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## **AC 2011-1501: A CASE STUDY-BASED GRADUATE COURSE IN ENGINEERING ETHICS AND PROFESSIONAL RESPONSIBILITY**

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# **A Case Study-Based Graduate Course in Engineering Ethics and Professional Responsibility**

## **Abstract**

This paper examines in detail the development of a graduate-level course in engineering ethics and professional responsibilities. Case studies covering the field from the Texas A&M Bonfire to Bhopal, the Quebec Bridge to the Kansas City Hyatt Regency, and many other notable incidents are used extensively to give the students insight into how a lack of ethics or an abrogation of professional responsibility has resulted in some of the major engineering failures for which we have records. Students prepare in advance for a discussion of the day's topics through researching the historical record. The class leader then guides the class through a close examination of cultural, managerial, commercial, governmental and human factors in the context of the time in which the failures occurred.

In one 3-hour class, as an example, aerospace and aviation was the topic as seen through the stories of Apollo 1 (1967), TWA Flight 800 (1996) and the Concorde crash (2000). In Apollo 1, faulty wiring in an explosive atmosphere led to loss of the capsule and crew. (Three years later, Apollo 13 was almost lost due to faulty wiring in an explosive atmosphere.) Almost thirty years later, TWA Flight 800 was lost with all aboard due to faulty wiring in an explosive atmosphere. The Concorde, which had a long history of tire failures causing wing and fuel tank damage, was lost when it hit debris and a tire failed, fatally damaging the wing and fuel tank.

Disasters rarely happen without a string of warnings. The manner in which these warnings are handled is a fertile ground for class discussion of how professional responsibilities were or were not handled in an ethical way. The course uses as a text the book *"Truth, Lies, and O-Rings: Inside the Space Shuttle Challenger Disaster"* by Allan J. McDonald. This is a first-hand account of the events leading up to and following the loss of *Challenger*. It is written in a very readable style, and students in the course have expressed a keen interest in the story, both as a "good read" and as one of the best, most detailed accounts of ethics, professional responsibility and even management politics to be found anywhere. Additionally, research papers and presentations explore cultural views on these topics and more detailed personal analyses and applications of the material.

## **Introduction**

In many engineering and engineering technology programs, there is much emphasis on the development of technical skills and considerably less on the development of "soft skills". Soft skills usually deal with the interpersonal relationships which are so essential to the long-term career success of any graduate. One of these skills is the acceptance of professional responsibilities for one's action. The National Society of Professional Engineers has published a Code of Ethics for Engineers<sup>1</sup> which explains in detail what these responsibilities are. The first and cardinal Fundamental Canon is to "Hold paramount the safety, health, and welfare of the public." It is followed by five others that enlarge upon the concept of ethical conduct. The last of these is Fundamental Canon #6 which states that engineers shall "Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and

usefulness of the profession.” These characteristics are universally recognized as essential in the conduct of one’s personal and professional life.

The author, in his professional practice, has seen many examples of honorable and ethical engineers striving to follow these Canons. Unfortunately, he has also witnessed and worked with individuals for whom other priorities have replaced the Code of Ethics. The results can be, and have been in many cases, tragic, not only in terms of corporate performance, but more importantly in terms of life and limb for workers made victims of unethical and irresponsible actions.

In the last cycle of ABET<sup>2</sup> accreditation for our department and its programs, we were encouraged to make ethics and its instruction a more integrated part of our curriculum. The Philosophy department has an excellent freshman-level course in ethics which also meets a general education requirement for graduation. Lacking such a course in our own program offerings, we strongly encourage our undergraduates to take this course, although it is not directly targeted at our students and their needs. For the graduate students, we wanted a course which would explore the subject in much greater depth and with a more relevant focus. The present course has been developed to fill that need.

### Methodology

Felder & Silverman<sup>3</sup> determined that the “[l]earning styles of most engineering students and teaching styles of most engineering professors are incompatible in several dimensions. Many or most engineering students are visual, sensing, inductive, and active, and some of the most creative students are global; most engineering education is auditory, abstract (intuitive), deductive, passive, and sequential. These mismatches lead to poor student performance, professorial frustration, and a loss to society of many potentially excellent engineers.”

Felder describes the main characteristics of these learning styles as a preference for 1) visual (external) – pictures, diagrams, graphs, demonstrations; 2) sensing – sights, sounds, physical sensations; 3) inductive – facts and observations are given, underlying principles are inferred; 4) active – engagement in physical activity or discussion; and 5) global – in large jumps, holistically. The main characteristics of the teaching styles are a preference for 1) auditory – words and sounds; 2) intuitive (internal) – possibilities, insights and hunches; 3) deductive – principles are given, consequences and applications are deduced; 4) passive – introspection; and 5) sequential – in continual steps.

A theoretical discussion of abstract concepts is harder for these students to engage in than a case study of actual events, complete with data and illustrations. Learning styles are a good consideration, but even more compelling than they are is that the narrative nature of case studies is a form of storytelling, which is the oldest form of transmission of human knowledge. Narratives help the listener (and often the teller) make better sense of the topic under discussion and draw critical learnings (“morals”) from the stories. For this reason, a case-study-intensive format was chosen for this course. Case studies, in which the students engage in group discussions about historical events, complete with illustrations, data and a compelling story line,

offer a better learning atmosphere than a straight lecture format, and so more fully meet the needs of the students' learning styles.

The course was three semester hours, meeting once weekly for three hours in the evening. With a class of that length, there is ample opportunity to explore topics in greater detail than can be done in a one-hour meeting. The case studies were drawn from many of the classic engineering failures and disasters. Each class meeting had a theme. The incidents selected were categorized loosely into groups for analysis along common lines and also to show how the earlier events had (ideally) helped to inform those involved in the later ones.

As an example, in one class whose theme was nuclear energy we investigated the incidents at Idaho National Laboratories with the SL-1 reactor, Three Mile Island and Chernobyl. Areas that were covered ranged from engineering design to operator training to media coverage and governmental responses. At SL-1, three operators were killed when they accidentally triggered a steam explosion in the reactor. There was total secrecy applied to this disaster. At Three Mile Island, there was a reactor meltdown triggered in large part by operator training and workplace design. The media covered the incident, in which there were no injuries, extensively and (some would say) at times hysterically. At Chernobyl, lack of operator training and poor reactor design triggered a massive explosion which scattered radioactive debris across half of Europe and ultimately killed a great many people. The Soviet government tried to cover it up and denied that it had taken place as long as they possibly could.

Date	Topic	Reading
8/24	Introduction; I-35W bridge collapse	
8/31	Titanic; BP Oil Spill; Texas A&M Bonfire	
9/7	<b>O-Rings</b>	<b>Part I</b>
9/14	Three-Mile Island; Chernobyl; SL-1 – Idaho National Labs	
9/21	Concorde crash; TWA Flt 800 explosion; Apollo 1 fire	
9/28	<b>O-Rings</b>	<b>Part II</b>
10/5	Space Shuttle Columbia; Hubble telescope; Apollo 13	
10/12	Cultural Ethics Presentations	
10/19	<b>O-Rings</b>	<b>Part III</b>
10/26	Pinto Ford fires; Sudden Unintended Acceleration (SUA)	
11/2	Kansas City Hyatt Regency; Big Dig collapse; Imperial Sugar explosion	
11/9	<b>O-Rings</b>	<b>Parts IV &amp; V</b>
11/16	Quebec Bridge collapses; Tacoma Narrows Bridge collapse; Vancouver Ironworkers Memorial Bridge collapse	
11/23	Bhopal Union Carbide gas release	
11/30	<b>O-Rings</b>	<b>Parts VI &amp; VII</b>
12/7	<b>Final Exam – 5:00 – 8:00 PM</b>	

Table 1 - Topics for case studies. "O-Rings" refers to the course textbook<sup>4</sup>.

Table 1 shows a complete listing of topics. Students were asked to prepare for each meeting by researching each incident and learning all they could about it in the week prior to class. They were each given the opportunity to lead the class discussion about an incident. Everyone contributed their point of view from their own experience and perspective. Some class members remembered the incidents, some had heard of them, and some knew nothing about them. The eleven members of the class represented six different countries from the wealthiest to the poorest

on four continents. The cultural cross-pollination of ideas was a large factor in the success of the course.

Although the course calendar identifies only disasters and spectacular failures, many other less-dramatic studies were used in each class period. Many were taken from situations the author has encountered in a 30-year career in industry. While most of these made no headlines, the ethical issues and situations involved were more representative of what the students may encounter in their own practice.

### Textbook

The book “Truth, Lies and O-Rings: Inside the Space Shuttle *Challenger* Disaster”, by Allan McDonald was selected for a long-term, in-depth analysis of one of the major disasters of our time, the explosion of the Space Shuttle *Challenger*. Mr. McDonald was the only person who raised his voice to ensure that the truth of the disaster was known by the Presidential Commission investigating it. His story begins years before the explosion and traces design and management decisions through the disaster to the consequences. The story is told in the first person and explains the hell that his life became after he stood up for the truth. Everything in this book is exhaustively researched and/or taken from his personal journals made at the time if these events.

In any discussion of ethical conduct and responsibility, Mr. McDonald’s actions set a high standard. As shown in Table 1, the book was analyzed in great detail over a number of meetings. After the second section, students were reporting that they were reading ahead because they couldn’t put it down and wanted to see what would happen next.

### Results

Course assignments encouraged in-depth examination of news stories of relevance to the course. For instance, we discussed the BP oil spill in our second meeting. A week later, BP released their report on the explosion, fire and spill. An assignment for a short report (3-4 page minimum) analyzing the report and media coverage and comparing the chain of events to other incidents we had discussed soon followed.

Midway through the semester, each student was asked to analyze ethics from a cultural perspective. This could be national or corporate cultures, it could be current or historical, it could be a study of the contrasts or similarities between two different cultures. In addition to a written report, the students were asked to prepare a 15-20 minute presentation for the class. Topics that they covered ranged from oil spills in Nigeria to air pollution in China, road construction in Colombia compared to the USA, lithium mining and pollution in Bolivia and many others.

We had analyzed the crash of the Concorde in Paris in some detail in one of our class meetings. The day before the final exam, the French court found Continental Airlines criminally liable for the accident. One question on the final was to comment on this story from the points of view of 1) the French court, 2) Continental Airlines and 3) the mechanic who was found guilty of making

an unauthorized modification to the Continental DC-10 that shed a part in the Concorde's path even though his supervisor, who ordered him to make the modification, was cleared of all charges.

The same day that the Concorde verdict was announced, an article appeared in a British newspaper about an accidental decapitation of a worker at a poultry processing plant in Australia. We had discussed conditions at an American poultry processing plant at which the author had done some consulting and at other such plants around the country. Students were asked on the final to analyze this incident as well as they could from the news article.

The class itself was subjective in nature, so the assignments and final exam were also. There were no "right" or "wrong" answers. The grading was based on the students' ability to apply the ethical concepts derived from the case studies and discussed in class to other, seemingly unrelated, incidents and to show how ethics and professional responsibility, or the lack thereof, played a role in them.

### Results and Student Assessments

At the end of the class, each student submitted an ungraded evaluation of the course and its personal affect on him or her. The question itself was "Contrast your views on professional ethics and responsibility back at the start of the semester with your views now. Have there been any significant changes? If so, what has changed? What was the most interesting or formative part of the class for you? What was the least?"

Portions of the students' responses are given in Table 2 below, along with the student's home country. No editing or corrections have been made in these remarks.

Country	Comments
Nigeria	At the start of the class, I viewed ethics and responsibility has a major part of carrying out one's duties. ... Now, I see that not everybody sees that ethics should be incorporated into their duties as a result of the different industrial accidents that we covered in class. ... The most formative was the individual presentations we had in class.
Bangladesh	As a graduate student, still so far I was dealing with engineering policies and strategies. I never took any course regarding ethics and responsibilities ... But now I am aware and acknowledged about the ethics culture. In the industrial sector of third world country I have seen responsibility more rather than ethics, such as more work, less pay, forced work, biased policy ... and all of these are completely violation of ethics ... Now after that course, where I will work in which ever company, I will raise my voice against unethical manner of the treatment. ... The most interesting and formative part of the class 1) the discussion of unethical strategy, 2) the detection of the error that caused due to illicit agenda or fault strategy, 3) investigate the proper cause of the fault.
Nepal	In this class, I learn the core value of the ethics and responsibility. Yes, there is great change come in thought. Before this class, I used to focus only on how to solve the engineering problems and implementation of technologies. I wouldn't

	realize that how it can makes different if the person or expert is not so ethical or responsible. We have gone through so many example of disaster from Deep Horizontal to the Challenger and many other. Now, I think that we should be more responsible what we should. If we don't, it can cause many lifes. This was the most informative and interesting part of the class.
India	At the beginning of the class I just had a one-sided view on the issue of ethics. But as the course progressed I learned that it is important to look at the story from every perspective possible. Often a chain of events is responsible for a system failure. It is very critical to understand the chain of events to find out what went wrong.
Colombia	My views on professional ethics and responsibilities haven't changed, rather my knowledge of examples of how some people and companies have (haven't) applied these concepts has expanded. I had no idea how much cover-up some companies and agencies have done / do on a regular basis. I never expected to learn about such blatant efforts to lie and dupe government and the people in need of consolation and answers. The most informative part of the class was also the most thoroughly covered – O-Rings! I never knew that NASA and its space program were so FLAWED!
USA	At the beginning of the semester I did not have a very good understanding of how liability can be acquired through the purchase of companies. Additionally I did not have many real life examples of why or how companies / individuals could be placed in those situations to do unethical things. Most interesting / formative: Group discussions, hearing how others perceived things.
USA	My viewing of professional ethics has changed during the class. After seeing how Mr. McDonald and the two gentlemen from the Chile miners incident acted during such catastrophic events, I hope that if I was ever put into a situation like theirs I would follow suit. The most interesting part of the class was researching disasters and seeing how management, employees, civilians, etc. acted. I have never been an avid news watcher and it was a chance to catch up on current disasters, such as BP, and learn about historical disasters.
USA	... I think the largest effect this will have on me will be in me seeing things I am involved in as being something that, no matter what, I cannot wash my hands of risks associated with. To pass off a risk will mean that everyone will have to know the risk, from top to bottom. The most interesting part of the class in my view was in the dissection of the disasters and how anyone of many people could have prevented them. It really does take a lot of people ignoring obvious problems to allow them to become disasters.
USA	I never really focused on or thought about professional ethics or responsibility before this class. I guess one way to put it is, I only thought about my actions now or today. I never thought about how it could affect things tomorrow or later into the future. The most interesting part of the class was the discussions on a wide range of topics from a wide viewpoint or background of people and cultures.
USA	... To me the thing that sticks out most about this class is that if you make a mistake and own up to it right away, that ends up with the best outcome. It may not be the easiest choice at the time, but in the long run it will pay off. ... I also recognize more the value of making sound ethical choices no matter what you are

	doing. To me the most interesting parts of this class were the discussions about the Challenger disaster, the nuclear power plant cases and the case about drug tampering. The drug tampering case really showed how stepping up and addressing the issue head on can really have a positive result.
USA	The biggest change is seeing and studying real-life example of how “going with the flow” can result in catastrophe. When we lose sight of our main focus to do no harm is when people can get hurt. This class has above all taught me to double check uncertainties. It has given me awareness to ask the questions and do the right thing because knowing you didn’t can lead to costs, unsafety, death, denial and ruin your life and the people around you. Most – the courage to do the right thing knowing the consequences.

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<sup>1</sup> “Code of Ethics for Engineers”, NSPE, 2007. This can be found at <http://www.nspe.org/Ethics/CodeofEthics/index.html> .

<sup>2</sup> <http://www.abet.org/>

<sup>3</sup> Felder, R. M. and Silverman, L. K., Learning and Teaching Styles In Engineering Education, [Engr. Education, 78(7), 674–681 (1988)]

<sup>4</sup> **Truth, Lies and O-Rings: Inside the Space Shuttle Challenger Disaster**, McDonald, Allan J., Hansen, James R., 2009, University Press of Florida, ISBN 978-0-8130-3326-6