Using Case Studies to Teach Engineering Design and Ethics

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Abstract:

At the University of Virginia, we have developed (researched and written) a set of case studies for teaching engineering ethics, engineering design, and environmental issues. These cases have been used in a course on *Invention and Design*, and in other courses offered by our Division of Technology, Culture, and Communications (TCC). Many of these cases have been published in book form [1]. Others are available through the course website for *Invention and Design* [2], the TCC Engineering Ethics site [3], and the Olsson Center for Applied Ethics at the Darden Graduate School of Business Administration [4]. This paper will review the nature and use of case studies, discuss their value for developing higher level thinking skills, and describe some of the ethical, environmental and design issues we introduce through cases.

The Case for Cases:

Case based learning is again becoming popular in engineering education. A case can be used to present open-ended engineering problems (design, analysis, selection, planning), ethical issues, and business decision situations. Teams of students must analyze the problem presented by the case, develop a solution, present their results to the class, and be prepared to defend their analysis. Although in some fields cases are analyzed individually, team solutions are most common in engineering and business.

What are cases?

A case is a narrative account of a situation, problem, or decision usually derived from actual experience. [5] Cases often reflect real world concerns, situations, and issues managers and engineers encounter in practice; they are often open-ended, with no clear-cut solution. Which answer is ``best'' depends on the relative importance one assigns to various criteria. In business schools, cases frequently describe critical decision points in the history of a company. In engineering, cases may provide an account of a problem, technical issue, ethical dilemma, or design challenge.

Cases provide a context for the application of knowledge and techniques learned in engineering courses. In a corporation, technical work occurs in the context of the institution, and the acceptance and implementation of engineering solutions often depends on a variety of business, political, and cultural concerns.

Why should we use them?

Cases promote active learning [9], team-based activities, and the ability to deal with open-ended problems. With cases, students can be exposed to realistic situations - those involving open-ended problems, multiple possible answers, key decision points, and tradeoffs. Thus, cases are a natural way to introduce engineering design and decision-making.

The case method also fosters the development of higher-level cognitive skills.[10, 11] It forces students to go beyond rote learning. Cases address problems that require analysis, judgment, decisions, perspective taking, role- playing, independent thought, and critical thinking

Shapiro reviews several approaches to developing knowledge and skills: **lectures and readings** facilitate "acquiring knowledge and becoming informed about techniques"; **exercises and problem sets** provide "the initial tools for exploring the applications and limitations of techniques", while the **case method** promotes the "development of philosophies, approaches and skills." [12]

The case method is a particular teaching strategy. It has been described as "using cases in the classroom to structure an active learning process of self-discovery." [13] The case method is prevalent at many graduate business schools, including the Harvard Business School and the Colgate Darden Graduate School of Business Administration at the University of Virginia. Many business school cases have significant engineering content, and require technical decisions.

The case method is built around the concepts of **metaphor**, and **simulation**. [12] "Each case is a description of a real business situation and serves as a metaphor for a particular set of problems." Students learn by practice in a simulation-type process. Cases are designed to force students to think about particular issues, and face ambiguities and uncertainty associated with real-world decision-making.

Case formats: Cases may be presented in a variety of formats, including case histories, case problems, case studies, and video and multimedia cases. A *Case History* is an account of an actual event or situation, it reviews the variables and circumstances, describes how the problem was solved, and examines the consequences of decisions and the lessons learned Examples of Case Histories include the Challenger and Columbia Space Shuttle Disasters, the Hyatt Regency Walkway Collapse, the Tacoma Narrows Bridge Failure, the Three Mile Island incident, the Bhopal Chemical Plant leak, and the retrofitting of the Citicorp Building. Each of these has been well documented, and illustrates both technical and ethical issues.[14] A *Case Problem* presents an open-ended situation that allows many possible solutions. Analysis of the problem and choice of approach are left to the students. They must come to a position or solution, and defend it. Sometimes a Case Study includes an "ideal" or "benchmark" solution. The purpose of the case is to identify or illustrate "Best Practice." The goal is to demonstrate a principle or the value of an approach. This kind of case study has been used in computer science.

Multimedia cases: Modern computer and communications technology can enhance and enrich the case method. Videotapes and CDs provide the means to bring site visits, factory tours, and

interviews into the case method. Engineering cases usually involve substantial amounts of graphic information and numerical data. The multimedia format will help students understand and integrate diverse types of information. A case may include film clips and animated sequences as well as standard diagrams and images. In these formats, cases may be highly interactive.

Availability of cases – where to find them: There have been several case development projects for engineering education since the early 1960s. The two primary sources of online cases are the Center for Case Studies in Engineering at Rose- Hulman [15] and the National Engineering Education Delivery System (NEEDS) [16] developed by the NSF Synthesis Coalition. The ASEE case library, at the Rose-Hulman Institute of Technology, has over 250 cases, and is now accessible on the World Wide Web. It was originally based on the Stanford University case studies for engineering design, but many cases have been added over the years. New cases are welcome. The NEEDS multimedia case studies of design were developed at UC-Berkeley by Alice Agogino and her students, and are distributed on-line through the NSF Synthesis Coalition.

An interdisciplinary team at Auburn University has developed a set of cases focused on engineering design decisions.[17, 18, 19] They have a book [18], a CD, and a website devoted to these cases. At the University of Virginia, cases on ethics and the environment are also available on-line.[1, 2] Many collections of cases are available in books and journals. Henry Petroski of Duke University has advocated the study of cases involving disasters and failures [20], and one of his books provides several examples.[21] Other books emphasize design cases. [22, 23] The *Harvard Business Review* publishes case studies in most issues of their journal; some are useful for engineering courses. The Design Management Institute also regularly publishes case studies. There are many sources of good cases, but often our students are best served when we develop our own.

Writing and distributing cases: Cases are usually developed to illustrate the themes of particular courses. At the University of Virginia, cases been have developed for courses on *Invention and Design, Total Quality Engineering, and Engineering Ethics*. In Business Schools, cases are considered publications on par with the research projects of their colleagues in science or engineering.

Developing and testing cases typically involves at least four stages:

- Problem identification
- Investigation, interviewing, and information gathering
- Case development and use
- Evaluation and refinement

Of course, teachers constantly face the problems of finding relevant new cases and keeping old ones fresh. Existing cases need to be kept current. They must be updated to reflect changing circumstances and technologies. Revising existing cases can also be an act of creation.

Integrating cases into courses:

Cases are commonly used in schools of business, education, and medicine. Fitzgerald [6] provides an introduction to the use of cases in engineering, and Richards et. al. [7] review the use of cases and the case method in business and engineering education. Engineering cases typically address topics in design, ethics, and entrepreneurship.

Students study the case materials, seek to understand the problem or situation, and identify the options available to various participants. This may be done individually or in teams. Often, individual study and preparation are followed by informal small group discussion. The students aim to understand the perspective of each of the participants in the case. They may be asked to commit to a role and position, and to present and defend that perspective. This is usually done via classroom discussion, with the teacher as facilitator. Eventually the class reaches a resolution of the case. Then we have an end-of-case debriefing: what lessons were learned from this experience? Reflection is an essential part of the case experience. What have we, as a class, learned? Can we generalize lessons from this case to other situations?

The advantages of case studies include providing a broader perspective on the issues, focusing on decision-making processes, revealing the organizational structures (and barriers) within a company, highlighting uncertainty, ambiguity, and risk, and emphasizing the role of politics in the final outcomes. Cases extend the learning experience beyond the classroom and laboratory.

Well-prepared cases provide relevance, motivation, active involvement, consolidation/ integration, and transfer of knowledge and techniques to new situations. Let's consider each of these features: *Relevance:* Cases provide experience with the kinds of problems practicing engineers and managers must solve. *Motivation:* The realism and complexity of cases create interest and provide incentives for role-playing. *Consolidation/Integration:* Students learn to solve problems by bringing diverse perspectives and knowledge to them. *Active involvement*: The case method requires participation, discussion, analysis, commitment and resolution. *Transfer:* The knowledge and skills developed from using cases can be transferred to other situations and problems.

What We Have Learned:

Cases work best when they are used extensively during a semester. There is a learning curve for both students and teachers. A single case in a course is generally not productive; at least three should be included for optimal results. In some schools and departments, entire courses are structured around the case method.

Students must be prepared for the case experience. Is the case to be analyzed by individuals, or by a team? Do the students know in advance what role or perspective they are to assume? How much preparation time and background research is required of the students? Some cases can be read and discussed in a single class; others require greater preparation, including computation and analysis. Cases may vary from a single page to an entire book, and may consume one class or several weeks.

When using cases in a class, it is important to select or write cases to address the goals of the course. What techniques and issues are you trying to address? The individual cases should be able to stand-alone; supplemental lectures should not be necessary to understand the case. As a course progresses, the cases should become more complex. As students, and teachers, become more comfortable working with cases, greater sophistication and better analyses will result.

Example Cases

Westinghouse Electronic Systems: At the University of Virginia, a case development project was undertaken involving faculty members from Business (Robert Landel) and Engineering (Larry G. Richards) jointly supervising a graduate student (John Kamauff). The National Consortium for Technology in Business (which was a collaboration between ASEE and AACSB) funded this project. It involved writing case studies about the introduction of a new management philosophy (Integrated Product Development) at the Westinghouse Electronic Systems Division. The new philosophy required organizational changes within the company. Previously independent functional areas (Marketing, Manufacturing, Design Engineering, Systems Design and Development, and Quality assurance) had to collaborate at all phases of the product development process. This change imposed different roles on the participants and required them to assume different perspectives.

Building these cases required more than a year of research, writing, and revision. Both faculty and graduate students made trips to Baltimore to conduct interviews, see the facilities, and meet with management. Our contacts at Westinghouse facilitated our trips to the site, helped us understand the problem, and assured access to all the key players. Our team (Kamauff, Landel, and Richards) conducted interviews with all parties, summarized these interviews, looked for recurring themes, and then structured a narrative about the situation, context, key issues and decision points. Each of the participants reviewed our accounts and made suggestions for corrections. Then, the cases were tried with students, evaluated, revised, and refined. The final version of the cases were published in Aldridge and Swamidass [24] and reprinted in Swamidass.[25]

DesignTex, Inc.: Matthew Mehalik, under the direction of Mike Gorman, Andrea Larson, and Patricia Werhane has developed a set of cases based on the work of architect William McDonough and Chemist Michael Braungart. They designed and produced environmentally friendly fabrics for a new line of office furniture. The case reviews the difficulties and key decisions resulting from a commitment to environmentalism in the production of designer fabrics. This case appears in Gorman, Mahelik, and Werhane [1].
Since these cases involve several decision points, students read and discuss them in stages. Each team is assigned the role of one of the participants and must decide on a course of action. The decision is resolved through class discussion. Then the next case is introduced; it includes the actual resolution from the previous stage. By the end of this case, the class knows how the entire project developed, but they may have different ideas about what should have been done.

New Product Design and Entrepreneurship: Entrepreneurship is another area where cases can be used to introduce issues and decisions engineers will encounter. In courses on new product

development, the various decisions and commitments required to bring a product to market are introduced through case studies. The SolidWorks case in Bygrave [26] illustrates the many problems a start-up venture can face.

Changing jobs: Gorman has also developed several short cases about the ethics of moving from one company to another. These situations are structured to raise issues about non-compete clauses, intellectual property, and proprietary information; but they also include information about the business and economic climate and the personal motivations of the parties involved. These cases raise issues engineers are likely to encounter as they advance in their careers.

Conclusions

The case method is an interesting option for engaging students and presenting complex material. Students, teachers, managers, and engineers from industry view cases as effective tools for instruction. Cases allow us to introduce problems and questions we could not otherwise consider, and they lead students to higher levels of cognitive functioning.

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