

# Use of Industrial Case Studies to Teach Engineering Economy

## Abstract

This paper summarizes the results of using industrial case studies to teach engineering economy. An experiment was structured to determine if a student's learning was significantly improved in a class where case study participation was mandatory (the "experimental" group). Another section of engineering economy did not utilize industrial case studies and served as the "control" group. It was observed that the experimental group did better, as measured by the final score in the courses, than the control group. Thus, it is generally concluded that the extra effort required to offer industrial case studies pays handsome dividends and should be considered as a "cost-beneficial" enhancement to an engineering economy course.

## 1. Introduction

The inclusion of industrial case studies in undergraduate education reinforces concepts and improves learning in ways not available through traditional methods of lecture or predefined case problems. Students can develop problem solving skills, project management skills, communication and teaming skills, and a sense of professionalism through such experiences. For Engineering Economy in particular, the potential benefits to students may be great from industrial case studies though the investment of time and effort in creating and running such projects can be significant. Our objective was to determine whether use of industrial projects can potentially result in higher quality engineering economy courses offered in a cost-effective manner<sup>1-3</sup>.

During the Spring semester of 2000, a set of industrial case studies from General Electric in Salem, Virginia was made available to students in the 8:00 a.m. section of ISE 2014 (the experimental group). The class was divided into 20 groups of four students each, and each group bid on one of the four GE case studies. Students in the 10:00 a.m. section (the control group) were not given access to these materials.

A total of four industrial projects sponsored by General Electric (GE) were offered to the students in the 8:00 a.m. section. The primary objective of the case studies was to allow students to interact with engineers from GE to demonstrate, extend, and integrate knowledge of engineering economy in the solution of real industrial problems<sup>4</sup>. The case studies were designed to:

- Increase the student's competency in the economic principles of engineering design.
- Better prepare the student for engineering practice.
- Improve the student's skills in problem solving.
- Improve the student's ability to work in a team.

The collaborative projects provided the students with a rich opportunity to understand the difficulties associated with solving a real problem, work with practicing engineers and managers

in industry, make industrial contacts which may be helpful in the future, and improve their skills in design and economic analysis<sup>5</sup>. Each of the four projects offered is now summarized.

### 1.1 Increasing Profits by Finding “Best in Class” Suppliers

General Electric introduces many new products throughout the course of every fiscal year. These New Product Introduction (NPI) projects typically incorporate a new technology that is expected to increase market share and/or achieve a cost “take out” over an existing product<sup>6</sup>.

These NPI projects often do not incorporate the best cost solution for one or more of the subassemblies that make up the “new” product. In the first project, students were given information about the current cost of a particular subassembly and the number of units GE expected to sell per year.

The students were given a 20% cost reduction target for the subassembly and were told to manager four steps of the NPI project: Supplier Pool Definition, Supplier Selection, Supplier Qualification, and Part Qualification. Students were asked to develop a plan to achieve the cost target while addressing the following questions:

- How much will this project cost GE?
- How long will the project take?
- What is the expected “break even” date?

Students were also asked if it was beneficial to spend more money and accelerate the NPI project (reduce the “break even” date). Essential data accompanied the problem statement, but many of the assumptions were purposely left up to the individual student groups.

### 1.2 Minimizing the Number of New Parts Introduced Through Reuse of Existing Parts

The second project involved an enormous inventory control challenge where incidents of multiple functional equivalent parts denoted by different part numbers and/or different descriptions existed in a database. The parts were similar in form, fit and function, but due to their representation in the database there was no easy way to identify or combine them. Students were informed of three main cost categories of interest<sup>7</sup>:

- Cost of carrying the “extra” inventory.
- Cost associated with qualifying a new supplier.
- Cost of qualifying a new part (when its equivalent already exists).

Students were given information regarding a potential solution to the problem that involved the purchase of a costly data management system that would cleanse the database over a period of time. They were also given information about the cost of introducing a new part, the rate of new part introduction, and an estimate on the number of functional equivalents in the database. The students were asked to develop a model that would enable GE to predict the cost over a three-year period of having a certain allowable level of “extra” parts in the database.

### **1.3 Balancing the Initial Cost of Ownership of a Power System with Efficiency, Reliability, and Life Expectancy**

The third project involved selecting the most cost effective type of transformers for a recently constructed industrial complex. The complex needed to balance the initial cost of ownership with increased efficiency, reliability, and life expectancy of the power distribution transformers purchased. There was a critical need to validate cost, reliability, and longevity to insure the complex did not overpay initially or have to replace too many transformers too soon. The project extended over a 25-year study period.

Specific technical information about three types of transformers (Dry Type, Cast Coil, and Liquid Filled) was provided to the students. Additional cost information was also given to the students regarding transformer space requirements for indoor floor space and outdoor space. Transformer operating and replacement costs were also provided. The students were charged with developing a cost model that would determine the least expensive transformer type over the 25-year period.

### **1.4 Optimizing Product Development Cost through Off-Shore Out-Sourcing**

The fourth project involved the possible out-sourcing of off-shore labor and facilities to develop and design new products<sup>8</sup>. Product development activity in other countries is hampered by the lack of experienced designers in low-cost foreign countries. The objective of the project was to determine the best method to expand the GE design team to meet an expansion of a particular product line over the next five years. Students were given information regarding the number of people currently assigned to the design team and the team's expected requirements for the next five years. Students were given the option to hire three different types of employees during the five-year period:

- Experienced designers at the same hourly rate as current employees.
- Inexperienced designers that will go through the training program at a slightly reduced hourly rate (after 2 years the hourly rate for these designers will increase to the same hourly rate as current employees).
- Inexperienced workers from a foreign country at a much lower hourly and efficiency rate.

The inexperienced workers weren't as efficient as experienced workers, so their effectiveness was reduced. Students were charged with developing a proposed hiring and assignment plan for the entire five-year period that minimized cost while satisfying the demand expected for the design team.

## **2. An Earlier Study of Student Learning**

From an earlier study (1993-1996) of student performance in ISE 2014, we developed a good predictor of student learning in engineering economy (ISE 2014). Multivariate data collected were used to develop linear regression equations for predicting weighted final scores in ISE 2014<sup>9</sup>. Over 1,400 students voluntarily participated by making available data on their SAT scores, grade point average, and high school standing. Absolute error for the regression equation for

each year ranged from  $\pm 6.13$  points to  $\pm 7.42$  points, indicating a high degree of accuracy<sup>10</sup>. The linear regression equations developed over 1993 to 1996 were used in the Spring 2000 classes to compare predicted performance to actual performance for students in the experimental and control groups. We hoped to measure the effect on student learning, if any, of providing an industrial-sponsored case study<sup>11</sup>.

### 3. Research Questions

The following three hypotheses were used in determining learning differences between the 8:00 a.m. and 10:00 a.m. sections of ISE 2014.

- (1) No significant difference existed between actual performance of students in the 8:00 a.m. section and students in the 10:00 a.m. section.
- (2) No significant difference existed in the change in performance of students in the 8:00 a.m. section compared to the change in performance of students in the 10:00 a.m. section.
- (3) No significant difference existed between predicted performance of students in the 8:00 a.m. section and students in the 10:00 a.m. section.

### 4. Spring 2000 Experiment

During pre-registration, students had the choice of enrolling in either the 8:00 a.m. or the 10:00 a.m. section without having any prior knowledge of the difference between the two sections. Furthermore, students were allowed to switch between sections during the first three weeks of the semester.

The multiple regression model developed by Sullivan and Daghestani<sup>10</sup> was used to predict student performance. The equation, shown in Table 1, uses a student's class level, cumulative QCA, SAT math score, SAT verbal score, and high school rank to predict his or her final score. For each variable, values from Table 1 were used.

Table 1. Multiple Regression Equation and Classification of Variables

$\text{Predicted Final Score} = 45.58 + 3.40 (\text{CLASS LEVEL}) + 6.08 (\text{QCA}) + 2.46 (\text{SAT MATH}) - 0.47 (\text{SAT VERBAL}) + 1.35 (\text{HS RANK})$				
<i>Quartiles</i>	1	2	3	4
<i>LEVEL</i>	10–freshman	20–sophomore	30–junior	40–senior
<i>QCA</i>	0 – 1.99	2 – 2.499	2.5 – 3.249	3.25 – 4.0
<i>SAT MATH</i>	0 – 490	500 – 590	600 – 690	700 – 800
<i>SAT VERBAL</i>	0 – 490	500 – 590	600 – 690	700 – 800
<i>HS RANK</i>	0 – 79.9	80 – 89.9	90 – 94.9	95 – 100

The design project grade was not included in the calculation of final scores for the experimental group. For the purposes of this paper, both group's scores were calculated using the formula in Table 2.

Table 2. Weighted Final Score Formula

Weighted Final Score = 0.20 (HOMEWORK and QUIZ AVERAGE) + 0.25 (TEST 1 SCORE) + 0.25 (TEST 2 SCORE) + 0.30 (FINAL EXAM SCORE)
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Table 3 summarizes descriptive statistics for the weighted final scores of the control and the experimental groups. Students with incomplete data, mainly missing high school standing or SAT scores, were removed from the pool of data. For the analysis, 51 data points were available in the experimental section and 179 data points were available from the control section. The mean predicted score for the experimental group was 78.395 and the mean actual score for the same group was 80.143, a difference of +1.747 points. For the control group, the mean predicted score was 81.572 and the mean actual score was 77.450, a difference of -4.122 points.

Table 3. Descriptive Statistics of Weighted Final Scores

	<b>Control</b>		<b>Experimental</b>	
	<i>Predicted Score</i>	<i>Actual Score</i>	<i>Predicted Score</i>	<i>Actual Score</i>
<i>N</i>	179	179	51	51
<i>Range</i>	35.12	79.2	28.73	55.98
<i>Minimum</i>	61.23	42.20	61.23	40.08
<i>Maximum</i>	96.35	96.50	89.96	96.05
<i>Mean</i>	81.572	77.450	78.395	80.143
<i>Std. Deviation</i>	7.7614	14.326	7.317	10.128

#### 4.1 Hypothesis 1 – Comparison of Actual Score Means

$H_0$ : The mean actual score of the experimental (8:00 a.m.) group was not significantly different from the mean actual score of the control (10:00 a.m.) group.

Hypothesis 1 proposes that students in the experimental section will receive weighted final scores that are no different from the final scores of peers in the control group. The mean final weighted score for the experimental group was 80.143 with a standard deviation of 10.128. The mean final weighted score for the control group was 77.450 with a standard deviation of 14.326.

A two-tailed  $t$ -test was used to test for a difference between the actual final scores of students in the control section and experimental section. Because the two samples were drawn from the same underlying population, equal variances were assumed when performing the test. At a  $\alpha = 0.05$  level, a significant difference was found between the means of actual final scores ( $p < 0.01$ ). Note that the  $p$ -value indicates the probability that the observed difference can be attributed to pure chance<sup>12</sup>. The test indicates that students in the experimental group did perform better than students in the control group.

## 4.2 Hypothesis 2 – Change in Scores Comparison

$H_0$ : No significant difference existed between the change from predicted scores to actual scores of students in the experimental (8:00 a.m.) section and students in the control (10:00 a.m.) section.

Hypothesis 2 suggests that the mean change from predicted scores to actual scores will not be significantly different for the two groups. The mean score change for the experimental group was +1.747 points with a standard deviation of 8.613. The mean score changes for the control group was -4.122 with a standard deviation of 16.369. A bi-directional  $t$ -test ( $\alpha = 0.05$ ) was used to test for a difference between the mean change in scores for students in the experimental section and the mean change in scores for students in the experimental section. The  $t$ -test indicated that a difference did exist between score change means. At a  $\alpha = 0.05$  level, a significant difference was found between the mean change in scores of the two groups ( $p = 0.01453$ ). Furthermore, a one-tailed  $t$ -test indicated that the mean change for students in the experimental group was higher than the mean change in the control group. At a  $\alpha = 0.05$  level, a significant difference was found between rise in experimental group scores and the drop in control group scores ( $p < 0.01$ ). The tests indicate that the experimental group performed as predicted while the control group showed a significant decrease in actual scores from predicted scores.

## 4.3 Hypothesis 3 – Comparison of Predicted Score Means

$H_0$ : Predicted scores for students in the experimental group are not significantly different from predicted scores for students in the control group.

The null hypothesis proposes that the mean predicted final score for students in the experimental section was not different from the mean predicted final score of students in the control group. The mean predicted score for the experimental group was 78.395 with a standard deviation of 7.317. The mean predicted score for the control group was 81.572 with a standard deviation of 7.761.

A bi-directional  $t$ -test was used to test for a difference between the predicted final scores of students in the control section and experimental section. Equal variances were assumed when performing the test because students were drawn from the same underlying population. The  $t$ -test indicated a significant difference between the mean predicted scores of both sections. At an  $\alpha = 0.05$  level, a significant difference was found between the predicted score means ( $p < 0.01$ ).

A one-tailed  $t$ -test was used to determine if the mean predicted score for the experimental group was significantly lower than the mean predicted score for the control group. At an  $\alpha = 0.05$  level, the mean predicted score for the control group was significantly higher than the mean predicted score for the experimental section ( $p = 0.00482$ ). The test suggests that, on average, the control group should have received higher scores than the experimental group.

## 5. Conclusions

From our results, it appears that required team-based industrial case studies, such as those offered by GE, improve learning by forcing students to integrate the principles of engineering economy during actual problem solving activity<sup>13, 14</sup>. The externally sponsored projects and team based problem solving also apparently energized the class through promotion of a peer-based learning experience. Case study activity in general may produce these desirable results<sup>15</sup>.

Comparison of the actual scores of students in the 8:00 a.m. section and 10:00 a.m. section did reveal significant differences, when using only students who had complete data sets available. Actual final scores were significantly higher for the experimental group than the actual final scores of the control group ( $p < 0.01$ ).

Comparing final scores between the 8:00 a.m. and 10:00 a.m. groups revealed interesting results. From the outset, there were no reasons to expect one group to perform better than the other. Predicted scores were compared between the groups to test this assumption. A difference was found in the mean predicted scores of both groups, with the control group having a mean predicted final score higher than the mean predicted final score for the experimental group ( $p < 0.01$ ). It was surprising to find that the control group did not perform as predicted. The mean actual final score was 4.437 points lower than the mean predicted final score, a drop from 81.568 to 77.131 points. The difference was found to be statistically significant indicating that actual final scores were lower than predicted final scores ( $p < 0.01$ ). It appears that the students in the control group did perform differently than expected.

## References

- 1 J.-P. Bailon, B. Clement, and P. G. Lafleur, "Same course, two methods of learning: Assessment of the student's success," *ASEE Annual Conference and Exposition, Conference Proceedings, 2005 ASEE Annual Conference and Exposition, Conference Proceedings*, Portland, OR, 2005, pp. 12447-12462.
- 2 D. R. Falkenburg and D. S. Miller, "Strategies for creating web-based engineering case studies," *ASEE Annual Conference Proceedings, ASEE 2004 Annual Conference and Exposition, "Engineering Education Researchs New Heights"*, Salt Lake City, UT, 2004, pp. 15401-15412.
- 3 J. H. Russ and W. R. Nance Jr, "Learning across disciplines: A case-study approach to teaching engineering economics and business policy," *ASEE Annual Conference Proceedings, ASEE 2004 Annual Conference and Exposition, "Engineering Education Researchs New Heights"*, Salt Lake City, UT, 2004, pp. 8799-8807.
- 4 J. Birge, S. Henderson, and L. Olsen, "Improving quality in introductory industrial engineering through case studies and communication," *ASEE Annual Conference Proceedings*, Milwaukee, WI, 1997, pp. 12.
- 5 S. M. Sbenaty, "Industrial partnership for the enhancement of Engineering Technology Education," *ASEE Annual Conference Proceedings, 1999 ASEE Annual Conference and Exposition: Engineering Education to Serve the World*, Charlotte, NC, 1999, pp. 2885-2891.
- 6 M. Ishioka and K. Yasuda, "Product development strategies for innovative product," Singapore, 2004, pp. 1008-1012.
- 7 W. J. Hopp and M. L. Spearman, *Factory Physics: Foundations of Manufacturing Management*, 2nd ed. Boston: McGraw-Hill, 2001.
- 8 H. Bowers, "Subcontracting as an alternative to accessing low cost offshore sources," *Conference Record - Electro*, Boston, MA, 1984, pp. 3.
- 9 R. A. Adeleke, "Statistical analysis of students performance at the Ondo State University Ado-Ekiti," *Modelling, Measurement and Control D*, vol. 21, pp. 33-42, 2000.

- 10 W. G. Sullivan and S. F. Daghestani, "Multivariate analysis of student performance in large engineering economy classes," *ASEE Annual Conference Proceedings*, Milwaukee, WI, 1997, pp. 9.
- 11 L. G. Richards and M. E. Gorman, "Using case studies to teach engineering design and ethics," *ASEE Annual Conference Proceedings, ASEE 2004 Annual Conference and Exposition, "Engineering Education Researchs New Heights"*, Salt Lake City, UT, 2004, pp. 14967-14973.
- 12 D. C. Montgomery, E. A. Peck, and G. G. Vining, *Introduction to Linear Regression Analysis*, 3rd ed. New York: Wiley-Interscience, 2001.
- 13 S. M. Sbenaty, "Industry-based case-study models in technical education," *ASEE Annual Conference Proceedings, 2003 ASEE Annual Conference and Exposition: Staying in Tune with Engineering Education*, Nashville, TN, 2003, pp. 11546-11552.
- 14 P. Kauffmann, T. Abdel-Salam, K. Williamson, and C. Considine, "ASEE Annual Conference and Exposition, Conference Proceedings, 2005 ASEE Annual Conference and Exposition, Conference Proceedings," Portland, OR, 2005, pp. 11503-11509.
- 15 Z. Liao and A.-Y. Chen, "Reflective group learning model for case studies in engineering and technology management," *International Journal of Continuing Engineering Education*, vol. 8, pp. 47-57, 1998.