

## Bringing Ethical Considerations and Contemporary Issues into an Engineering Economy Course

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### Abstract

With the adoption of EC2000, many engineering faculty believe they are being asked to add more topics to an already full curriculum in order to demonstrate accomplishment of several of the a-k learning outcomes. One solution is to incorporate curricula related to ethical considerations and contemporary, societal issues into existing courses. Through the use of carefully selected case studies, the engineering economy course provides an ideal environment in which students may demonstrate teamwork and communication skills, awareness of ethical standards, and an understanding of the impact of engineering solutions on society. Case studies based on the Challenger disaster and the Ford/Firestone controversy have direct relevance to the industrial engineering curriculum and can be adapted to meet the needs of specific courses such as engineering economy, project management, and quality control.

### Introduction

Recent revisions in engineering accreditation guidelines have raised awareness of the wide range of learning outcomes that comprise a modern undergraduate engineering education<sup>1</sup>. In addition to technical competence in engineering science, students need to develop skills in communication, teamwork, ethics, and project management.<sup>2</sup> At many engineering schools, this awareness has resulted in changes in course content as well as teaching methods. Case studies and open-ended problem assignments are especially effective ways to help students develop engineering-related professional-practice skills such as awareness of the impact of engineering decisions on society, ethical and professional practices, and knowledge of contemporary issues.<sup>3,4,5</sup> Recognition that instruction on the impact of engineering decisions on society is an essential part of the modern engineering curriculum has spread to Europe as well.<sup>6</sup>

What does this mean for the engineering economy course of the future? Survey results suggest that the content areas of engineering economy courses across the country are quite diverse.<sup>7</sup> Is there room for an ethics case study in the typical engineering economy course? Are engineering economy texts filled with over-simplified examples that have neatly defined alternatives and largely numerical answers? Do faculty need to supplement the texts with detailed case studies? Who would be willing to teach such a case study? Should courses in engineering economy provide more of an engineering decision making focus as suggested by Wells<sup>8</sup> and Hartmann<sup>9</sup>?

There has been little written directly about ethics curricula in engineering economy courses. Of the 48 references cited by Haws<sup>10</sup> in his meta-analysis of ethics instruction in the engineering curriculum, only one specifically addressed economics. This Principles of Management and Economics course incorporated a three week module on ethics during the two-semester course

sequence.<sup>11</sup> However, half of the conference papers Haws reviewed referred to the use of case studies as an instructional technique. Haws asserts that case studies may help engineering students and faculty think more divergently. He also suggests that case studies have value in that they may help engineering students view engineering solutions from the perspective of the larger community.

In a national study of engineering economy professors<sup>12</sup>, approximately half of the respondents indicated their school was engaged in a redesign of the engineering economy course. Slightly less than half of the respondents (44%) stated that they used groups as part of their course. Fewer than 10% indicated that they used case studies to supplement the engineering economy text. Furthermore, the case study accounted for 15% of the final course grade, on average. Incidentally, non-IE faculty who teach engineering economy tend to weigh case studies more heavily than IE faculty. Those who are still actively engaged in the redesign of the engineering economy course may want to consider incorporating a multimedia case study that reflects the complexity of economic decisions in a real-world environment.

### **Background**

Mercer University offers an ABET-accredited BSE degree with biomedical, computer, electrical, environmental, industrial, and mechanical engineering specializations. A course in engineering economy has been part of the required BSE curriculum ever since Mercer University established a School of Engineering. For many years, the course was taught at the junior level and included standard engineering economy topics. The transformation of the Engineering Economy course began with a two-year-long curriculum renewal effort instigated by the transition from the quarter system to the semester system. As part of the redesigned engineering core curriculum, the engineering economy course, traditionally taught at the junior level, became part of the freshman year curriculum. Furthermore, in response to a requirement that we limit the basic curriculum to 128 semester hours, as well as a desire to cover a variety of topics, certain faculty were asked to develop hybrid courses. Two core courses traditionally taught by industrial engineering faculty were changed into hybrid courses. Content from a microeconomics that had been a separate quarter-long required course taught by the business school was integrated into a new semester-long engineering economy course (EGR 120).

The process of designing and implementing the hybrid courses offered both challenges and opportunities. It was, and continues to be, a challenge to integrate material from what were traditionally two separate courses into a single course. On the other hand, the hybrid courses gave us an opportunity to modify parts of the curriculum to accommodate EC2000 learning outcomes. Two earlier papers described the development and evaluation of the integrated economics/engineering economy course in great detail.<sup>13,14</sup> Since those papers were written, we have changed the content of the course to include project management and cost estimation topics in place of microeconomics. In addition, we have moved the course from the freshman year to the junior year and renamed it EGR 312. This paper will concentrate on the project management component of EGR 312 during the fall 2001 term.

## **Learning Objectives**

Due to the fact that all Mercer engineering students must take the engineering economy course, the course curriculum can be used to document interdisciplinary teamwork that is introduced to the students as freshmen in a required introduction to design course. The written and oral presentation requirement allows us to evaluate communication skills that are also introduced in common freshman engineering courses and reinforced in a required junior-level technical communication course. Topics such as the Challenger incident or the Ford/Firestone controversy deal directly with the societal impact of engineering decisions as well as a knowledge of contemporary issues that build on the students' humanities and social science electives. Finally, such case studies offer students the change to reinforce their ability to identify, formulate, and solve engineering problems that is introduced in our freshman-level problem solving course.

## **Implementation of the Project Management Unit**

The project management unit that was administered in EGR 312 during the fall 2001 term was used to evaluate communication, interdisciplinary teamwork, ethical and professional practices, the impact of engineering decisions, and knowledge of contemporary issues. Student performance on the project management unit accounted for 15% of the student's final grade in the engineering economy course. The three-week long project management unit was introduced after the students had received eight weeks of instruction in more typical engineering economy topics (cash flow, equivalence, interest factors, economic analysis using Excel, present worth analysis, annual worth analysis, and rate of return).

The Design of Field Joint for STS 51-L (Challenger) multimedia CD-ROM case study materials designed by a team of engineering and business educators<sup>15</sup> were a key component of the unit. According to the authors, the case study was developed with consideration of the technical, business, ethical, and managerial issues involved in the design of the solid rocket motor over a period of fifteen years.<sup>16</sup> The case study booklet included the following chapters:

1. Introduction
2. Importance of Decision Making To Engineers
3. Engineering Ethics: From Theories to Practice
4. Engineering Design Fundamentals
5. Design of Field Joint for STS 51-L: Launch or No-Launch Decision
6. Multimedia Version of the Case Study

The engineering design chapter included several topics related to engineering economy. There was a review of basic cost categories: materials, labor, quality and overhead. There was a brief discussion of the importance of cost estimating and how the company assesses the potential financial benefits of various projects. The project management section included a discussion of scheduling, including Gantt charts, CPM and PERT. The risk analysis section included an introduction to Fault Tree Analysis (FTA) and Failure Modes and Effects Analysis (FMEA).

I supplemented the multimedia case study materials with discussions of project management principles, organizational charts, teamwork principles, congressional investigations, and the social and political climate in the 80s. Books by the Project Management Institute<sup>17</sup>, Scholtes<sup>18</sup>,

Pinkus. et al.<sup>19</sup>, and Vaughan<sup>20</sup>, as well as various engineering ethics Web sites, were rich sources of information.

The students were required to make two PowerPoint presentations. Using the structured controversy model, I assigned a certain position to each team. As a result, some students were caught defending a position they did not believe in. This proved to be very difficult for some students; however others felt the exercise was very beneficial. After the student teams had delivered their presentations, I loaded the PowerPoint files into the WebCT course shell I had developed for EGR 312 that term so that all students could review all presentations in preparation for the final exam. After all the presentations and subsequent discussions, students were required to write a brief statement indicating their original position, which team was most convincing, and whether their own beliefs were changed by the opposing team.

### Assessment of the Project Management Module

A variety of methods were used to evaluate the effectiveness of the project management component of EGR 312. The authors of the "Design of Field Joint for STS 51-L: Launch or No Launch Decision" case study provided two evaluation instruments. The first instrument (Case Study Evaluation I) pertained to the content of the case study; the survey consisted of 24 polarized pairs of descriptors and used a five-value continuum. The students' responses were evaluated on a scale of 1 through 5, with 5 indicating highest agreement. The survey results are reported in Table 1, using the four constructs described by the authors of the case study<sup>21</sup>.

Table 1: Case Study Evaluation I

Construct	Items	Mean Rating**	Standard Deviation
Useful	Meaningful, Relevant, Useful, Important	4.00	.08
Clear	Clear, Easy to comprehend, Straightforward, Well organized	3.63	.51
Attractive	Interesting, Exciting, Lively	3.69	.27
Challenging	Successful at bringing real-life problems to the session, Helpful in transferring theory to practice, Helpful in providing a sense of accomplishment, Helpful in learning difficult concepts, Extraordinary, Challenging	3.47	.47

\*\* Evaluated on a scale of 1 through 5, with 5 indicating highest agreement

The second instrument (Case Study Evaluation II) pertained to students' self-assessed learning outcomes; it consisted of 18 learning statements and used a 5-point Likert scale. Table 2 lists the mean score for each outcome.

Table 2: Case Study Evaluation II

Learning Outcome	Mean Rating*
Make connection between engineering concepts and case study	4.25
Improve ability to identify design and ethical issues	4.17
Improve ability to identify various alternatives	4.17
Think for myself about design and ethical issues	4.08
Integrate design and ethical issues	4.00
Discuss design and ethical topics outside of class	4.00
Interrelate important topics and ideas	3.92
Evaluate design and ethical alternatives	3.83
Value colleagues' points of view	3.83
Learn from other colleagues	3.83
Identify central design and ethical issues	3.82
Gain confidence in expressing my ideas	3.75
Conduct additional reading on design and ethical topics	3.75
Solve problems based on engineering theories	3.75
Improve understanding of basic design concepts	3.58
Learn new concepts in engineering	3.58
Improve oral communication skills	3.58
Improve written communication skills	3.58

\* Strongly Agree=5, Agree=4, Neither Agree or Disagree=3 Disagree=2, Strongly Disagree=1

Identification and integration of design and ethical issues were rated very highly. Improvement in written and oral communication skills received low ratings. The relatively low ratings for the development of basic design concepts and new engineering concepts may be due to the fact that most of the students were juniors who had already successfully completed courses in the fundamental of engineering, engineering design, and professional practices (including ethics). Engineering economy is a junior level course. Several students were taking this course at same time they are enrolled in the technical communication course that also emphasizes written and oral communication skills. Teamwork, written and oral presentations were covered in freshman design class. The topic of ethics was first introduced in a freshman-level professional practices class. There was slight resistance to the inclusion of this case study in an engineering economy class. One student commented that ethics should be covered in an ethics class, and that communication skills should be covered in a technical communication class, etc., and that there was no need for repetition. To quote another student, "We used this case study in our economics class. I feel that it was not suited for this class. It should be used in our ethics class instead. As for the case study itself, no particular weaknesses. Overall it was a good case study." Several students expressed concern with the timing of the project management unit. One student commented, "I felt unsettling that we left economics for so long and then went back to it." These comments show how students tend to compartmentalize their studies in separate bodies of knowledge. Nevertheless, the School of Engineering curriculum design includes a commitment to curricular "threads" in communication, design, and ethics. The inclusion of this case study at the junior level supports the thread concept. The full set of results for the two case study

instruments have been sent to the authors of the case study for statistical analysis of the test constructs.

The students took two quizzes pertaining to the subject matter content of the project management unit. The students did very well on the teamwork material and technical issues presented in the case study booklet. On average, their performance on ethical principles was not as good, in spite of the fact that many students had received ethics instruction two years earlier in their freshman-level professional practices class. The final assessment measure involved student ratings of team performance. Each student was required to complete a modified version of the Self/Peer Team Assessment Form that was developed by members of the NSF-sponsored Synthesis Coalition<sup>22</sup>. Students were told in advance that they would be completing self/peer assessment forms and the information in these forms would be used to adjust the students' final course grade.

### **The Ford/Firestone Controversy**

Safety issues regarding Ford Explorers and Firestone tires provide ample data for another case study that can relate engineering economics to a contemporary issue. The events leading up to the Challenger disaster have been described in detail by a number of authors. Volumes of data have been analyzed. Investigators have determined the likely cause of the explosion. In contrast, there are a lot of unknowns in the Ford/Firestone controversy. There is much evidence that the rate of failure for certain models of Firestone tires is higher than for other brands of tires. Ford claims that the tire design and manufacturing errors are the cause of the failure. Firestone states that the higher than average rollover rates for Ford Explorers as compared with other SUV's is a contributing factor. There are concerns about Ford's decision to replace certain models of tires in the Saudi Arabia while similar models were being used as standard equipment on US-made SUV's.<sup>23</sup> Congressional investigators have raised questions about potentially improper testing procedures and inadequate documentation. Firestone engineers asserted that tire pressure recommendations should be higher, but Ford chose to keep the lower values. Both Ford and Firestone have pointed the finger at consumer use and improper repairs. Studies indicated that much of the problem could be attributed to poor quality monitoring at the 59-year-old Illinois facility. One source estimated that closing the plant would result in a cost savings of more than \$100 million year.<sup>24</sup> Finally, the controversy raises questions about the customer-supplier relationship; should suppliers meet international standards such as ISO/TS 16949 or is QS-9000 sufficient?

The Ford Explorer/Firestone controversy has striking similarities to the NASA/Morton-Thiakol relationship. Issues surrounding the customer supplier relationship, data collection and data analysis, asking the right questions, ethical decision making, and pressure to maintain schedules are common to both cases. Ford's engineers were constrained by early design decisions to use a narrow truck frame and a front-end suspension that had been developed years earlier.<sup>25</sup> (Greenwald, p. 28) In the late 80s Ford engineers reviewed four possible ways to improving the stability of the SUV: lower the engine, widen the chassis, stiffen the springs, or lower the tire pressure. As a result the 26psi became the recommended tire pressure.<sup>25</sup> However, the lower tire pressure resulted in lower gas mileage, so Ford directed Firestone to make the tires lighter.<sup>26</sup> This design decision opportunity and the subsequent economic consequences are reminiscent of

the Leon Ray memo discussed in the STS 51-L Case Study. Management decision making is a common theme in both cases. At least one expert asserts that the Challenger case does not show evidence of "intentional managerial wrongdoing" <sup>20</sup> p.xiv, whereas others assert that the case involves serious ethical issues for engineers. <sup>19</sup> The "jury is still out", so to speak, on the Ford/Firestone controversy. Various sources support differing views on management's performance during the tire recall investigation. <sup>27, 28, 29, 30</sup> Indeed, the principals of the investigation themselves offer their own explanations through their Web sites. <sup>31, 32</sup>

However, there is one important difference between the two cases. In contrast to the Challenger case, the Ford/Firestone situation is a work in progress. It is unlikely that students have studied this case in other courses or formed lasting opinions on the causes of the problem. I plan to introduce a case study on the Ford/Firestone controversy the next time I teach engineering economy. The use of the Ford/Firestone material will allow me to compare student reaction to a case study with a known outcome (Challenger) with a case study whose outcome is still developing.

### **Conclusion**

Although including real-world case study materials in an engineering economy course has its advantages, there are disadvantages as well. Preparing and delivering course materials related to engineering ethics, project management skills, teamwork skills, and engineering design issues for this open-ended multidisciplinary teamwork instructional unit consumed more time than was anticipated. The sheer volume of information about the Challenger incident and the Ford/Firestone controversy makes the task of keeping up with contemporary events extremely difficult. As with most open-ended assignments, additional instructor time is needed to deal with student questions related to clarification of *exactly what is expected*. Discussions with disgruntled students concerning perceived inequities in team performance are also a time-sink. Nevertheless, the instructional unit that was designed added richness to the engineering economy course. The unit also yields data by which the school can assess a number of the EC2000 a-k learning outcomes.

Finally, successful application of engineering economy principles depends on the proper formulation of alternatives. Of necessity, alternatives as presented in typical engineering economy texts are simplistic in nature. The presentation of real-world case studies such as Challenger and Ford/Firestone as part of an engineering economy course gives new meaning to concepts such as cost-benefit analysis and cost estimation. Real-world contemporary cases allow students to see the impact of ill-advised design decisions and manufacturing imperfections on the economic health of the company. Students can picture themselves being required to make difficult choices in a complex engineering environment and having to live with the consequences of their decisions. Although students sometimes express frustration with open-ended team-based assignments, the potential of an extremely positive learning opportunity outweighs the negatives.

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31. See [www.firestone.com](http://www.firestone.com)
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