Introducing Students to Engineering Using a Case Study Approach

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I. Introduction

Improving student retention in engineering programs is an on-going and important goal. Some reasons given for poor retention of engineering freshman are lack of contact with engineering faculty during freshman courses, and a lack of understanding on the part of students of what they will do as engineers when they graduate[3]. Case studies are one method that has been suggested as a means to enhance learning, because, for instance, they illustrate the real life complexities of course content and provide a realistic setting to apply course material[1,2,4]. In engineering, cases have been suggested as an illustration of the multi-disciplinary nature of engineering projects[1]. For these reasons, a case study presentation involving a multi-disciplinary group of engineers and engineering faculty may have a positive impact on freshman engineering student retention.

To this end, a case study was developed to give students an idea of what engineers' tasks would be in the design of a large, complex system that is currently under development- the Intelligent Transportation System. The case was designed to be used near the beginning of a freshman level introductory engineering course. The case had the following objectives:

1. To introduce new engineering students to the discipline of engineering by illustrating the roles of various types of engineering in a large, current engineering project that has the potential to greatly impact aspects of society - the Intelligent Transportation System (ITS).

2. To introduce these students to the idea that engineering projects are multi-disciplinary in nature.

3. To introduce the students to a fundamental way of engineering thinking – the decomposition of problems and systems into smaller, more manageable parts.

4. To introduce the concepts of system reliability and redundancy.

5. To expose freshman students to engineering faculty.

II. The Case Study - “What is it that Engineers **Do**, Anyway?”

The case consists of three parts, and is designed to be taught by a panel of 3-5 guest engineers (faculty members or practicing engineers) from different engineering disciplines, along with the course instructor. During the first part of the case, students are presented with a short description of the Intelligent Transportation System (see Figure 1), and work in groups of 3 to 5 students to identify systems and subsystems of the ITS. Students are asked to list at least five parts of the ITS on large (easel-sized) pieces of paper. The concepts of system, sub-system, and components are then introduced using a simple diagram of the ITS system (Figure 2). One student from each group is asked to comment on 2 or 3 items from their list. As the discussion progresses, the course instructor draws and describes a block diagram of the ITS system, with its sub-systems and components based on items from the students lists.

In the second part of the case, the groups of students decide how engineers from different disciplines could contribute to the design of the system, after reading short descriptions of the roles of different kinds of engineers. There should be one description for each guest engineer present, corresponding to his or her specialty (see Figure 3 for an example). Students are asked to assign at least 2 jobs in the design and implementation of the ITS to each engineer. Students describe their list to the class, and each guest engineer discusses whether or not the assigned roles are appropriate.

Part 1: The Intelligent Transportation System

In today's society, traffic accidents and congestion take a heavy toll. Many highway accidents are caused by human error, such as failing to yield the right of way, improper passing, or running stop lights. Additionally, there is heavy traffic congestion in many urban areas, and current patterns of suburban growth and job movement to suburban areas will only lead to more and more traffic problems, both in transit from suburb to city and suburb to suburb travel. To address these problem, a multi-million-dollar research initiative--the Intelligent Transportation System--is being undertaken by corporations, universities, and federal and state agencies (e.g., the Federal Department of Transportation).

One part of this system, the Automated Highway System (AHS), involves automatically controlled cars, specially designed highways, management of traffic flow, automatic alerting of traffic congestion, and in-car computerized navigation systems. For example, the number of cars allowed on any section of highway--and their speed--will be automatically controlled by a central traffic control center, similar to the way planes are controlled by air traffic control centers. One method for automatically managing traffic flow is the "platoon" concept. In certain areas of the highway, vehicles will be grouped into a multiple car platoon, automatically traveling at high speeds close together. Another idea is to construct special lanes on the highway for use by cars whose steering, speed, and braking systems are automatically controlled to avoid accidents with other cars. Researchers of this system believe that the AHS will reduce accidents due to driver error and increase the capacity of the highways by allowing more cars to travel at higher speeds, thus reducing traffic congestion.

Figure 1: Reading for Part 1 of the case.

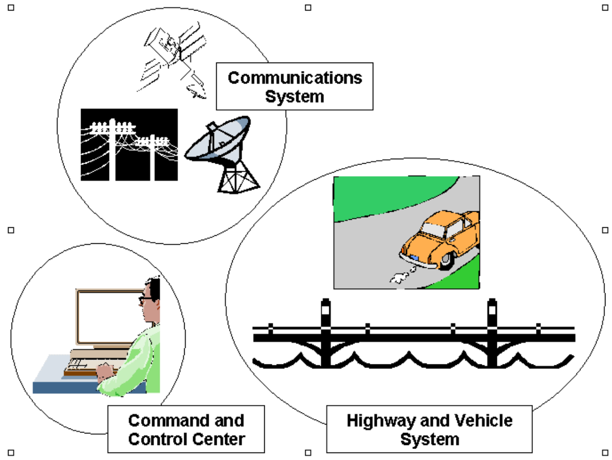

Figure 2: Discussion Diagram.

Part 2: Engineers and Their Roles

Alex is an electrical engineer specializing in communications and display systems. Specifically, his work involves the design and implementation of systems that can display information to users and allow communications between humans, computers and humans, and computers and computers. These two areas do not encompass the entire spectrum of electrical engineering. The governing body of electrical engineering is the Institute of Electrical and Electronics Engineers, Inc. This group includes representatives of all majors areas of EE, from more applied physics areas such as lasers and photonics (using light instead of electricity to communicate) to traditional areas like the design of electrical circuits, control systems, and the communication of information. Electrical engineering also includes the development of materials -- for instance, compounds that are similar to glass or sand that include the element silicon and can conduct electricity -- that can be used for the development of advanced circuits and computer components for the next generation of information transfer systems. It is important to understand that electrical engineering should be distinguished from computer science: Computer scientists develop complex computer systems which use building blocks -- such as integrated circuit chips -- developed by electrical engineers. Traditionally, electrical engineers have been responsible for the development of an extensive set of products, such as radio equipment, CD players, control systems (e.g., automated feedback through a circuit to control the speed of an automobile), circuits for electrical products, antennas, radar systems, electrical power distribution systems for homes (e.g., power plants, power lines, and transformers), and materials development (e.g., silicon based semiconductors).

Figure 3: Example Engineering Discipline Description.

Finally, students are asked to read a synopsis of a recent, high-profile communications satellite failure (see Figure 4). Students and guest engineers then discuss, as a group, issues of reliability and redundancy in the context of the ITS system. In particular, students are asked to comment on how each of the engineers should take into account the possibility of their portion of the system failing. Possible topics for discussion include measuring reliability of system components, designing redundant systems, and examining the impact of catastrophic failures on co-located back-up systems.

Part 3: Reliability and Redundancy

At 6:00 EST on Tuesday May 19, 1998, there was a failure of a major communication satellite, Galaxy IV, operated by PanAmSat. Press releases from PanAmSat identified the problem as one which affected the on-board spacecraft control processor, which is the primary system used to orient, or point the spacecraft. The automatic switch to a backup control unit also failed. Due to these failures, the satellite no longer maintained the necessary fixed orientation with respect to the earth, disrupting its ability to transmit video and telecommunications information.

The New York Times (May 22, 1998) reported that approximately 80 percent of the nearly 50 million pagers in use in the United States lost service because of the satellite failure, affecting everyone from physicians and salespeople to parents checking up on their teenagers. While some corporations, such as CBS or HBO, reserve capacity on other satellites or utilize a set of satellites and therefore can shift programming transmissions to other satellites, smaller companies such as many pager companies cannot afford the cost of maintaining the reserve capacity (New York Times, May 21, 1998).

To solve the problem, PanAmSat rerouted communications data to other satellites which had excess capacity. This necessitated engineers and field technicians to redirect several hundred thousand satellite dishes in order to pick up data from the other satellites. According to the New York Times (May 22, 1998) due to the urgency of the situation and the limited number of technicians available, one company, Wall Street on Demand, redirected its satellite using an interesting combination of old and new technology--they found the position of the Galaxy IV and the new satellite by looking on the World Wide Web, and then repositioned the satellite dish guided by a string and protractor. The majority of customers were receiving service via alternative satellites by Friday, May 22.

References:

The New York Times, May 21, 1998. "Satellite Failure is Rare, and Therefore Unsettling." L. Zuckerman.

The New York Times, May 22, 1998. "Most of Silenced U. S. Pagers are said to Operate Again." S. Schiesel.

Figure 4: Description of a Communications Satellite Failure.

III. Initial Evaluation Methodology

The case was developed and pilot tested during a week-long NSF sponsored Case Studies in Science Workshop held at the State University of New York at Buffalo. The approximately 1.5 hour case was presented to 16 freshman and sophomore honors students who were paid to participate in the workshop and act as course students. The authors (faculty from three engineering disciplines) facilitated and served as the engineering experts for the case. The majority of students were majors in the life sciences or chemistry; only one student was an engineering major. This test group was appropriate for our purposes as it reflected a student population with some scientific, but little engineering background, similar to populations in freshman engineering courses. The case was conducted in a manner similar to that presented in the previous section, with a few minor differences. Faculty verbally described their disciplines in Part 2 rather than giving students written descriptions. Additionally, in Part 3, students were given actual press releases rather than a summary to read.

Presentation results were assessed by means of a short survey and a one minute paper. The survey asked students to rate their impressions of the subject presentation, quality of reading materials, assignments and activities, and the experience overall, on a 5 point scale. The one minute paper asked students to describe aspects of the class they found to be difficult to understand, aspects that were interesting, and aspects which were important to learn. Additionally, students were given the opportunity to provide open-ended, written comments.

IV. Results

Results from the survey are summarized in Table 1. Overall, students had a positive impression of the case study, including the subject matter, materials, and assignments. The pace of the case study, and the readings were judged to be of appropriate speed, amount, and difficulty.

Table 1: Survey Results. Students rated subject presentation, reading materials, activities, and provided an overall reaction on 5 point scales. Mean scores were computed based on the endpoints of 1 and 5 shown in the table. Scores closer to 1, or to 3 for starred means, were considered favorable.

Topic	End Point Scored (1)	End Point Scored (5)	Mean
Presentation of Subject	Stimulating	Boring	1.6
	Presents materials clearly	Presents materials unclearly	1.5
	Materials presented too quickly	Materials presented too slowly	2.2 *
Reading Materials	Useful to class	Useless to class	1.8
	Stimulating	Boring	1.9
	Integrated with the class	Not integrated with the class	1.8
	Reading load too heavy	Reading load too light	2.8 *
	Readings too difficult	Readings too easy	2.7 *
Assignments/Activities	Useful to class	Useless to class	1.4
	Explained clearly	Unclear	1.5
	Novel and interesting	Routine and uninteresting	1.8
Overall Reaction			
I learned a great deal in this class	Strongly Agree	Strongly Disagree	1.7
I found this class to be personally fulfilling	Strongly Agree	Strongly Disagree	2.0
I found this class to relevant to my life	Strongly Agree	Strongly Disagree	2.3
Overall, I felt the class was:	Excellent	Poor	1.6

Additionally, a categorical analysis of answers to the one-minute papers indicated that students found material presented in the case to be understandable and interesting. Comments are summarized in Table 2. Eleven out of 15 responses indicated that there was nothing difficult to understand. Twelve out of 15 responses indicated that there was something intellectually interesting and engaging in the case. Of those 12, the ITS itself and the systems/subsystems concepts accounted for 7 comments. Responses were more divided on the question of if the case presented facts or ideas that were personally relevant or emotionally engaging. Seven students responded negatively, while the rest (eight students) responded either positively, or said that the information was somewhat relevant or engaging. This result is not too surprising, considering that the test population included only one engineering major. Presumably, more students in a freshman engineering course would have a personal interest in the material. Interestingly, three of the "nothing" or "some" responses to this question indicated that the response was due to the fact that the ITS was too futuristic and would not cause an impact during the respondent's lifetime, rather than simply indicating a belief that the material was irrelevant.

Table 2: Comments taken from the One minute paper exercise. Questions are given in the first row, and student comments are transcribed below.

What material have we covered in this unit that is difficult to understand, or is in some way unclear to you?	**In this unit, have we covered any ideas, concepts, or facts that engage you intellectually?**	**Have you found any of the facts, ideas, or concepts in this unit to be important to you (i.e., personally relevant or emotionally engaging?)**
Systems	Yes, although a little boring	Yes, I think some crazy ideas can someday come true.
None	Yes, these automated cars are in the near future and I would like to know more about them	Yes, I find it very interesting to see how the internal mechanics of an operation would work.
It was easy and clear	No	Highway discussions were very good.
Clear	Yes, because it concerns everyone	Yes, because the whole country will be affected by the mass transit system.
It was difficult material but by breaking it down like the professors did, it made it easier to grasp the information	Yes, this information was very interesting	I don't think this unit was particularly relevant to me unless I live to see this new automated highway.
None	Not really. Some is relevant.	Some.
None	Interesting concepts about satellite failure or possibility of automated transportation system	None right now, seems too futuristic.
None, very explanatory	The concept of the automated cars is very interesting.	
The material seems to be broken into segments that weren't connected well		
Nothing	Yes, teamwork, systems, sub-systems	Yes, I love this stuff.
No material was difficult to understand or unclear	I was very interested in the concept of designing the system and all the components and the problems surrounding the project	No, it wasn't very emotionally engaging material.
No, I got everything	Interesting to think that the government will slowly take over our lives with these systems to read the ultimate goal of the man's take over of the world	Conspiracy Theory.
Engineering in general. I'm glad I didn't major in it, but I'm glad others do!	Yes, the whole idea of the automated transportation system	Maybe, I'm not sure a perfected system will be in existence during my life.
The first task I thought was difficult to understand	I realized all the different things engineers do. My dad's an engineer and now I know the things he does.	
None	Breaking Down of Systems	

Finally, open-ended comments, though few, included remarks that indicated the value of the case in illustrating the role of engineers in system design. Comments were the following:

> *"Good for an introductory class"*
>
> *"I thought the session was very interesting. It gave me a glimpse into what engineers do"*
>
> *"I hate engineering, but even I had fun. Well presented, clear, fun format, makes you think about interconnection."*
>
> *"It was mildly interesting. It was better than I have though learning engineering would be. It was entertaining but very non-descript. "*
>
> *"It was a good presentation. A little boring but informative."*

V. Extensions to the Case

The case was designed to be utilized in an introductory engineering class with students from more than one engineering discipline. However, the case could be adapted to discipline specific introductory courses, but with faculty from different sub-specialties within one engineering discipline on the guest engineering panel.

Additionally, the case was developed to be conducted in one 90 minute class session. However, the case can be modified to work over two shorter sessions, or expanded to a longer time period. For the former, class discussion during the first period can end after Part 2 of the case, and Part 3 can be conducted in a subsequent class. Students can be given the news summary to read before the subsequent class and can be asked to bring news articles about the incident, or other incidents which may have an affect on ITS reliability to class for discussion. To further extend the case, students could create their own block system/sub-system diagrams given a simple example during Part 1. Additionally, for Part 3, students could conduct out of class research about the tasks different types of engineers have with respect to creating a reliable ITS system. These discipline-specific design problems, including constraints, methods, and possible solutions could then be discussed in class.

VI. Conclusions

To address problems of retention and student interest in engineering at the freshman level, we designed a multi-disciplinary case study to introduce students to engineers' tasks and responsibilities in the design of a complex system, and to certain fundamental concepts in engineering. Preliminary results with a test group of students indicate that students found the case effective and intellectually engaging. Extensions of the case to discipline specific courses, or to multiple class periods, were discussed.

The complete case, along with case teaching notes including possible homework questions, can be found at the UB Case Studies in Science Web site:

http://ublib.buffalo.edu/libraries/projects/cases/case.html

VII. References

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