Online Ethics Center
FOR ENGINEERING AND SCIENCE

Engineering a Catastrophe: Ethics for First-Year STEM

Author(s)

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Description

This activity is considered an NAE Exemplar in Engineering Ethics Education and was included in a 2016 report with other exemplary activities. This activity is a first-year course where students reflect on historical engineering catastrophies.

Body

Exemplary features: Use of historical cases paired with contemporary issues/topics to examine ethics from the perspective of multiple stakeholders

Why it’s exemplary: Engineering a Catastrophe: Ethics for First-Year STEM is an exemplary cornerstone ethical experience because of its ability to engage students in balanced ethical and technical discussions in a diverse environment using risk benefit analysis and ethical audits to address both macro- and microethical issues. Current engineering achievements and disasters are considered in light of past failures, allowing students to both explore historical ethical decisions and see these issues echoed in current engineering challenges. Engineers benefit from the ability to take the view of a nonengineer, develop empathy, and think divergently, facilitated by the ethical discussion in environments where other majors (both STEM and non-STEM) are engaged. This exposure to ethical constructs and problem solving for first-year engineers is critical to supporting future modules of engineering ethics in later major courses that build on this solid foundation to provide vertically integrated learning.

Program description: Engineering a Catastrophe is offered as part of the one-credit Byrne Freshman Seminar program at Rutgers University. The seminar is intended to provide a broad introduction to ethics through discussions and writing assignments focused on case studies of engineering catastrophes, meeting once a week for 90 minutes, and to encourage students in college-level critical thinking skills. The main goal of the seminar is to engage first-year STEM students to discuss ethics from an engineering perspective, give them tools beyond their intuition, and assist them in their transition to college-level academic work.

Students are introduced to a risk assessment–based approach to ethical decision making. This approach incorporates basic questions of risk-benefit analysis with information on the decision makers, constraints and context, and implementation of the system. This simplified framework allows students to more easily explore complex catastrophes from multiple points of view and to draw parallels with current technological issues, with these skills significantly improving over the course of the semester. The course is described broadly to attract engineering, STEM, and nontechnical majors. In fact, the title of the course, “Engineering a Catastrophe,” explicitly does not mention ethics in order to appeal to the widest audience. The course typically enrolls 20 students, 50% of which are engineers, 25% other STEM, and 25% non-STEM.

This seminar is designed to explore both the engineering and cultural implications of recent and historical disasters with examples taken from natural (e.g., levee failures, earthquake damage), engineering (nuclear power generation, aerospace), and conflict (terrorism) tragedies. Students are guided to learn and discuss which factors led to these cataclysmic events and how engineering development, public policy, and society have responded. To focus on the relevance of the course to future events, readings and discussions center on how advances in engineering both solve current problems and cause new issues and unforeseen complications.

The educational goals of the course are to understand (a) the factors that lead to an engineering catastrophe (human, economic, social, safety, environmental); (b) ethics and ethical behavior in engineering practice; and (c) how decisions throughout the engineering design and implementation processes affect the failure modes of a system. Students consider current engineering achievements in light of historical failures. A case study is used to direct the ethical discussions. However, instead of focusing on individual catastrophes, discussion topics attempt to weave several events together to create a coherent story about a single issue. For example, a typical discussion of human factors and how safety is managed in large organizations centers on how initially harmless technical or managerial decisions can grow and propagate throughout a project, eventually leading to failure. This typical topic for ethical analysis is usually framed around a single event (like the faulty oxygen cylinder on Apollo 13); but the approach in this seminar frames the topic around a single issue (the transport of pure oxygen) with a multiplicity of historical and modern examples. Short histories are given of relevant historical space and aviation events involving oxygen transport followed by a discussion of the transportation of lithium batteries. Parallels are drawn between the historical oxygen-related tragedies and current issues associated with aviation battery systems and battery transport. The description largely focuses on why these types of similar events keep occurring throughout history even though the engineering community is aware of the attendant problems.

Before the open discussion, two writing prompts are given for each topic for the students to consider individually and then in small groups. Writing prompts typically focus the students on the both the societal implications of catastrophes [A-type questions] and the personal ethical issues [B-type questions] that a practicing engineer might face. For examples: [A] When US companies work in a global marketplace, whose laws prevail? Who takes responsibility? [B] How can safety/ethics be communicated across cultural and socioeconomic divides? [A] How can ethical and safety standards keep up with a rapidly advancing scientific forefront? [B] How do engineers best approach the unknown unknowns of new technologies used in consumer products? The success of such discussions and directed writings require the students to have reasonably well developed ethical analysis skills.

First-year students experience difficulty in objectively assessing the events leading up to these incidents with their hindsight and knowledge of the consequences. Therefore, a framework using a risk-benefit analysis (with which the students are somewhat familiar) and an ethical audit are used to give the students some constraints with which to approach their exploration. Students are instructed to evaluate hazards both in and out of the technical realm. Discussion of uncertainty in engineering design and operation is balanced with estimation of nonroutine operation, historical failures, managerial complications, and consequence potential. Hazards are then folded into a risk profile with sufficient resolution for the students to capture the most important and provocative hazards. Special detail is given to the quantification of personal/public risk and risk perception (as often the mere hint of a catastrophic risk in an engineering project can seal its fate). Finally, the original risk-benefit analyses of each catastrophe are outlined such that the students can appreciate that well-developed foresight in a large, complex system is very difficult to achieve. With additional evaluative tools students discover a greater ability to personally relate to complex ethical decisions inherent in the more complicated case studies. They find comfort in defending their risk profiles and analyses rather than relying on and upholding their own personal opinions. Using these tools, their discussions and papers present a more nuanced and enlightened approach to the discussion of the acceptability of risk. With this better understanding of risk, students have a larger appreciation for the difficulties of the ethical decision making process.

Assessment information: Assessment of this course is done through student surveys (using a typical Likert scale) and by evaluating student work from the earlier and latter parts of the semester. Students report high levels of satisfaction with the class discussions (4.6/5), their ability to consider multiple sides of an issue (4.7), and their engagement (4.7). Because introduction of first-year students to college-level academics is also an important goal, survey questions are targeted toward the students' engagement with the discussion process and their level of comfort with the new intellectual material. Students report that the course inspired them to think in new ways (4.6) and to ask questions and express ideas (4.3), engaged them with new ideas (4.8), and was a positive learning experience (4.6). Assessment of written student work is performed using a rubric that evaluated their early in-class writing assignments and their final risk assessment papers. The seminar is a one-unit course, so the number of out-of-class writing assignments is kept to a minimum. The initial writing assignment is geared toward a risk assessment analysis of cheating on exams at the college level. A short lecture in the introductory class introduces the students to the tenets of risk assessment. Students are tasked with explaining the ethical concerns by viewing the risks and benefits from many perspectives (their current standing, their future, parents, professors, school administrators, future employers, and alumni). Their papers are evaluated on the depth of their exploration of the ethics of professionalism and their ability to identify motivations of each of the stakeholders. On average, students' early understanding of ethical concepts was scored at 2.1 out of 5 and their ability to apply risk assessment tools to ethical problems was scored at 1.6 out of 5. The final risk assessment paper is a detailed examination of a catastrophe that was related to one examined during the seminar but not specifically discussed. Example subjects of final student papers are typhoons in the Philippines, postearthquake structural failures in China and Haiti, vaccinations and the swine flu pandemic, and drone aircraft. Students are asked to analyze these (potential) catastrophes in light of the historical case studies presented in class, applying the risk assessment tools developed during the seminar. Final papers are judged using the same rubric as the initial writing assignment. On average students' understanding of ethical concepts more than doubled to 4.3 out of 5 as did their ability to apply risk assessment tools to ethical problems (4.1 out of 5).

Additional resources:

1. Ethics for First-Year STEM: A Risk Assessment–based Approach: www.asee.org/public/conferences/56/papers/11730/view

Resource Type

Educational Activity Description

Parent Collection

NAE Exemplars in Engineering Ethics Education

Topics

Catastrophes, Hazards, Disasters
Risk

Discipline(s)

Engineering
Teaching Ethics in STEM