Implementation and Assessment of a Failure Case Study in a Multi-Discipline Freshman Introduction to Engineering Course

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Abstract

Twelve university partners are extending the use of case studies across multiple engineering disciplines. This paper focuses specifically on the implementation and assessment of a failure case study in a first year *Introduction to Engineering* course by the Department of Engineering Fundamentals at the University of Louisville.

Case studies tie together technical, ethical, and procedural aspects of engineering and require students to undertake higher order thinking in order to synthesize the relevant issues. Case studies require students to synthesize the facts and engineering principles they have learned. A major objective of the case studies is to expose students to some aspects of the modern practice of engineering, namely: teamwork, problem and data analysis, design creation, presentation and defense of a designed solution, and professional ethics. In the fabric of a first year course, where students do not have existing engineering principles to build upon, case studies help introduce the engineering profession, teamwork, critical thinking, and presentation of supporting materials.

A common case study used in engineering training is the examination of the failure of the skywalk at the Hyatt Regency Hotel in Kansas City. This failure is beneficial for incoming students because the technical reason for the failure is easily understandable and straightforward. However, the most challenging part of this particular case study is understanding how the deficient walkway supports were allowed to be constructed and installed. Most incoming students have little knowledge of the complex relationship of the design, fabrication, and construction steps in large projects such as the Hyatt Regency Hotel, some instruction in the roles and responsibilities of each entity is presented and discussed with the students before they begin digesting the information of the case.

In prior use of this case study in the *Introduction to Engineering* course, students were asked to read published papers reporting on this event, formulate an opinion on the party most responsible for the failure, and write a paper explaining and defending their opinion. These early efforts were somewhat successful, but lacked fully engaging the students in the necessary work of delving into the details, developing a full understanding of the problem, and logically reaching a defensible conclusion. To increase the engagement of the students, a group paper and a mock hearing before the Professional Engineering Board of Licensure was added to the case study activities. The mock hearing allowed the students to assume the roles of the involved entities (owner, fabricator, project engineer, etc.) and represent each of these entities at the hearing.

The students are surveyed after all case study activities are completed. The surveys collect information regarding how each of the elements of the case study impacted the students' interest in the engineering profession and their understanding in the engineering profession. This paper presents a discussion of the modified case study as well as student survey results.

1. Background

Lessons learned from engineering failures have substantially affected many engineering disciplines' practice. The history and development of engineering practice is, in large part, the story of failures and of the changes to standards and procedures made as the result of analyses of these failures. Common practice in engineering is to review projects, systems, and incidents to identify root causes for either success or failures and to share these findings with others. The continuous improvement with how engineering is practiced is a core feature of the engineering profession. Case studies of engineering activities (successes and failures) offer students a unique insight into the actual practice of engineering. In addition to technical issues, concepts such as professional and ethical responsibility may be highlighted by case studies. More background information and rationale for this project has been documented by Delatte, et al.[1]

Case studies have the potential to reach students who have difficulties relating to the engineering profession. One of the sources of problems commonly identified for women students is that they often don't have the background of helping their parents with hands on projects.[2] This issue might also apply to many students who grow up in urban environments, or without fathers. Overall, fewer and fewer engineering students are entering college with prior hands-on technical experience.

If case studies are introduced and taught properly, students will have something to use as a foundation for their theoretical knowledge, and to help build their engineering identity. This is particularly important for the students who don't have engineers in their family. When they tell their families about what they are learning at school, concrete examples provided by case studies are easier for the students to explain than abstract theories. This is particularly important in courses for freshmen, such as the *Introduction to Engineering* course discussed herein. This paper discusses one case study that has been used in the course and presents survey data from the 2009, 2010, and 2011 freshmen classes.

2. Introduction

All incoming students to the J.B. Speed School of Engineering are required to take the *Introduction to Engineering* course. The course goals are numerous including: introducing the new students to college campus life and resources, making the students aware of the different engineering disciplines, and introducing them to the engineering profession.

A failure case study is used in the *Introduction to Engineering* course as a way for the incoming students to experience and evaluate various aspects of the engineering profession. Many authors have pointed out the need for lessons learned from failure case studies in engineering education[3–7]. A major objective of the use of a failure case study in *Introduction to Engineering* is to expose students to some aspects of the modern practice of engineering. These aspects are teamwork, problem analysis, data analysis, presentation, defense of a solution, and professional ethics. The case study used in this course is structured to engage students in these aspects as well as critical thinking. The highly technical aspects of the case study requiring engineering training is avoided or explained in a way that students can understand.

The case study used in this study was the examination of the skywalk failure at the Hyatt Regency Hotel in Kansas City. This failure killed 114 people and injured many others. This case study has been used in engineering education, but it is not commonly used in freshman courses. This failure case is beneficial for incoming freshmen due to the straightforward and easily understood technical details of the collapse.[8–11] However, trying to determine and understand how the insufficient walkway supports were allowed to be constructed is a more complicated task. This complication comes from many freshmen have not experienced working in a large team environment, nor working on highly complicated problems. Since many of the incoming students have little knowledge of the complex relationship of design, fabrication, and construction steps in projects, it has been determined through past teachings of the course that instruction in the roles and responsibilities are needed. Each entity's (owner, designer, architect, fabricator, general contractor, etc.) involvement in the design, fabrication, and construction process needs to be explained to the students.

3. Implementation of the Hyatt Case Study

The case study has been broken into in-class activities, and homework assignments. The first in-class meeting is used to introduce the Hyatt Case Study to the students. The introduction includes some historical information about the incident as well as a brief video regarding the collapse. After this introduction, each class is broken into teams of 5 students. Each team member is assigned different material to read, and is expected to bring any pertinent information from their reading back to the team. The team members are also given questions related to their reading material that they are expected to have answered for their team. The readings are published papers reported in the literature covering the disaster.[8–11] The Hyatt Regency collapse case study has been discussed in other areas of engineering education by Newson and Delatte.[12]

In the second class session, every student was given a readiness quiz. The students were quizzed based on which materials they were to have read. This was to help ensure the students were prepared to share their findings with their team. The technical reason for the failure of the skywalks is discussed with the students in this second class. This discussion is to help the students understand why the skywalks failed and collapsed. This second class session also includes a discussion of the roles and responsibilities of each entity (owner, designer, architect, fabricator, general contractor, etc.) involved in the design and construction process. The student teams are then given time to discuss questions with their team members. Some of the questions we prompt them with are: "How did this occur?", and "Which party is most responsible for the collapse?" Each individual student is then responsible for writing a one to two page paper expression their opinion which who was the most responsible and who else shared responsibility of this failure.

Before the mock hearing occurs, each student team was assigned an entity to represent. These entities are: Engineer of Record, Project Engineer, Owner, General Contractor, Fabricator, Testing Agencies, and the Sub-Fabricator. The teams must develop a defense for who they represent. The team is expected to develop a defense document that has three main items:

1. Opening Statement: The defense strategy must be clearly stated, and the evidence that will be used to prove each entity's innocence must be reviewed.

2. Defense Witness List: The document must identify which other entities will be called in each defense. The questions to ask each witness, as well as their expected answers should be included.
3. Closing Summary Statement: The final portion of the document is a summary of how the testimony presented should show that the person represented is innocent or at most shares only partial responsibility for the disaster.

The last class session is a mock hearing before a Professional Engineering Board of Licensure. This mock hearing was added to enhance the case study. The mock hearing helps reinforce the concept that engineers hold positions of responsibility, and are expected to hold public safety, health and welfare in high regard during all aspects of their work. The mock trail also gives the students an opportunity to devise a defensible and logical opinion based on the case data. A secondary benefit of the mock hearing is to put the students in a position of public speaking. The speaking role of each team must rotate through all of the team members during the course of the mock hearing. A mock Professional Engineer Licensure Board (3 member panel made up of J.B. Speed School of Engineering professors and the Engineering Fundamentals teaching assistants) conducts the hearing and controls the proceedings. This hearing begins with a reading of the purpose of the hearing by the board. All students are expected to be prepared to represent their assigned entity. The case study concludes with general discussion between the students and professors regarding engineer's roles and responsibilities.

4. Case Study Survey and Results

The students in the *Introduction to Engineering* course were given a survey regarding the use of the Hyatt Case Study. This survey was conducted at least a week after the case study ended. The ten-question survey is broken into two parts, five questions related to interest and five questions related to understanding. These ten questions are:

1. How well did the case study Classroom Lectures contribute to your interest in the engineering profession?
2. How well did the case study Group Activities contribute to your interest in the engineering profession?
3. How well did the case study Independent Research contribute to your interest in the engineering profession?
4. How well did the case study Projects contribute to your interest in the engineering profession?
5. How well did the case study Readings and Supplements to the Lectures contribute to your interest in the engineering profession?
6. How well did the case study Classroom Lectures contribute to your understanding in the engineering profession?
7. How well did the case study Group Activities contribute to your understanding in the engineering profession?
8. How well did the case study Independent Research contribute to your understanding in the engineering profession?
9. How well did the case study Projects contribute to your understanding in the engineering profession?
10. How well did the case study Readings and Supplements to the Lectures contribute to your understanding in the engineering profession?

The survey uses a self-reported Likert scale with valid responses being: 5-Very High, 4-High, 3-Moderate, 2-Low, 1-Very Low. With Figure 1 (raw data in Table 1 in Appendix A) and Figure 2 (raw data in Table 2 in Appendix A) showing the average Likert scores based on gender (Male vs Female) and ethnicity (White vs Under-Represented Minorities (URM)) for the 2009 freshmen class.

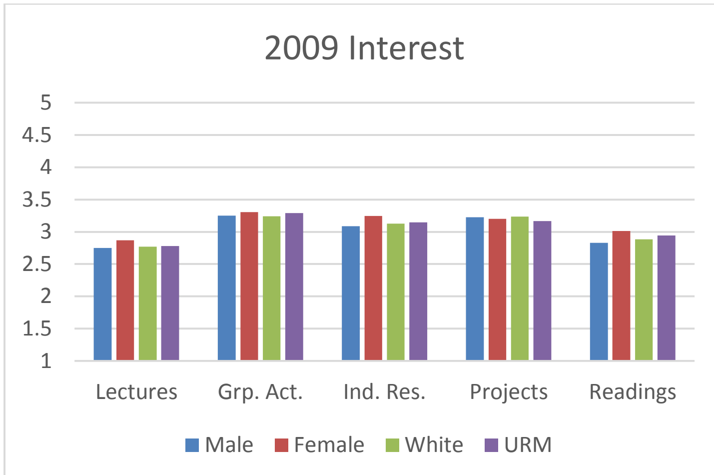

Figure 1: 2009 Self-Reported Interest

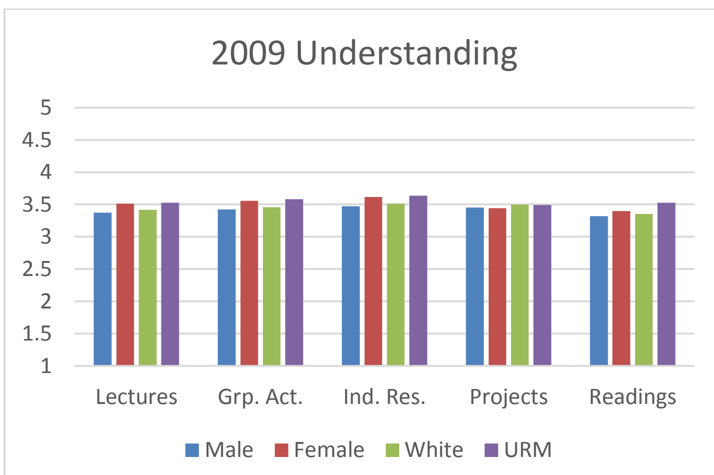

Figure 2: 2009 Self-Reported Understanding

Average statistics above three indicate that students benefitted from the case study activity by increasing the students self-reported interest and understanding. As Figure 1 shows, it is deduced that case study activities benefit female students positively versus their male cohorts, except possibly in the group projects. Also from Figure 1, it is shown that the case study activities (Group Activities and Readings) positively benefit URMs versus their white cohorts. As Figure 2 shows, case study activities positively impacted female students in their self-reported understanding of the engineering profession. Figure 2 shows that URMs benefited in their self-reported understanding of the profession as well, with projects being the only category equal to their white cohorts.

With Figure 3 (raw data in Table 3 in Appendix A) and Figure 4 (raw data in Table 4 in Appendix A) showing the average Likert scores (5-Very High, 4-High, 3-Moderate, 2-Low, 1-Very Low) based on gender (Male vs Female) and ethnicity (White vs Under-Represented Minorities (URM)) for the 2010 freshmen class.

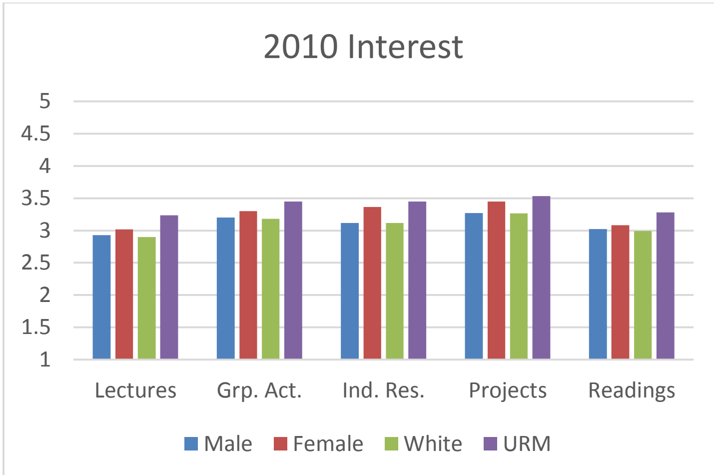

Figure 3: 2010 Self-Reported Interest

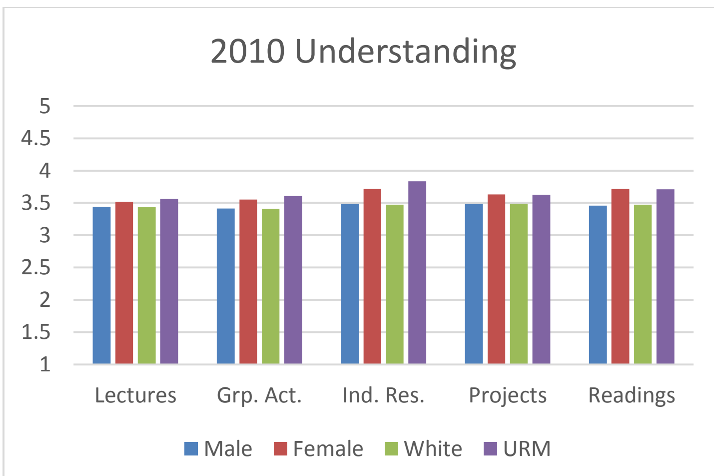

Figure 4: 2010 Self-Reported Understanding

Average statistics above three indicate that students benefitted from the case study activity by increasing the students self-reported interest and understanding. As Figure 3 shows, all of the case study activities benefit female students positively and positively versus their male cohorts. Figure 3 also shows that the case study activities positively benefit URMs versus their white cohorts. As Figure 4 shows, case study activities positively impacted female students in their self-reported understanding of the engineering profession. Figure 4 shows that URMs benefited in their self-reported understanding of the profession as well.

Figure 5 (raw data in Table 5Table 1 in Appendix A) and Figure 6 (raw data in Table 6 in Appendix A) showing the average Likert scores (5-Very High, 4-High, 3-Moderate, 2-Low, 1-Very Low) based on gender (Male vs Female) and ethnicity (White vs Under-Represented Minorities (URM)) for the 2011 freshmen class.

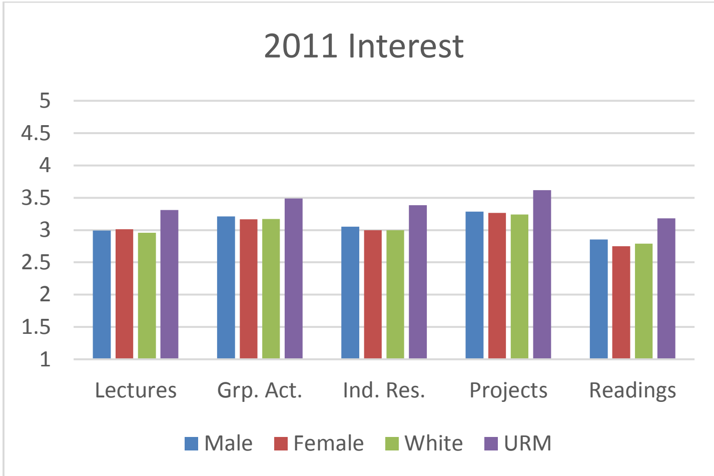

Figure 5: 2011 Self-Reported Interest

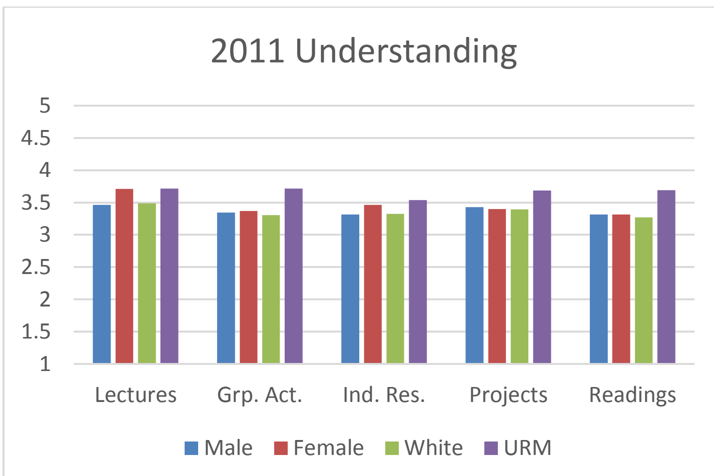

Figure 6: 2011 Self-Reported Understanding

Average statistics above three indicate that students benefitted from the case study activity by increasing the students self-reported interest and understanding. Figure 5 shows, the case study activities with the exception of the reading assignments benefit female students positively. The positive benefits for the female students is not really greater than their male cohorts. Figure 5 shows that the case study activities positively benefit URMs versus their white cohorts. Case study activities, with the exception of group projects, positively impacted female students in their self-reported understanding of the engineering profession according to Figure 6. It is also shown in Figure 6 that URMs benefited in their self-reported understanding of the profession.

5. Conclusions

The summary statistics (averages>3) indicate that students benefitted from the case study activities in their freshman *Introduction to Engineering* course by increasing the students' interest and understanding of the engineering profession. By positively increasing the interest and understanding of the engineering profession, two goals of the course should be met. These goals are: 1. Broadening student understanding of the impact of engineering solutions in global and social contexts; and 2. Increasing students' ability to apply knowledge of engineering to real life situations.

Based on the information presented, case studies in a freshmen course should require students to synthesize the facts and engineering principles they have learned, and combine them with their broader education in the arts, humanities, and sciences. Case studies also have the potential to further reach female and URM students that have difficulties relating to the engineering profession.

6. Acknowledgements

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Appendix A

Table 1: 2009 Self-Reported Interest Raw Data

Category	Count	% of total	Lectures	Grp. Act.	Ind. Res.	Projects	Readings
Male	283	80.17%	2.744	2.744	3.271	3.094	3.229
Female	70	19.83%	2.899	2.899	3.174	3.261	3.232
White	298	84.42%	2.770	2.770	3.240	3.128	3.236
URM	55	15.58%	2.782	2.782	3.291	3.145	3.164
All	353	100.00%	2.772	2.772	3.248	3.131	3.225

Table 2: 2009 Self-Reported Understanding Raw Data

Category	Count	% of total	Lectures	Grp. Act.	Ind. Res.	Projects	Readings
Male	283	80.17%	2.839	3.392	3.440	3.485	3.451
Female	70	19.83%	3.116	3.586	3.586	3.671	3.614
White	298	84.42%	2.885	3.419	3.456	3.510	3.497
URM	55	15.58%	2.945	3.527	3.582	3.636	3.491
All	353	100.00%	2.895	3.436	3.476	3.530	3.496

Table 3: 2010 Self-Reported Interest Raw Data

Category	Count	% of total	Lectures	Grp. Act.	Ind. Res.	Projects	Readings
Male	284	82.56%	2.929	3.199	3.118	3.270	3.021
Female	60	17.44%	3.017	3.300	3.367	3.450	3.083
White	296	86.05%	2.898	3.180	3.116	3.264	2.993
URM	48	13.95%	3.234	3.447	3.447	3.532	3.283
All	344	100.00%	2.944	3.216	3.162	3.301	3.032

Table 4: 2010 Self-Reported Understanding Raw Data

Category	Count	% of total	Lectures	Grp. Act.	Ind. Res.	Projects	Readings
Male	284	82.56%	3.438	3.413	3.482	3.481	3.459
Female	60	17.44%	3.517	3.550	3.717	3.633	3.717
White	296	86.05%	3.434	3.410	3.473	3.488	3.471
URM	48	13.95%	3.563	3.604	3.833	3.625	3.708
All	344	100.00%	3.452	3.437	3.523	3.507	3.504

Table 5: 2011 Self-Reported Interest Raw Data

Category	Count	% of total	Lectures	Grp. Act.	Ind. Res.	Projects	Readings
Male	296	80.22%	2.993	3.212	3.052	3.285	2.853
Female	73	19.78%	3.014	3.167	3.000	3.264	2.750
White	330	89.43%	2.960	3.169	3.000	3.241	2.791
URM	39	10.57%	3.308	3.487	3.385	3.615	3.179
All	369	100.00%	2.997	3.203	3.041	3.281	2.832

Table 6: 2011 Self-Reported Understanding Raw Data

Category	Count	% of total	Lectures	Grp. Act.	Ind. Res.	Projects	Readings
Male	296	80.22%	3.463	3.344	3.316	3.429	3.315
Female	73	19.78%	3.712	3.370	3.465	3.397	3.315
White	330	89.43%	3.488	3.305	3.322	3.392	3.270
URM	39	10.57%	3.718	3.718	3.538	3.684	3.692
All	369	100.00%	3.512	3.349	3.345	3.423	3.315