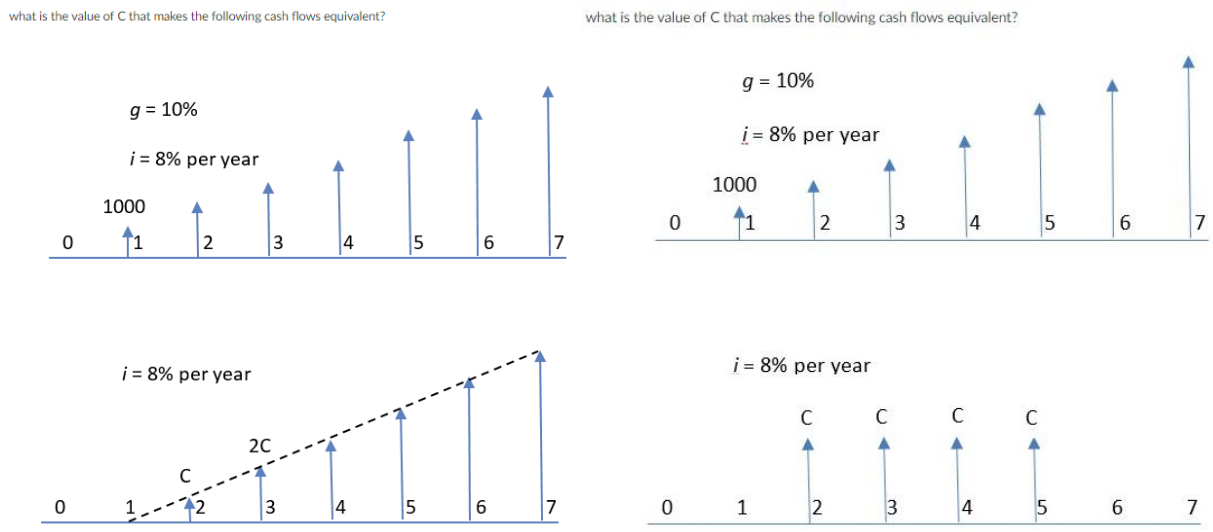

Figure 2. Questions from the First and Second Trials of the Second Quiz

Table 2. Mastery Grading

Trial	Criteria	Grade
First attempt	The grade should be ***greater than or equal 80% (B)***, If not, the student should retake the quiz	Same grade
Second attempt	The grade should be ***greater than or equal 80% (B),*** If not, the student should retake the quiz	0.80*grade
Third attempt	N/A	0.65*grade

Each mastery quiz involves 10-14 multiple choice questions. The quizzes are administered online using a learning management system – Canvas in this case. The students are given a 48-hour window to take each quiz but once the student starts the quiz, s/he will have a limited time to finish it (between 1 and 1.5hours). The quizzes are not administered in a classroom and they can be taken anywhere, anytime within the 48-hour window. Students are allowed to use their notes and textbooks to respond to the quiz questions. The purpose of these quizzes is not just to test the students' knowledge but also to act as a motivation tool to keep students studying and on pace with the course material being presented. The questions in each quiz test a collection of concepts and each question is targeting a specific concept. Quiz feedback is instantaneous and the students receive their grades upon submitting the quiz. The final answers are released at the end of the 48-hour period. The detailed answers are not given to the students. The instructor did this on purpose since the second and third trials involve similar questions and he wanted to encourage the student to review the class material and solve the quiz questions that they fail on

any trial on their own to learn from their mistakes. Another reason for not releasing the detailed solution to the quiz questions is that the quiz questions are similar to in-class and homework questions. On the other hand, if a student asks about any quiz question after performing any trial, the instructor is willing to help the student. Again, the main purpose of this approach is to motivate the student's learning not to create frustration or anxiety of earning low grades. A retake quiz will usually be open 24 hours after finishing the previous trial.

Data Collection and Analysis

Population

The mastery learning and assessment approach was implemented in the Engineering Economy course at Penn State Behrend in Fall 2016. Before that, traditional teaching with no assessment retakes was used. The course is taught in fall and spring semesters and one section is offered in each semester. In this study, both semesters were chosen to be fall semesters since the instructor believes that students groups within similar semesters would be similar in performance and preparation level compared to choosing different semesters. Table 3 shows the number of students in each semester by gender. There were 37 and 30 students in Fall 2015 and Fall 2016, respectively. This is a typical engineering course where the number of male students significantly outnumbers female students as shown in Table 3.

Table 3. Study Population

Gender	Semester	Sample Size
Male	Fall 2015	32
	Fall 2016	22
Female	Fall 2015	5
	Fall 2016	8

Learning Metrics and Analysis

To measure the gain in students' learning after implementing the mastery learning and assessment approach, a two-sample t-test was performed to test the difference between students' grades in the first, second, and final exams in Fall 2015 and Fall 2016. Exam questions were kept the same in both semesters. The instructor made sure to collect all exam papers after handing out the grades to minimize carrying the questions from one semester to another.

Logistics and Time Commitment

The mastery learning and assessment approach demands significant amount of time at the beginning when preparing the quizzes questions and setting them up on the course management system. More time will be required if the instructor wants to build a questions bank to minimize students sharing the answers. After that, the approach does not require additional preparation and grading time. Grading is done automatically and students receive their grades instantaneously. Ashour et al.,[7] provide insights and feedback about the logistics involved in conducting the mastery learning and assessment approach in engineering courses. The logistics and time commitment for the engineering economy course is different from Ashour et al.[7] because that study involved multiple course sections of administering paper and evening exams.

Students Perspective

Student perspective was not sought in this current engineering economy implementation study and is left as a future work. It should be mentioned though that very few students in the engineering economy course expressed complaints about their grades earned using the mastery learning and assessment approach. For these cases, a simple explanation to the student on how the grading system works and why it works this way was sufficient to resolve the grading issue.

On the same line, one of the authors of this paper was involved in the implementation of mastery in a sophomore level engineering mechanics course, i.e., statics[6]. In that study, a survey was developed and distributed to two groups of students: Students who were still enrolled in the statics course at the time of the study and the other group of students who had previously been exposed to mastery learning and assessment approach and now are enrolled in more advanced course. The results of the study showed that, in general, students in the first group do not appreciate the benefits of mastery learning and assessment approach while the other group had realized the benefits after they took future engineering courses[6]. Moreover, the results showed that mastery learning and assessment approach motivates students to look back and check the problems that were incorrectly solved which is often not the case with traditional learning and assessment approach[6].

Results and Discussion

The preparation level of students before enrolling in the Engineering Economy class was tested for the two student groups, i.e. Fall 2015 and Fall 2016. The preparation level is measured by the students' grade point averages (GPAs) at the beginning of the Engineering Economy course and the students' grades in the prerequisite of this course, i.e., the second course in calculus. Table 4 shows the means and standard deviations of the students' GPAs and grades in the prerequisite course. A two-sample t-test was performed at $\alpha = 0.05$ and showed that these groups are statistically indifferent in terms of GPA and prerequisite grade with p-values equal to 0.759 and 0.431, respectively. Therefore, it is safe to assume that the groups are comparable in terms of the level of preparation before starting the course. Note that the sample size of the prerequisite grade is less than the sample size of the GPA. The reason for this is that some of the students are 'transfer students' and they have taken and passed the prerequisite course outside Penn State Behrend, therefore no grades are recorded for them in the university's system.

Table 4. Mean and Standard Deviation of Students' GPAs and Prerequisite Grades

	GPA				Prerequisite Grade			
Semester	N	Mean	Std. Dev.	P-Value	N	Mean	Std. Dev.	P-Value
Fall2015	37	2.899	0.489	0.759	28	2.750	0.564	0.431
Fall2016	30	2.859	0.556		27	2.901	0.816	

The Engineering Economy course topics were covered at the same pace and taught in the same manner for both groups. The only difference was the mastery learning and assessment intervention in Fall 2016. To assess the gains in students' learning between Fall 2015 and Fall 2016, the difference in the means of students' scores in the first, second and final exams were tested using a two-sample t-test. The statistical analysis is summarized in Table 5. It is clear that the average of students' scores were higher under the mastery learning and assessment approach (Fall 2016) compared to the average scores under the traditional approach for the first and second exams. There were gains of 12.04 points and 13.88 points in the averages of the scores in the first and second exams, respectively. These gains were statistically significant with p-values = 0.001 and 0.006 for the first and second exams, respectively.

The averages of the final exam scores showed no statistical difference between semesters. This is because the final exam is not comprehensive and involves questions that relatively are not related to the material in the first and second exams.

Table 5. Two-Sample T-Test of Students' Scores in the First, Second, and Final Exams

Exam		Fall 2015	Fall 2016
First	N	37	30
	Mean	75.9	88.0
	Std. Dev.	15.7	11.5
	P-Value	0.001	
Second	N	37	30
	Mean	54.2	68.1
	Std. Dev.	18.8	20.6
	P-Value	0.006	
Final	N*	33	26
	Mean	81.9	79.6
	Std. Dev.	12.4	16.2
	P-Value	0.549	

* Some students late-dropped the course due to poor performance

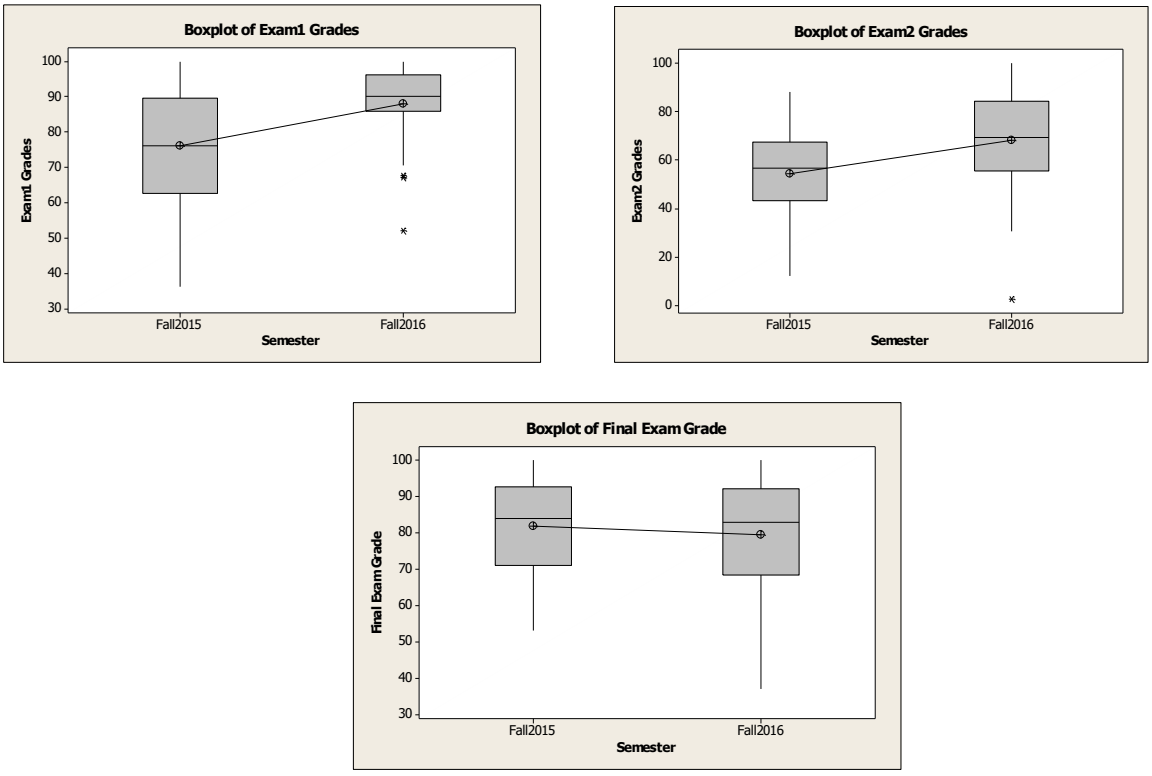

Figure 3. Boxplots of the Students' Scores in the First, Second and Final Exams

Further, Figure 3 shows box plots for the first, second, and final exams. Examining the boxplot of the first exam scores shows a tighter distribution under the mastery learning and assessment approach, which suggests that the intervention helped most of the students to achieve relatively high and close scores, compared to the traditional approach. This effect was not presented in the

scores of the second exam and final exam as well. To confirm this observation, Levene's test* was used (at $\alpha = 0.05$) and the resulted p-values are shown in Table 6.

Table 6. Levene's Test of Students' Scores in the First, Second, and Final Exams

Exam		Fall 2015	Fall 2016
First	N	37	30
	Variance	247.33	133.22
	P-Value	0.022	
Second	N	37	30
	Variance	355.10	424.58
	P-Value	0.691	
Final	N*	33	26
	Variance	153.03	263.21
	P-Value	0.327	

* Some students late-dropped the course due to poor performance

The analysis indicates that the effect of the mastery learning and assessment approach seems to disappear with time. Future work should focus on applying the intervention throughout the semester to include all the concepts in the course and investigate the impact on the overall learning performance.

Conclusions

This paper presents a case study of implementing mastery learning and assessment approach in an engineering course, i.e., Engineering Economy. The course is deemed a hybrid because the mastery approach is implemented in the first third portion of the course while the rest of the course is traditional learning and assessment approach. The concepts taught in the first one-third of the class are vital for learning and understanding the rest of the concepts in the course. This was the reason for converting the first one-third of the course to the mastery learning and assessment approach. The results of the study show that mastery learning and assessment approach has improved the averages of the students' scores in the first and second exams, i.e., 12.04 and 13.88 points higher, respectively. Moreover, the variance in the first exam scores has reduced compared to traditional approach. It is observed that the effect of the mastery approach kept decreasing throughout the semester with no effect on the scores of the final exam between the semesters.

* Note that Levene's test was performed before performing the two-sample t-test in order to check the variability assumption.

Future work should focus on gathering and analyzing more data to confirm the results of implementing mastery learning and assessment in the Engineering Economy course. In addition, the results suggest implementing the mastery approach throughout the semester to investigate its impact on the overall performance of the students. Furthermore, work should be carried out to understand students' opinion of mastery approach in engineering economy courses. Additionally, mastery tests could be broken down to specific concepts and data could be collected and tracked in a way that provide feedback to the instructors on what areas to focus on when planning for future offerings of the course.

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