

Using “Real World” Problems in Engineering Economy

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Abstract

We have previously reported on the use of supplementary materials, such as *The Wall Street Journal*, in engineering economy teaching environments. Specifically, we used newspaper articles as the basis for classroom discussions and open-ended exam problems. The students were generally receptive as they saw how engineering economics could be applied to real problems. In this paper, we outline an experiment to determine whether “real world” problems can be substituted for traditional “plug and chug” problems in homework and quiz environments. Our hypothesis is that students will prefer to study and answer problems set in reality. However, we concede that this approach may not help, and may even inhibit, the learning of engineering economy topics as students may “miss” the underlying theory covered in the question. We describe our experiment in detail and present preliminary findings available at the time of printing. The full results of the experiment will be presented at the conference as the class is being taught in the Spring of 2005.

1. Introduction

Going to school and studying engineering is often characterized as being difficult (and sometimes boring), especially in the first few years of coursework. This is because engineering and technology majors take courses in science (physics, chemistry), mathematics (linear algebra, calculus, differential equations), computing, and economics (economics, engineering economy). In these courses, students are generally taught methods and are not exposed to the applications of these methods until later in their education. Unfortunately, it is difficult to motivate students when they do not see how their work applies to the real world [1].

We have previously reported on the use of *The Wall Street Journal* [2], among other media sources, in the classroom in order to motivate students and improve the learning environment for students in engineering economy. This paper describes an experiment performed in the Spring of 2005 to compare the use of traditional “plug and chug” type problems with those motivated from real world occurrences. We believe that students will have a greater appreciation for the problems being analyzed if they are presented in this realistic setting. However, we concede that this setting may distract students from learning the intended content of the problems.

This paper details the experiment performed in the Spring of 2005. The class consists of roughly 50 junior class Industrial Engineers, although there are a few other majors in the class. We present initial findings and will disseminate the complete results at the conference.

2. Example Problems

The easiest way to describe our experiment is to illustrate a number of different example scenarios. First, consider a typical cash flow example as follows.

Traditional Example: Find the present worth (at time zero) of a series of five equivalent cash flows of size \$720 occurring in years four through eight. Assume end of year cash flows and a 12.5% annual rate of interest.

We now consider a revision of the problem above using a recent story from *The Wall Street Journal* concerning airplane manufacturer Boeing.

Revamped Example: In December of 2004, Japan Airlines (JAL) announced that it would purchase 30 7E7 aircraft from Boeing Co. to replace aging Boeing 767s and Airbus A300-600s. JAL also purchased options on another 20 aircraft. The planes, which carry a per-unit list price of \$120 million, are to be delivered starting in 2008 [3]. Make the following assumptions: Six planes are to be delivered at the end of years 2008 through 2012. If the annual rate of interest is 12.5% and list prices are paid, what is the present worth of the transaction (time zero is the end of 2004)?

The above examples represent common cash flow analysis problems usually analyzed when learning “time value of money” calculations and their associated financial mathematics. To add another layer of complication, we consider a mining investment example.

Traditional Example: Construction and development of a uranium mine is being considered in order to take advantage of increase nuclear energy production. Construction would cost \$450 million, spread evenly over three years (assume end of year cash flows). Production is expected to reach 6 million pounds of ore in the final year of construction, growing at 6 million pounds per year until reaching the maximum production level of 18 million pounds of ore per year. If revenues are \$12 per pound, production costs are \$5.50 per pound, maximum production lasts 10 years, and remediation costs are \$25 million at the end of the mine’s life, what is the present worth of the investment? The MARR is 18%.

Revamped Example: A consortium led by Cameco Corporation is proceeding with development of the Cigar Lake mine in Saskatchewan, Canada to produce uranium due to strong growth in the nuclear energy sector. Construction is expected to take 27 months with production ramping up in years 2007 through 2009 before reaching full production of 18 million pounds of high-grade uranium a year. Investment costs are expected to be about C\$450 million [4]. Make the following assumptions: Construction costs are incurred evenly over years 2005, ‘06 and ‘07 with 6 million pounds of uranium produced in year 2007, increasing to 12 million in ‘08, and 18 million in ‘09. Full production is expected to last for 10 years with each pound costing \$5.50 to product but generating \$12 in revenue. Clean up and remediation costs are estimated at \$25 million at the end of production. What is the present worth of the project assuming a MARR of 18%?

These two examples illustrate how we intend to infuse “real problems” into problems for students to evaluate. In the next few sections, we detail our experiment.

3. Hypotheses

There are two hypotheses that we want to investigate in this experiment. The first concerns the student’s ability to learn material using the revamped problems:

H₁: Students given more-involved questions containing real world data (Revamped) would not perform differently from students given less-involved generic questions (Traditional).

We will test this hypothesis through a systematic experiment detailed in the following section. Our second hypothesis concerns student reaction to the use of these problems:

H₂: Students would prefer to work on problems containing real world data (Revamped) than on contrived hypothetical questions (Traditional).

We will analyze this hypothesis with use of a questionnaire.

4. Experimental Design

The idea behind our experiment is to quiz the students using both traditional and revamped problems. From the results of the quizzes, we hope to ascertain whether there is a difference in learning that can be attributed to the different problem sets.

There were 48 students registered for IE 226, Engineering Economy and Decision Analysis, at Lehigh University for the Spring of 2005. We randomly assigned students to one of two equally sized groups (GROUP 1 and GROUP 2). We verified that the groups were essentially equivalent by comparing GPA statistics through a pooled t-test. The test also showed that the populations could be compared under the assumption of having equal variances.

Each group will take four quizzes, two during the first half of the semester with introductory material and two in the second half of the semester with more advanced material. Each quiz will consist of three questions that must be answered in a 20-minute time window. Each quiz, in its entirety, will consist of either traditional questions or revamped questions. However, each group of students will take two “traditional” quizzes and two “revamped” quizzes, as noted in Table 1, where X_T involves traditional questions and X_R involves revamped questions.

Table 1. Experimental Design for Student Quizzes.

	First half of semester (Introductory Material)		Second half of semester (Advanced Material)	
	Quiz 1	Quiz 2	Quiz 3	Quiz 4
GROUP 1	X_{T1}	X_{R2}	X_{R3}	X_{T4}
GROUP 2	X_{R1}	X_{T2}	X_{T3}	X_{R4}

According to the schedule in Table 1, Group 1 will have a sequence of traditional/revamped/revamped/traditional questions. Group 2 will have a sequence of revamped/traditional/traditional/revamped questions. Comparing group scores for each quiz provides four tests of H_1 . As of the printing of this article, the first two quizzes were completed.

To address our second hypothesis, we will ask the students to answer a questionnaire after each pair of quizzes. The following questions are to be asked:

- To what extent did you feel prepared for the quizzes?
- To what extent did the information given in the problem affect your ability to solve the problem?
- Did you feel the quizzes were different?

The students will have the ability to answer according to a 4-point likert scale ('not at all', 'somewhat', 'moderately', or 'very much') and also provide their qualitative feedback. We also will ask a number of questions to compare the quizzes:

- Which type of problem were you more prepared to answer?
- Which type of problem did you find more challenging?
- Which type of problem did you find more interesting?
- Which type of problem did you prefer?

The students were able to rank their preference according to 'strongly prefer', 'prefer', or 'no preference' for the last question and 'strongly', 'slightly', or 'no difference' for the others.

5. Interpreting the Results

Each quiz will be systematically graded, including partial credit. For example, a cash flow diagram will be worth a certain amount of points as will be writing down the correct time value of money equation. It is believed that the instructor can assign scores in an equitable manner.

Given scores for each quiz, we can perform a t-test to determine if there are significant differences in the scores. There are essentially three outcomes for a given quiz: (1) No difference, (2) X_T performs better, or (3) X_R performs better. In the first case, H_1 is supported. In the second case, it may be concluded that the revamped questions are more difficult than the traditional questions. In the final case, a definitive conclusion is difficult but it would clearly support the use of these types of problems. Given the data, we may also examine if there are other influences (i.e. gender).

Having four quizzes over the semester may lead to interesting (and difficult) interpretations. For example, what would cause the outcome for Quiz 2 to be different from that of Quiz 1? It may be attributable to some learning such that the experience of having more involved questions on Quiz 1 causes Group 2 to do better on the less involved questions in Quiz 2. We will address these issues as they arise. Insight from our questionnaire may help in answering these questions.

6. Preliminary Results

We completed two quizzes by the proceedings due date. The statistics for the individual quizzes are summarized in Table 2. The average and standard deviations are calculated for both the first two quizzes and for the quizzes separated according to traditional and revamped problems.

Table 2. Means and Standard Deviations for First Two Quizzes.

Quiz	Number	Mean	Standard Deviation
Quiz 1 Traditional	20	10.78	3.15
Quiz 1 Revamped	21	11.24	3.02
Quiz 2 Traditional	23	11.60	1.96
Quiz 2 Revamped	22	10.77	2.83

Assuming the populations to be approximately Normal with equal variances, we use a pooled t-test to analyze the following hypotheses:

$$H_0: \mu_T - \mu_R = 0$$

$$H_1: \mu_T - \mu_R > 0$$

Note that we are only interested in comparing the traditional and revamped scores.

The calculated t-statistics are -0.489 for quiz 1 and 1.092 for quiz 2. These both lead us to the conclusion not to reject H_0 at the $\alpha=0.05$ level of significance. (The significance levels are 0.627 and 0.282, respectively.) These conclusions support our first hypothesis that the students would not perform differently with the different types of problems.

Table 3 provides aggregated data according to both quizzes. Similar t-tests for this data showed that the null hypothesis should not be rejected as there was no significant difference in the means of the traditional and revamped quizzes. Furthermore, it was shown that there was no significant difference in the means of Quiz 1 versus Quiz 2.

Table 3. Means and Standard Deviations for Aggregate Data for First Two Quizzes.

Quiz	Number	Mean	Standard Deviation
Traditional	43	11.16	2.66
Revamped	43	11.00	2.89
Quiz 1	41	11.00	3.06
Quiz 2	45	11.17	2.46

As for our second hypothesis, we turned to the questionnaire. From the responses, the students felt that the information given in the quiz greatly affected their ability to solve the problem (average 3.19, on an increasing scale from 1 (not at all) to 4 (very much)), but they felt the quizzes were only somewhat different (average 2.20).

The students were also asked to compare the two types of questions on a five-point scale, with 1 (strongly) and 2 (somewhat) favoring the traditional questions, 3 denoting no difference, and 4 (somewhat) and 5 (strongly) favoring the revamped questions. The averages of the results are given here with the conclusions:

- The students felt slightly more prepared to answer the traditional questions (2.52).
- The revamped questions were slightly more challenging (3.69).
- The revamped questions were slightly more interesting (3.44).
- The traditional questions were slightly preferred (2.81).

According to the qualitative feedback, the students generally cited the “timed quiz-taking environment” as the reason that they preferred the traditional questions. In future research, we will seek their preferences in homework environments where time is not critical.

7. Conclusions

We have detailed an experiment to be performed in an undergraduate engineering economy class in the spring of 2005. Hypotheses concerning whether problems designed from real-world data have any effect on learning are to be tested. If it is shown that these problems (1) do not hurt the learning process (when compared to traditional methods) and (2) students find the new approach appealing, we are motivated to continue our experiments and provide ways for professors to apply these concepts in the classroom. For example, development of a problem set database that can be accessed by interested parties would relieve the burden of constructing these examples, which are clearly more difficult to develop than traditional examples. It is also believed that these concepts can be applied in other disciplines, although the sources of data are not as obvious as in engineering economy applications. The ultimate goal is to motivate engineering students real-world based problems.

Our initial results (from two quizzes tested early in the Spring 2005 semester) are positive in that the statistical evidence suggests that students perform equally well with both types of problems in quiz-taking environments. Qualitative evidence suggests that they prefer traditional problems in these environments as time to absorb information is constrained. We intend to explore this issue further while continuing with the statistical testing.

7. Bibliography

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8. Biographies

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