Classroom Experiences with the Challenger Case Study: Design of Field Joint for STS 51-L

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Abstract

ABET EC 2000 criterion 3 (letter f) Program Outcomes and Assessment states, "engineering programs must demonstrate that their graduates have an understanding of professional and ethical responsibility [Engineering Accreditation Commission, 4]." In accordance with this criterion, Mercer University School of Engineering (MUSE) students are introduced to engineering ethics during the freshmen year in a required course entitled Professional Practices. One tool used to promote discussions and critical thinking associated with ethical issues was the case study entitled "Design of Field Joint for STS: 51-L Launch or Do not Launch Decision" by Raju and Sankar. This case study is centered around the January 1986 Challenger shuttle disaster and the decisions made by NASA and associated consulting firms.

The freshmen class was divided into four teams with each team given a specific assignment as follows: Team A. Defend the launching of the STS 51-L: Team B. Present a case that does not support launching the STS 51-L: Team C. Evaluate case study data from the non biased viewpoint of an engineering consultant; and Team D. Assume the role of NASA management and critically evaluate the data presented by teams A-C and make a decision regarding the launch of the STS 51-L. At the conclusion of the activity, students were asked to complete a survey that was supplied on the CD-ROM associated with the case study materials. This paper details the results from that student survey.

Introduction

As the needs of the workforce evolve, the visage of the successful engineering graduate will shift to include not only traditional technical training, but will also require the graduate to possess a set of "orthogonal skills" [American Society for Engineering Education, 1; Committee on Science, Engineering, and Public Policy, 2]. To be equipped for the workforce, engineering graduates must now be able to synthesize and communicate information to both technical and non-technical audiences, perform on interdisciplinary teams, and possess attributes indicating professional and ethical standards [NRC-NSF, 15; NSF, 16; Smerdon, 23]. It was anticipated in the 1996 NRC Analysis to Action report that "students educated with a narrow disciplinary focus and in solitary learning styles can have difficulties adjusting to…" the changing workforce environment. Therefore, many engineering schools are incorporating "softer skills" into their curricula and are trying a variety of pedagogical approaches such as case studies.

The Harvard business school initiated the use of case studies in the classroom in the early 1900s. Since that time, the case study has become a standard in graduate economics courses and during the past several decades, case studies have become more prominent in science and engineering classrooms. Case studies introduce the student to actual engineering in practice. A well-documented case provides students with both breadth and depth of the scenario; they are then required to devise a solution to the posed problem. The use of case studies is an effective

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way to encourage student teams to both identify and solve the posed problem [Kulonda, 12]. Furthermore, case studies have proven to motivate students by showing them the relevance of coursework [Fuchs, 6], and to facilitate an understanding of the importance of economics, safety, cost, and social issues [Raju and Sankar, 21].

MUSE freshmen students are required to take a Professional Practices course (EGR 108) that emphasizes technical writing, history and ethics. Student outcomes for EGR 108 are listed below:

(1) To demonstrate the ability to read critically for content, implications, and communication strategies by keeping a critical notebook and writing short essays
(2) To develop an understanding of the history of engineering and its impact upon society by writing several short essays and a comprehensive research paper
(3) To develop and apply methods for solving moral and ethical engineering problems by analyzing and presenting several case studies
(4) To communicate successfully in formal and informal, individual and group presentations.

The EGR 108 course content is divided into two distinct modules. Module 1 introduces students to the engineering innovations that have caused paradigm shifts in society. Three books are read: *Five Equations that Changed the World [*Guillen, 8*], Beyond Engineering [*Pool, 19], and *Science and Technology Today [*MacKenzie, 13*]*, which document the social, political, and global forces that shape engineering and scientific developments. Students also select a specific engineering innovation, research its development, assess its impact on society, and present their findings in writing and orally. This module is designed to foster critical reading, thinking, writing, and speaking skills. Students are introduced to a variety of active reading strategies and to a variety of rhetorical devices for both written and oral communication. Module 2 introduces the student to personal and professional ethics that govern the actions of engineers. Using a multimedia case study of the Challenger disaster [Raju and Sankar, 20], as well as case studies from the book *Engineering Ethics [*Fleddermann, 5*]*, students identify ethical problems/issues and develop a means for solving them. Engineering code of ethics serves as a framework for discussing issues of professional conduct. Students focus on what it means to be a responsible engineer and how the actions of engineers can affect the well being of others. Working in small groups, students develop and resolve an ethical case study to present to the class.

This paper describes our experiences associated with incorporating the Challenger Case Study developed by Raju and Sankar, 2000, in the EGR 108 classroom.

Methods

The EGR 108 instructor placed freshmen engineering students in teams of three to six. A total of four teams were assembled. Each group was given the following responsibilities (the following assignment statement is an excerpt from Raju and Sankar, 20):

Group 1. Defend launching STS 51-L
Group 2. Defend not launching STS 51-L
Group 3. Assume the role of a consulting team critically evaluating the data provided in the case study with respect to the following and provide recommendations to management:

(a) Engineering design considerations – consider the aspects of risk management, evaluation of test data, and blow-by considerations.

(b) Statistical data analysis – analyze the data provided using statistical methods and interpret the data accordingly.

(c) Ethical considerations – consider the aspect of managing risk, maintaining competence, and behaving responsibly using utilitarianism, Kantianism, and ethical codes.

Group 4. Assume the role of NASA and MTI management and make a final decision on the launch of STS 51-L.

Each team presented their conclusions orally with their presentations enhanced by appropriate PowerPoint slides. Students were evaluated on the quality of content and style of the oral presentations. Student teams were also given the opportunity to evaluate the performance of each team member. Peer evaluation was accomplished using a form adapted from a self/peer assessment instrument developed by members of the Synthesis Coalition and reported in Van Duzer & McMartin [24]. This case study exercise was completed in approximately 3.5 weeks.

At the students' request, there were two significant deviations made to the case study assignment. The assignment, as written in the text, suggests that student teams should present orally in order (i.e., Group 1 going first and Group 4 presenting last). The students in Groups 1 and 2 realized the benefit of giving their presentation just prior to the presentation by Group 4 ("Management Team"), as the final comments made in the discussion would potentially be more memorable, thus more influential, on the launch decision made by Group 4. To this end, students were allowed five minutes in the class period preceding their formal presentations to verbally state their case as to why their group should be the last discussion prior to the management team making their final decision. A second deviation from the instructions provided in the case study allowed Groups 1 and 2 to give a five-minute rebuttal to the opposing group's statements. Both rebuttal statements were issued just prior to the management team decision and presentation.

Findings

At the conclusion of the activity, students were asked to complete an evaluation form that was supplied on the CD-ROM associated with the case study materials. The questionnaire consisted of 24 bipolar descriptors used to rank the student experience with the case study. The student circled the number on the scale from 1 to 5 that most closely corresponded to their attitude toward that element of the case study. A response of 1 represented the most favorable reply with a response of 3 being the midpoint. This same process was completed for all 24 Likert-style items on the evaluation form. A total of 16 students completed the survey (4 female and 12 male students). Table 1 shows the results from the student survey. Note that the average response for each survey item was less than 2.5, indicating that the case study provided a positive learning experience for the students.

The survey measured four different constructs (interesting, important, instructionally helpful and relevant) relating to the students' attitudes toward the case study. Literature suggested that specific survey items could be combined together to represent a particular construct [Hingorani et al., 9; Goodhue and Thompson, 7; Kramer et al., 11]. Mapping of the constructs with the 24 survey items is shown in Table 2. Notice that each construct was correlated to multiple items on the survey to ensure test reliability and validity. Reliability ensures that the test yields consistent measures over time and that the multiple items chosen to represent/measure the same construct will correlate with each other. Validity simply means that the scale used on the survey actually measures what it is intended to measure.

Cronbach's coefficient alpha is a measure of the internal consistency of the subscales, thus quantifying the use of survey item subsets to measure results associated with a single dimensional construct [Cronbach, 3]. A Cronbach alpha of 0.70 to 0.80 indicates that the items represent the construct appropriately [Nunnally, 17]. Alpha's that are less than 0.5 indicate that internal consistency reliability is very low [Nunnally, 18]. The Cronbach's alpha value for the "interesting and exciting" construct was 0.73, indicating that the items in table 2 associated with that construct (exciting, interesting, lively, colorful, emotional, personal, warm, extraordinary) did indeed belong together. The "Important and Valuable" construct was created by averaging the responses from five survey items as shown in Table 2. The Cronbach alpha value for this construct was 0.53 indicating that the grouping, as shown in Table 2, was shown to have a moderate degree of internal consistency. Similarly for the constructs "Instructionally Helpful" and "Relevant and Useful" the Cronbach alpha values were determined as 0.51 and 0.66, respectively.

Table 1. Design of Field Joint STS 51-L Case Study Evaluation.

Positive Descriptor	Average Score* ± Standard Deviation	Negative Descriptor
1. Successful at Bringing Real-Life Problems to the Session	1.38 ± 0.89	Unsuccessful at Bringing Real-Life Problems to the Session
2. Challenging	2.13 ± 0.89	Not Challenging
3. Clear	1.69 ± 0.87	Unclear
4. Close	2.31 ± 0.87	Distant
5. Lively	1.56 ± 0.63	Dull
6. Easy to Comprehend	2.13 ± 0.89	Difficult to Comprehend
7. Exciting	1.88 ± 0.62	Boring
8. Helpful in Learning Difficult Concepts	2.50 ± 0.82	Not Helpful in Learning Difficult Concepts
9. Humanizing	1.81 ± 0.83	Dehumanizing
10. Important	1.81 ± 0.98	Unimportant
11. Interesting	1.25 ± 0.45	Uninteresting
12. Colorful	2.06 ± 0.99	Ordinary
13. Meaningful	1.75 ± 0.86	Meaningless
14. Emotional	2.50 ± 1.09	Unemotional
15. Relevant	1.69 ± 0.60	Irrelevant
16. Straightforward	1.50 ± 0.52	Obscure
17. Personal	2.44 ± 0.89	Impersonal
18. Helpful in Transferring Theory to Practice	1.88 ± 0.72	Not Helpful in Transferring Theory to Practice
19. Useful	1.56 ± 0.51	Useless
20. Warm	2.38 ± 0.81	Cold
21. Well Organized	1.63 ± 0.62	Poorly Organized
22. Extraordinary	2.19 ± 0.83	Routine
23. Helpful in Providing a Sense of Accomplishment	2.00 ± 0.73	Not Helpful in Providing a Sense of Accomplishment
24. Sensitive	2.19 ± 0.83	Insensitive

- Each Student was asked to consider each set of bipolar descriptors and select 1 to 5 the value which corresponds closest to their attitude regarding the case study. A value of 1 represented the most favorable reply.

Table 2. Mapping of Constructs and Survey Items.

Constructs	Items
Interesting and Exciting	Exciting, Interesting, Lively, Colorful, Emotional, Personal, Warm, Extraordinary
Important and Valuable	Successful at bringing real-life problems to the session, Challenging, Helpful in learning difficult concepts, Helpful in transferring theory to practice, Helpful in providing a sense of accomplishment
Instructionally Helpful	Clear, Easy to comprehend, Straightforward, Well organized, Sensitive, Humanizing
Relevant and Useful	Useful, Important, Meaningful, Relevant, Close

Three of the calculated alpha coefficients are less than what is considered "good" for inner-correlation [Nunnally, 17]. As a result, factors that influence reliability were reviewed and are briefly summarized as follows [Jacobs and Chase, 10; Salvia and Ysseldyke, 22]:

1. test length – longer test typically being more reliable
2. time limits for test
3. homogeneity of group taking the test or survey – the more homogeneous the student sample, the lower the predicted alpha or reliability coefficient
4. difficulty of the survey or test items
5. administration and scoring procedures

We believe that the small, homogeneous student sample size that completed the survey influenced reliability coefficient results. Other researchers have used the same survey and obtain alpha coefficients greater than 0.7 [Kramer et al., 11], giving further credibility to the constructs tested in this study. Phase two of this work will incorporate results from a larger student population and it is anticipated that the constructs identified by the survey will prove to be reliable.

The means for the constructs associated with the survey are shown in Figure 1. The t-test was used to determine the student attitudes toward each construct. This was accomplished by comparing the mean of the measured construct to the score of 3 (a score of 3 was the midpoint value on the scale representing that the student neither agreed nor disagreed). The t-test showed that the means for all four constructs were significantly less than 3 when $p<0.001$. This result indicates that the students found the case study to be interesting and useful, important and valuable, instructionally helpful, and relevant and useful.

To obtain a qualitative indicator of the student view of the survey, the students were asked to write in paragraph/short answer form any other comments they felt relevant to their experience with the Design of Field Joint STS 51-L Case Study. Some of the student comments are displayed below:

- After the completion of this case study, I realized I had taken a giant step in becoming an engineer. I started to think more as an engineer.

- I believe that the Challenger Case study helped me further understand the responsibilities that an engineer has. Negligence on the engineer's part or a bad decision can have a tremendous impact on society as a whole and the company they work for. At the same time the case study helped me in my learning process.

- The Challenger case study was very helpful in that it taught me a sense of moral values in which I must apply in the workplace. It also showed me how morals must go before anything in life.

- The case study helped me to better understand the activities that took place involving the Challenger. The disagreements between those for and against the launch were very real and lively.

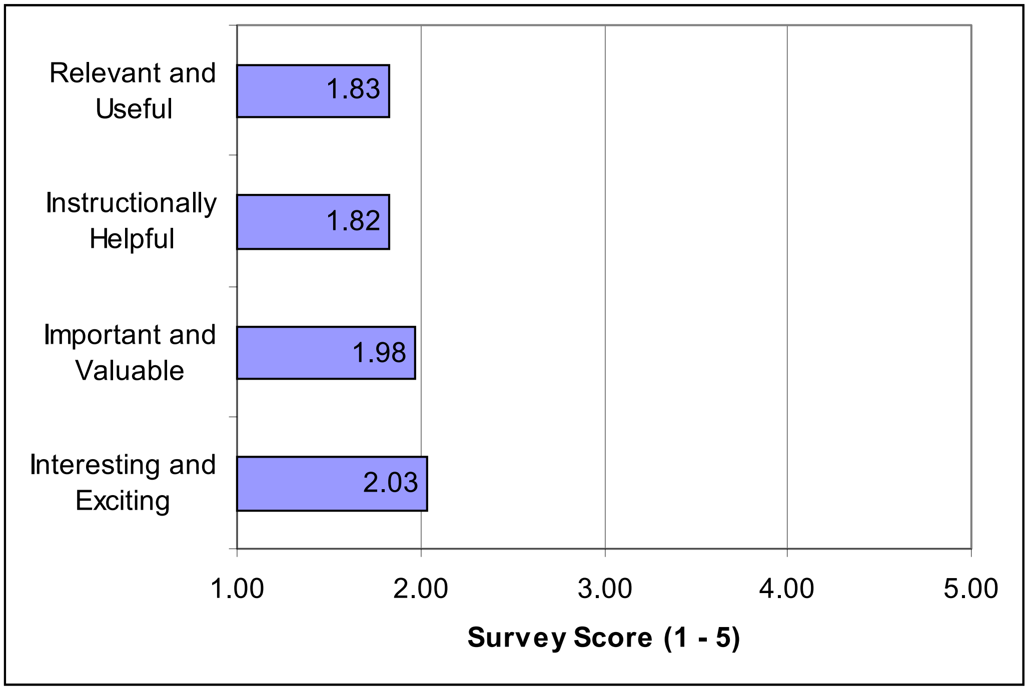

Figure 1. Means for Constructs in Challenger Case Study Survey

- Having only one book per group was difficult at times being able to read and study the material. The Challenger case study is good at showing engineering students that the right solution is not always the one used. In another revision of the book it would be better to provide more resources and a copy of the book on the CD.

- This case study taught me a lot about the Challenger explosion. Role playing helped me to understand both sides of the case.

- I really liked this exercise. It gave us an opportunity to see some of the difficult decisions engineers and management face. It was a good break away from reading a bunch of words, and allowed us to have some interaction with the text.

- The work done with the case study demonstrated the difficulty in weighing what is ethical against what is in the best interest, financially, of an organization.

- I marked that it was helpful and exciting. Learning and gathering the info was pretty dull at times, but once the debate started and we had to use the info we had learned, to try and persuade others to see it our way, things became more interesting. It gave an understanding of what the real engineers and managers most likely went through that night before the launch.

- I really liked learning about the true story behind the Challenger tragedy. It showed that even small factors may bring about such a catastrophe.

- This was an excellent project. I thoroughly enjoyed every aspect of it; especially the presentations. I, however, have only one quandary. The management team, it seemed, made their decision before presentation day. I thought they were supposed to listen to all the presentations, then make a decision.

- It made learning the technical difficulties of the Challenger easier by doing role-playing and re-enactment. It outlined good arguments on both sides of the launch decision. It was taught well.

- It was hard to put myself into the engineers point of view, especially after knowing the facts now that they could not know then. I did think it was very enlightening. But even now I don't know where I stand thinking, launch, or don't launch, but it definitely put this class into real life.

- As a whole, the case study was a good experience. It really helped me see that all issues are not "black and white," and that the Challenger decision was a difficult one. As wrong as it seems in light of what happened, had I been in a management position, I probably would have made the same decision--to go ahead with the launch.

Concluding Remarks

The Field Joint STS 51-L Case Study was used in a freshmen level engineering course entitled Professional Practices. The case study was used to introduce the students to real world situations requiring ethical decision-making. At the conclusion of the exercise, students completed an evaluation survey. Data collected from student surveys indicate that the case study provided the student with an overall positive experience. Student responses to all four constructs evaluated were significantly less than the midpoint value of 3 on the five point Likert scale employed on the survey. Each construct was tested by multiple survey items. Grouped items selected to represent an individual construct showed reasonable inner-correlation by Cronbach's alpha coefficient. Survey quantitative data indicated that the case study provided students an enjoyable and positive learning environment to study the engineering ethical decision making process and these data were corroborated by the qualitative student responses associated with their experience with the activity.

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