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CHAPTER 1

The Ethics Gap in Contemporary Engineering

TWO VIGNETTES

During the night of December 2–3, 1984, one of the worst industrial disasters in history occurred at Union Carbide's plant in Bhopal, Madhya Pradesh, India. Methyl isocyanate (MIC) liquid, an intermediate used in making Sevin, Union Carbide's name for the pesticide carbaryl, came into contact with water, boiled violently, and turned into MIC gas. Unchecked by various safety systems, tons of highly toxic MIC gas escaped from storage tank E610.[1] A cloud of MIC gas descended upon crowded shantytowns just outside the plant, as well as on Bhopal city. Estimates of the death toll from exposure to the gas, immediately or in the first few days afterward, range from 2,000 to 10,000.[2]

In February 1992, I attended a conference on professional ethics at the University of Florida, Gainesville. On the shuttle bus to the conference hotel, the only other passenger turned out to be a chemical engineer. I asked him whether there was any consensus in the chemical engineering community about what had caused the Bhopal disaster. His response was immediate and succinct: "Sabotage." Union Carbide has given the same explanation for three decades and continues to do so on its website.[3]

[1]Tank E610 contained 42 metric tons of MIC. See Chouhan (2005), p. 205. Estimates of how many tons of MIC gas escaped into the air range from "approximately 27 tons" (Cullinan, 2004) to "some 40 tons" (Peterson, 2009a).

[2]Edwards (2002), Broughton (2005), and Shetty (2014). If one counts those who died prematurely, months or years later, from effects of MIC exposure, the estimated death toll is much higher.

[3]See http://www.unioncarbide.com/history. On the company's historical timeline, the item for "1984" reads, "In December, a gas leak at a plant in Bhopal, India, caused by an act of sabotage, results in tragic loss of life." See also http://www.bhopal.com/Cause-of-Bhopal-Tragedy. Under "Frequently Asked Questions About the Cause of the Bhopal Gas Tragedy," the second question posed is "Who could have sabotaged plant operations and caused the leak?" The answer given reads, "Investigations suggest that only an employee with the appropriate skills and knowledge of the site could have tampered with the tank. An independent investigation by the engineering consulting firm Arthur D. Little, Inc., determined

On January 28, 1986, about 14 months after the Bhopal disaster, the U.S. space shuttle *Challenger* exploded and disintegrated 73 seconds after launch from Kennedy Space Center in Florida. The entire crew perished: six astronauts and Christa McAuliffe, the first "Teacher in Space."[4]

President Ronald Reagan appointed the late Arthur Walker Jr., at the time a faculty member at Stanford University, to serve on the Presidential Commission on the Space Shuttle *Challenger* Accident. Reagan charged the commissioners with determining the cause of the accident. In late 1987, after the commission had submitted its final report, I ran into Professor Walker on the Stanford campus and invited him to give a talk about his commission experience to a faculty seminar on technology in society. After his talk, I asked Walker what was the single most important lesson to be learned from the *Challenger* disaster. He replied, "Hire smarter engineers."

A GAP BETWEEN EDUCATION AND EXPERIENCE

The responses quoted in these vignettes are simplistic. The engineering outcomes involved cannot be explained as simply as those succinct replies suggest. The proffered explanations probably reflect the narrow educational backgrounds of those who offered them. Few intending engineers (or scientists) ever take ethics or social science classes that focus on engineering (or science) projects or practices. They are therefore predisposed to attribute the outcomes of destructive engineering episodes to technical failures or clear-cut, nontechnical factors. The latter include individual cognitive shortcomings, such as mediocre intellectual capability on the part of project engineers, and individual political motives, such as vengeful sabotage by a disgruntled employee.

Part of the appeal of such explanations is that they point up problems that can be readily "solved" by making specific changes, for example, hiring smarter engineers, and screening potential employees more rigorously. Engineers who never took ethics or social science classes closely related

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that the water could only have been introduced into the tank deliberately, since process safety systems—in place and operational—would have prevented water from entering the tank by accident." On Union Carbide's sabotage theory, see Weisman and Hazarika (1987) and Peterson (2009b), pp. 9–11.

[4]Besides the loss of human life, the harm caused by this accident also had a financial component. "The space shuttle *Endeavor*, the orbiter built to replace the space shuttle *Challenger*, cost approximately $1.7 billion." See http://www.nasa.gov/centers/kennedy/about/information/shuttle_faq.html#1.

to engineering endeavor rarely consider the possibility that some harmful engineering episodes may be partly attributable to ethically problematic conduct on the part of engineer-participants. They also rarely consider the possibility that social or technical features of the often-complex contexts involved can help set the stage for and elicit such conduct.

Not only does contemporary engineering practice pose many ethical challenges to engineers, engineers are rarely adequately prepared to grapple with them in a thoughtful manner. There is an ethics gap in contemporary engineering, that is, *a mismatch or disconnect between the ethics education of contemporary engineering students and professionals, and the ethics realities of contemporary engineering practice*. One purpose of this book is to help narrow that gap.

EVIDENCE

Is there *evidence* of a gap between engineering ethics education for engineering students and the ethics realities of contemporary engineering practice? If there is, does it suggest that the ethics gap is substantial? Consider the following.

Between 1997 and 2001, the author conducted an informal survey of Stanford undergraduate engineering students and the practicing engineers they contacted about two topics: the study of engineering-related ethical issues in undergraduate engineering education, and the presence of ethical issues in engineering practice.[5]

Of the 516 undergraduate engineering majors who responded and ventured an opinion,[6] about 17 of every 20 (86.1%) indicated they expected to face ethical issues or conflicts in their engineering careers.[7] But how well did respondents believe their education had prepared them to deal "thoughtfully and effectively with such ethical challenges as they might encounter"? About a seventh (14.2%) responded "a good deal" or "a great deal," whereas more than half (54.3%) responded "a little bit" or "not at all."[8]

The undergraduates' responses did yield some encouraging findings. About three-fifths (62.2%) indicated that during their engineering

[5] McGinn (2003).

[6] One hundred forty-seven engineering majors did not respond because they did not plan to become practicing engineers; 28 others indicated they had no opinion.

[7] Ibid., p. 521.

[8] Ibid., p. 523.

education they had received the message that "there's more to being a good engineering professional in today's society than being a state-of-the-art technical expert."[9] However, that finding was offset by the sobering fact that only 14.9% of the respondents indicated they had learned "anything specific" from their engineering instructors "about what's involved in being an ethically and socially responsible engineering professional in contemporary society."[10]

Thus, while a healthy majority of the respondents had gotten a message that there's more to being a good engineering professional in contemporary society than being technically competent, the message often lacked specifics. Most students learned nothing concrete about the ethical responsibilities of engineers from their engineering instructors. As they left their classrooms and headed for workplaces where most expected to encounter ethical issues, few engineering students took with them specific knowledge of the ethical responsibilities of engineers.

But how likely is it that engineers will actually confront ethical issues in professional practice? Of the 285 practicing engineers who responded and expressed an opinion, 84.2%[11] agreed that current engineering students are "likely to encounter significant ethical issues in their future engineering practice."[12] Indeed, almost two-thirds (65.4%) of the responding engineers indicated they had already been personally "faced with an ethical issue in the course of [their] professional practice." Almost the same percentage (64.3%) stated they knew or knew of one or more other engineers "who have been faced with an ethical issue in their professional practice."[13] Not surprisingly, a remarkable 92.8% of the practicing engineer respondents who ventured an opinion agreed that engineering students "should be exposed during their formal engineering education to ethical issues of the sort that they may later encounter in their professional practice."[14]

Unless these two groups of respondents are atypical of engineering students and practicing engineers in general,[15] these findings suggest a

[9]Ibid., p. 524.

[10]Ibid., p. 525.

[11]Nine of the 294 practicing engineer respondents did not express an opinion on the matter. Ibid., p. 527.

[12]Ibid. Interestingly, this percentage is close to the percentage of surveyed engineering students who *expect* to encounter ethical issues in their future engineering careers.

[13]Ibid.

[14]Ibid.

[15]This possibility cannot be ruled out. The 691 Stanford undergraduate engineering students and the 294 practicing engineers who completed the relevant parts of the survey

serious disconnect: between the levels of engineering-student expectation and practicing-engineer experience of being confronted by ethical issues in engineering work, and the amount of effective engineering-related ethics education provided to U.S. undergraduate engineering students.

IMPORTANCE

I shall proceed on the assumption that this disconnect persists[16] and is substantial. Why is it important to bridge or at least narrow the gap between engineering-related ethics education and the ethics realities of contemporary engineering practice?

First, as the case studies in Chapter 4 make clear, misconduct by engineers sometimes contributes to causing significant harm to society. Making engineering students aware of ethical challenges in engineering practice and illustrating the serious social costs attributable to engineering misconduct could help prevent or lessen some of those societal harms.

Second, it makes sense for engineering students to learn upstream, for example, during their undergraduate studies, about material pertinent to challenges they are likely to face downstream, such as being faced with ethical issues during their engineering careers. For many years there was a disconnect between engineers' need for good technical writing and other communications skills, and the scarcity of training dedicated to cultivating such skills in undergraduate engineering education. Happily, in recent years technical communication classes and programs for undergraduates have emerged in a number of U.S. engineering schools, to the benefit of those able to access them. The same attention should be given to cultivating engineering-related ethics awareness and skills as it eventually was to technical communications skills. Failure to nurture the former does as much a disservice to engineering students as did failure to develop the latter. It sends them out into engineering workplaces ill-equipped to recognize and effectively grapple with another important type of professional challenge they are likely to face.

Third, acquiring intellectual resources useful for making thoughtful ethical judgments about engineering conduct can help empower engineers

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questionnaire were not probabilistically random samples of the populations of U.S. undergraduate engineering students and U.S. practicing engineers, respectively.

[16] This disconnect might have decreased if a widespread increase in meaningful engineering-related ethics education had occurred since 2001. However, to the best of the author's knowledge, this has not happened.

to make up their own minds about the ethical acceptability of prevailing workplace culture and practices. Engineers who lack the skills to make thoughtful ethical judgments about questionable features of workplace culture or suspect work practices are more likely to yield to pressure to go along with prevailing attitudes and practices.

Fourth, equipped with an understanding of responsible engineering decision-making and practices, young engineers in the job market can better assess how committed the firms recruiting them are to supporting ethically responsible engineering work. It would be useful for would-be ethically responsible engineering students and practicing engineers in the job market to know to what degree the firms they are considering joining expect and exert pressure on their new engineer-employees to follow orders uncritically, even when the engineers have concerns about the ethical acceptability of some of the tasks they are assigned.

Fifth, the ability to recognize and comprehend the ethical issues in an engineering situation should make *inadvertent* irresponsible behavior by engineers less frequent. That recognition and understanding will diminish appeals to the classic excuse "I didn't realize there were ethical issues involved in that situation." Presumably, some engineers who are able to recognize ethical issues in professional practice will choose to avoid conduct they deem ethically irresponsible.

Sixth, a quite different kind of reason for the importance of bridging the ethics gap in contemporary engineering is that in recent years, pressure to provide engineering students with opportunities to study ethical issues in engineering has grown. This pressure stems from multiple sources:

- In a 2003 request for proposals, the U.S. National Science Foundation (NSF) stipulated that each group of universities submitting a proposal for funding to establish a network of nanotechnology research laboratories had to indicate how it was going to "explore the social and ethical implications of nanotechnology" as part of its mission.[17]
- In 2004, the U.K. Royal Academy of Engineering recommended that "consideration of ethical and social implications of advanced technologies . . . should form part of the formal training of all research students and staff working in these areas."[18]

[17] http://www.nsf.gov/pubs/2003/nsf03519/nsf03519.pdf.

[18] The Royal Society and the Royal Academy of Engineering (2004), Recommendation 17, p. 87.

- In 2006, a survey of 1,037 nanotechnology researchers at 13 U.S. universities posed this question: "How much do you believe that study of ethical issues related to science and engineering should become a standard part of the education of future engineers and scientists?" About three-tenths (30.1%) of the respondents replied "quite a bit," while another third (33%) replied "very much."[19] This suggests that significant interest in relevant ethics education exists among engineering students and young engineers themselves, not just on the part of accrediting agencies, professional societies, and engineering-related funding organizations.
- In 2009, NSF took a step toward requiring ethics education for engineering students. In implementing the America COMPETES Act of 2007, NSF stipulated that, as of January 2010, when an institution submits a funding proposal to NSF it must certify that it has "a plan to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students, and postdoctoral researchers who will be supported by NSF to conduct research."[20]
- The U.S. Accreditation Board for Engineering and Technology (ABET) currently requires that engineering programs seeking initial or renewed accreditation of their bachelor's degrees "document" that most graduates of the programs in question have realized 11 "student outcomes." Among them are "an ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability [constraints]"; and "an understanding of professional and ethical responsibility."[21]

In short, there are individual, organizational, and societal reasons why providing engineering students with meaningful engineering-related ethics education makes excellent sense.

UNFRUITFUL APPROACHES TO BRIDGING THE GAP

It is hoped that the reader is now persuaded that, all things considered, it would be worthwhile to expose engineering students to study of engineering-related ethical issues in their formal education. But even

[19] McGinn (2008), p. 117.
[20] https://www.nsf.gov/bfa/dias/policy/rcr.jsp.
[21] http://www.abet.org/DisplayTemplates/DocsHandbook.aspx?id=3149.

if that is so, the question remains: *what kind of approach to providing engineering students with education about engineering-related ethical issues is likely to be fruitful*?

I shall first describe two general approaches to engineering-related ethics education I believe are unlikely to be fruitful and then shall identify and briefly characterize one approach I regard as more promising. The two unfruitful approaches are (1) requiring engineering students to enroll in a traditional philosophy-department ethics course and (2) incorporating engineering-related ethics education into technical engineering classes.

Requiring a Typical Philosophy-Department Ethics Class

Requiring engineering students to enroll in a traditional philosophy-department ethics course is unlikely to be fruitful. Few such courses in the U.S. pay any attention to ethical issues in engineering. They tend to be concerned with ethical concepts and theories, the nature of ethical reasoning, and the status and justification of ethical judgments. With rare exceptions, the examples explored in such courses rarely involve professional contexts.[22]

It is not surprising that engineering-related examples and cases are typically absent from such courses. Few philosophy-department faculty members in U.S. research universities or liberal arts colleges have substantial knowledge of or interest in engineering (as distinguished from science). The same is true of the kinds of concrete situations in which engineers can find themselves that may give rise to ethical issues. In more than four decades of teaching at Stanford University, to the best of my knowledge no ethics course offered by the Department of Philosophy has paid any attention to ethical issues in engineering. I suspect that the same is true of philosophy-department ethics courses at virtually all U.S. universities and colleges.[23] Consequently, requiring engineering students to take a traditional philosophy-department ethics course with the hope

[22]The most common exception is that some such courses include exploration of phenomena that arise in medical professional contexts, for example, abortion, assistive reproductive technology, and organ transplantation.

[23]Engineering ethics courses are most often taught by instructors in academic units with names like General Engineering; Technology in Society; Engineering and Society; and Science, Technology, and Society, almost always at institutes of technology or universities with large engineering schools. Occasionally, an engineering ethics course is taught in an engineering department, such as computer science and civil engineering.

they will learn something useful about ethical issues in engineering would leave it completely up to the student to work out how the ideas and theories explored in such courses apply to engineering situations. It would therefore not be surprising if most engineering students perceived such courses as irrelevant to their future careers.

Integrating Ethics Study into Technical Engineering Classes

A second option is to attempt to cover engineering-related ethical issues in technical engineering classes. This could be done by a nonengineer guest instructor with expertise in engineering ethics, or by the primary engineer-instructor of the course.

If a nonengineer guest instructor with expertise in engineering ethics provides the engineering-related ethics education, it is likely to be limited to one or two lectures. Unfortunately, class members will almost inevitably perceive the (limited) material covered in such sessions as peripheral to the course. Moreover, the material covered will probably not be well integrated (by the main instructor) into discussion of the technical material encountered elsewhere in the course.

If the course's main engineer-instructor provides the coverage of ethical issues in engineering, then the consideration of ethical issues is likely to be intuitive and not grounded in ethics fundamentals. Having an engineer-instructor cover ethical issues in engineering is an excellent idea in principle; however, in practice it faces two problems: one pedagogical, the other temporal.

First, effectively integrating ethics into a technical engineering class is likely to be more pedagogically demanding for the engineer-instructor than getting back up to speed on a body of technical subject matter with which she or he was once familiar but has forgotten over time. Doing that integration *well* requires a grasp of key ethical concepts and principles, familiarity with a range of ethical issues in engineering, detailed knowledge of various cases, and the ability to apply key ethical concepts and principles to concrete cases in an illuminating way. It is difficult for an engineer (or anyone else) without formal ethics education and teaching experience to acquire such knowledge and ability in short order.

Second, required technical engineering classes are already tightly packed with technical subject matter. Engineer-instructors of such courses often complain that, in their classes as they now stand, they do not have enough time to cover even all the important *technical* subject matter that students need to know. But the more time that is devoted in such a class to studying engineering-related ethics issues, in hopes of making coverage of that topic nonsuperficial, the less time will remain for important technical engineering material. Hence, study of the latter would have to be diluted or truncated. That is extremely unlikely to happen.

Thus, what may sound ideal in principle—having instructors who are engineers provide education about ethical issues in engineering in technical engineering classes—faces serious practical barriers in the real curricular world of undergraduate engineering education.[24]

PREFERRED APPROACH

I favor a third kind of pedagogical approach to teaching engineering students about engineering-related ethical issues. In this approach, engineering students explore ethical issues in engineering in a separate course dedicated to such study. They read and discuss at length real-life cases in which engineering-related ethical issues arose, and make presentations on original cases of ethical issues in engineering they have researched and developed. The instructor has expertise and experience in teaching engineering ethics, has an abiding interest in engineering education, and is familiar with the realities of engineering practice. He or she is a full-time engineering school faculty member who believes analysis of ethical issues in engineering and evaluation of engineers' conduct from an ethics viewpoint are important tasks. Further, she or he believes such analysis and evaluation must be carried out with due attention to the specific contexts in which those issues arise and the related actions unfold.

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[24] To "learn how to incorporate ethics into engineering science classes," one mechanical engineering professor attended an Ethics Across the Curriculum Workshop given by Illinois Institute of Technology's Center for the Study of Ethics in the Professions. Shortly thereafter, he added an ethics component to his Automatic Control Systems course. It included exploration of two "Ethics Cases" inspired by actual events. Students were asked to generate a list of possible courses of action open to the engineer(s) who faced an "ethical dilemma" about what to do. The instructor "asked students to vote on their preferred choice" of action in each case. Encouragingly, a survey revealed that most students believed that the course had "increased their awareness of ethics issues." However, given the limited time available in the course for discussion of ethical issues, the "mini-ethics lessons" do not appear to have tried to impart to students any ethics fundamentals that they could draw upon in making thoughtful ethical judgments about engineering conduct in the future. See Meckl (2003).

Chapters 2 and 3 present background and foundational materials intended to help engineering students and engineering professionals develop the ability to make thoughtful judgments about ethical issues in engineering and related engineering conduct. Then, making use of those materials, Chapter 4 explores a wide range of cases from different fields of engineering and analyzes various ethical issues raised therein. Almost all the cases are real-life ones, and some include engineers speaking in their own voice as they wrestle with the ethical issues involved.

Subsequent chapters discuss noteworthy ideas and lessons distilled from the case studies (Chapter 5), identify resources and options that might be useful to those who care about ethically responsible engineering practice (Chapter 6), and discuss the author's general approach to exploring ethical issues in engineering in somewhat greater detail (Chapter 7).

By reading and reflecting on the wide range of cases presented, and by grasping the intellectual resources used in exploring them, engineering students and practicing engineers should become more aware of and better able to come to grips with the ethical dimension of engineering practice. More specifically, such exposure should also help them develop sensitive antennae with which to detect ethical issues present in concrete engineering situations, and improve their ability to unpack and think clearly, critically, and contextually about such issues. With careful study, engineering students and practicing engineers will acquire concepts and principles that can be added to their personal ethics tool kits and used to come to grips in a thoughtful way with ethical challenges in their professional careers.

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