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Using Case-based Instruction to Increase Ethical Understanding in Engineering: What Do We Know? What Do We Need?*

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Among various approaches, case-based instruction has been the most popular and widely employed method used in engineering ethics instruction. However, there is little empirical research on whether the use of cases is also the most effective teaching method in promoting ethical understanding for engineering students. This paper discusses the types of cases utilized and how they are implemented for educating undergraduate students in engineering disciplines. We then argue that empirical research is needed to examine the impact of case-based instruction on students' ethical understanding and that well-designed experiments can result in greater understanding of this approach and best practice for its use in ethics instruction.

Keywords: Ethics instruction, case-based instruction, case studies, research methodology.

INTRODUCTION

'ENGINEERING PROJECTS ARE SOCIAL EXPERIMENTS that generate new possibilities and risks, and engineers share responsibility for creating benefits, preventing harm, and pointing out dangers'[1]. This statement highlights the fact that most engineering solutions have double implications. While they solve problems and create benefits, they also lead to ethical and moral dilemmas [1]. Recently, there has been an increasing emphasis on engineering ethics as today's engineers face increasingly complex ethical and moral predicaments. So what is engineering ethics? Martin and Schinzinger define it 'as consisting of responsibilities and rights that ought to be endorsed by those engaged in engineering . . . and as a study of decisions, policies, and values that are morally desired in engineering practice and research' [1]. These ethical and moral dispositions need to be developed and maintained throughout a professional career, starting with the undergraduate program [1].

ABET (formerly known as the Accreditation Board for Engineering and Technology) is the primary agency responsible for accreditation of engineering degree-granting institutions in the USA. Institutions seeking accreditation via ABET must be able to meet the ABET Engineering Criteria 2000 and provide evidence that their graduates have developed a range of skills. One criterion is that graduates demonstrate an 'understanding of professional and ethical responsibility' (ABET Engineering Criteria, Criterion 3f). Thus, ethics instruction must form an integral part of engineering curricula for students to shape an understanding of 'professional and ethical responsibility'.

The methods and materials being utilized to teach engineering ethics are multifarious [2, 3]. In spite of the efforts of institutions, engineering programs and individual faculty, ethics instruction within engineering still lacks an effective integration in the engineering curriculum. Six basic approaches are being utilized to teach engineering ethics:

1) professional engineer's code of ethics;
2) humanist readings;
3) theoretical grounding;
4) ethical heuristics;
5) case studies;
6) service learning [2].

Among these, the use of case studies has been the most popular method to teach ethics [4].

Despite this, instructors know little about the influence of cases on students' ethical understanding. We argue that there is a need for improvement here, and we have developed models for researchers and/or faculty interested in collecting process data on the use of cases in engineering ethics and the impact on students' ethical and moral reasoning skills.

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CASE-BASED INSTRUCTION IN ETHICS: WHAT DO WE KNOW?

As engineering ethics education has moved from didactic instruction to more learner-centered methodologies, new and innovative techniques have been used to teach students how to address situations and problems relevant to an engineer's workplace, including ethical dilemmas [5]. One such approach is case-based instruction, where students are presented with authentic learning situations, similar to the ones they are likely to encounter in their profession. Case-based instruction has its roots in legal education, where it has been used for over a century to portray the complex and ill-structured nature of real world issues [6]. Other professional fields (e.g. business and medicine) have adopted case-based approaches to help students deal with the dilemmas and uncertainties presented in their profession and learn ethical issues [6]. Cases have been used as a way to engage students in critical thinking and seeing connections between theory and practice [7, 8]. Lundeberg stated, 'cases provide a situational context for students to connect ethical questions with theoretical concepts.' [7]

The Hastings Center, an ethics think tank in New York, identified five goals of ethics instruction:

1) to stimulate the ethical imagination of students;
2) help students recognize ethical issues;
3) analyze key ethical concepts and principles;
4) deal with ethical disagreement, ambiguity and vagueness;
5) encourage students to take ethical responsibility seriously [4].

Engineering ethics is complex as it calls for serious reflection and requires an individual to reason clearly and carefully about moral questions [1]. Case studies are able to present the 'messy' and complex nature of engineering ethics and hold promise to achieve these five goals. Herreid stated, 'The case method involves learning by doing, the development of analytical and decision-making skills, the internalization of learning, learning how to grapple with messy real-life problems, the development of skills in oral communication, and often teamwork. It's a rehearsal for life' [9]. This statement captures the potential of case-based teaching as a method to promote ethical understanding in engineering students through a process of presenting them with real-life scenarios and allowing them to take control of their own learning [5].

Types of cases

Harris identified three classifications of cases in engineering ethics: micro-cases, macro-cases, exemplary cases [10]. Micro-cases are those in which an individual profession, such as engineering, decides the ethical standards to be followed. Such cases guide ethical decisions that individuals might face in their day-to-day work. An example of a micro-case in engineering would be a scenario where a young engineer is asked to falsify data. Based on the engineer's education, training and work experience, he/she knows that this is unethical and unacceptable; the engineer must, thus, decide whether he/she is going to continue working on the project. Macro-cases, on the other hand, involve policies set forth by legislature, government, or professional societies. Thus, macro-cases deal with ethical decisions faced with regards to social concerns and their impact on a larger community. For example, the decisions of an individual performing research in the field of human genetic engineering may be influenced by the social implications resulting from genetic manipulation. These implications could include inequalities resulting from genetically increased intelligence among a select few individuals. Such a case could lead to engaging class discussions about genetics and its implications for society. Finally, exemplary cases provide examples of situations where individuals have performed a commendable job when faced with ethical decisions. A real example of an exemplary case in the field of engineering would be the life of Fred Cuny, a disaster relief worker who used his engineering background to perform humanitarian activities. Fred showed exemplary action by using his engineering skills in dangerous environments where people were in need. Additional information related to the definition and integration of micro-ethics and macroethics can be found in the writings of Herkert [11, 12].

Harris also described how there could be other issues at play that define a case [10]. Specifically, he suggested that there might be factual, conceptual, applicational, and/or moral issues that might determine what the case is about and how we need to address the ethical dilemmas presented in the case. For example, an instructor could describe a hypothetical, yet common, scenario where a utility contractor is installing a water line. The contractor makes an argument to the site engineer that the section to be installed is relatively short, will not require much time, and all the soil excavated thus far has shown an ability to stand with a near vertical cut. The contractor is proposing that the section of water line can be installed without the use of an excavation trench shield, typically used to protect workers within the trench from collapsing soil. Ultimately, the contractor is looking to the site engineer to make the ethical decision relative to approving or denying the contractor's proposition. Specifically, the contractor has cited factual evidence of soil conditions previously observed on the property. This case highlights the factual issues facing the site engineer and how he/she will address the ethical dilemma of risk versus safety of the workers.

In addition to the types of case suggested above, three other types—decision or dilemma cases, appraisal or issue cases, and historical cases—can also be utilized for ethics instruction in engineering [9]. Decisions or dilemma-based cases present 'problems or decisions that need to be made by a central character' in the narrative when there is no single consensual solution available. In terms of an ethical dilemma, cases can have no clearcut solution or a single 'right' answer. Instead dilemma-based cases provide students with opportunities to think critically about ethical dilemmas and clarify their thinking [13]. An example of a decision case could be whether a civil engineer preparing bid documents for construction of a bridge should accept an offer for dinner by a bidding contractor. Issue cases, on the other hand, focus more on the 'processes' occurring in the case and allow students to deliberate about 'what is going on here' [9]. Issue cases generally do not ask students to derive a solution; rather these cases focus the student's thoughts on the things occurring in the case. Finally, historical cases have already occurred and can be used as illustrative models of ethical decisions. Herried [9] stated that historical cases 'provide plenty of opportunities for Monday-morning quarterbacking'. Examples of historical cases include the Bhopal disaster, DC-10 crashes, Challenger and Columbia disasters, etc.

Davis, specifically, identified 15 different types of cases for ethics instruction. He suggested that cases can be very different ranging from:

- long (and very long) vs. short (and very short) cases;
- present single vs. multiple perspectives;
- be in narrative vs. dialogue format;
- portray realistic (hypothetical) or real (actual) situations;
- and/or present a successful (positive) or a failure (negative) scenario [14];

They could also be:

- documents vs. summaries;
- would vs. should cases;
- or personal vs. policy.

Davis argued that cases provide opportunities for students in a professional ethics course or segment of an engineering course to focus on 'standards of conduct that apply, or might apply, to members of a certain group' such as, engineers [14]. And he further indicated that cases can help students increase their ethical sensitivity to recognize professional standards, exercise judgment on how to resolve an ethical dilemma, and enhance their ethical willpower by helping them appreciate the idiosyncrasies common among members of their profession [14].

There is a clear definition of the type of cases available for implementation, as well as the perceived benefits of utilizing these various types of case-based instruction. However, there remains little empirical evidence on whether case-based approaches are more beneficial than other teaching methods in advancing the ethical decision-making abilities of students in engineering fields.

RESEARCH ON CASES IN ETHICS INSTRUCTION: WHAT DO WE NEED?

Even though the case method is the most popular pedagogy being utilized to teach engineering ethics [15], there is little empirical evidence on whether this approach is having the desired impact on engineering students, such as promoting ethical awareness, developing moral reasoning skills, and influencing ability to approach an ethical dilemma. Researchers need to develop research methodologies that adhere to scientific principles of inquiry and provide valid and reliable evidence to support and/or refute their claims about use of cases [16, 17].

Comparing other pedagogies with the case method

Haws has highlighted six basic pedagogies which are being used for ethics instruction [2]. However, there is a lack of consensus about whether the case approach is the most effective pedagogy compared to other teaching methods (such as studying a code of ethics via a traditional lecture). Let us examine how two instructors teaching an ethics course, using two different teaching methods (e.g. case studies and code of ethics), would conduct a research study to examine which method of instruction is more effective. The research design for this study would look like Table 1.

In this research design, we use counterbalancing for the content (such as, risk vs. safety and conflict of interest) and two teaching methods (such as, cases and code of ethics) to protect against bias towards a particular content or instructor. Thus, in this basic design, Instructor A's class uses the case method for risk vs. safety topic and the code of ethics teaching method for the conflict of interest. In contrast, Instructor B's class switches teaching method for the two contents, with code of ethics method being used for risk vs. safety and case method being used for conflict of interest.

Such a research design improves the internal validity of the research allowing a researcher to have more confidence in the results that the changes on the dependent variable (i.e. students' ethical and moral skills) are a result of the treatment (in this design, cases vs. code of ethics) and not due to instructor or content bias. This 'within subjects' design offers the two advantages suggested by Maxwell and Delaney [18]. First, it

Table 1. Counterbalanced research design: comparing two teaching methods

	Topic 1: Risk vs. Safety	**Topic 2: Conflict of Interest**
Instructor A	Teaching via *Cases*	Teaching via *Code of ethics via traditional lecture*
Instructor B	Teaching via *Code of ethics via traditional lecture*	Teaching via *Cases*

allows the researcher to collect more data points from the same number of participants. In our example, each subject contributes data to both the case method and the code of ethics condition, whereas if this was a 'between subjects' design, subjects would contribute data to only one of the two conditions, i.e. either the case method or the code of ethics teaching method.

Another advantage of this research design is that it reduces the extraneous error variance because 'each subject serves as his or her own control' [18]. In our proposed research design, variability between the two conditions (case method vs. code of ethics) as a result of individual differences is removed because participants are subjected to both conditions. The practical implication of these two advantages is that it increases our statistical power [18], hence, decreasing error.

Single case research

As stated above, this research design is available when there is a single class and the instructor is using the case teaching method. Gay, Mills, and Airasian emphasized that an important principle of single-case research is the need for the researcher to manipulate only one variable at a time in order to 'rule out factors other than the treatment variable as possible causes of changes in the dependent variable'[19, 20]. Within single-case research, three designs are most popular:

1) A-B design;
2) A-B-A design;
3) A-B-A-B design.

A-B design is the simplest of single case designs. This research design involves measuring the dependent variable during the baseline phase (A), introducing the treatment and measuring the dependent variable during the treatment phase (B). For example, consider an engineering ethics course where an instructor wants to examine the impact of cases on students' ethical understanding. As a researcher, the instructor would select two topics from his or her ethics class, such as risk versus safety and conflict of interest. The A-B design dictates that the instructor first measures the dependent variable (i.e. ethical understanding) before using the case method. Thus, the instructor will teach one topic (e.g. risk vs. safety) using the traditional lecture method and then measure students' ethical understanding on the topic. The instructor would then introduce the case method

Table 2. Single-case research: simple A-B design

Phase A		**Phase B**	
Teach 'risk vs. safety' using *traditional lecture approach*	Measure dependent variable	Teach 'conflict of interest' using the *case method*	Measure dependent variable

for the conflict of interest topic and measure students' ethical understanding for the conflict of interest topic. This research design is shown in Table 2.

However, the A-B design has its flaws in terms of low internal validity. Gall, Gall and Borg argued that it is difficult to attribute any changes as a result of the treatment because the effect of other extraneous variables cannot be ruled out [20]. This makes it possible that the changes observed with A-B design are not due to the treatment, but that there exists a rival hypothesis and other events occurring simultaneously that might have produced the shift. Gay, Mills and Airasian suggested that using an additive design improves the internal validity and allows the researcher more confidence in making the prediction that any change in the dependent variable is due to the treatment [19]. An additive design has the same basic design as an A-B design, but adds another baseline and/or the treatment. There are two additive designs: A-B-A design and A-B-A-B design. In the A-B-A design, a second baseline is added after the treatment, as shown in Table 3.

To extend our previous A-B example, the A-B-A design would involve a second baseline and return to traditional lecture method for a third topic, such as honesty (see Table 3). The researcher would then measure the dependent variable (i.e. students' ethical understanding) after the second baseline has been introduced. This design improves on the internal validity of the A-B design because any changes observed on the dependent variable could be attributed to the treatment. Whereas the A-B design creates the possibility that improvements in a dependent variable are not due to treatment, the A-B-A design removes this weakness [19]. Hence, in our context the researcher could more confidently argue for the effectiveness of the case method if he/she observed that the students' ethical understanding increased on the Phase B measure and deteriorated after returning to the baseline measure.

However, there is one drawback to the A-B-A design—it ends with students not receiving instruction via the case method, especially disadvantageous if it was shown that case studies improved students' understanding of ethical and moral issues. This problem is more a matter of principle than a design flaw as the A-B-A design concludes with the control condition. The use of A-B-A-B design removes this problem. The A-B-A-B design involves re-introducing the treatment (i.e. case study method) after the second baseline. Hence, this research design requires the baseline to be measured (first A), introducing the treatment (first B), returning to the baseline (second A), and finally re-introducing the treatment (second B). The dependent variable would be measured after each of the baseline and treatment phases. Expanding upon the previous example used in the A-B-A design, the A-B-A-B design would involve re-introducing the case method (the second B) for

Table 3. Single-case research: A-B-A design

Phase A		Phase B		Phase A	
Teach 'risk vs. safety' using *traditional lecture approach*	Measure dependent variable	Teach 'conflict of interest' using the *case method*	Measure dependent variable	Teach 'honesty' using *traditional lecture approach*	Measure dependent variable

Table 4. Single-case research: A-B-A-B design

Phase A		Phase B		Phase A		Phase B	
Teach 'risk vs. safety' using *traditional lecture approach*	Measure dependent variable	Teach 'conflict of interest' using the *case method*	Measure dependent variable	Teach 'honesty' using *traditional lecture approach*	Measure dependent variable	Teach 'environ-mental ethics' using *case method*	Measure dependent variable

teaching a fourth topic, such as environmental ethics, as shown in Table 4.

Assessment of student learning

Measuring student learning to assess the impact of an intervention (e.g. case studies) is important because of the effect the type of assessment used can have on outcome measures. Berliner's argument that education research is the 'hardest science of all' is especially true when it come to measuring student learning because of the nature of the assessment [21]. Consider the first research design where we proposed that researchers counterbalance the teaching method and the instructor when comparing case method with another teaching method. This design, in spite of removing the bias towards a particular content or instructor, can become inadequate if measures of student learning are weak and faulty. For example, use of multiple-choice questions to measure student performance from the case teaching method and traditional lecture is problematic. Since the goal of case studies is to foster critical thinking and problem-solving skills in students by using real-life situations, multiple-choice questions only allow students to use their factual knowledge rather than conceptual understanding. Similarly, analysis of cases as a measure to compare case teaching and traditional instruction is also problematic as the measure is likely to be biased towards those that received instruction via cases.

Lundeberg and Yadav have argued that assessment of critical thinking and conceptual understanding requires careful construction of measures of student performance [16]. One way to do this is to give students a traditional problem and then ask them to qualitatively elaborate on their response, similar to Mazur's paired problem testing [22]. Only students with good conceptual understanding would be able to explain their solution rather than just being able to 'solve the problem'. Another means of measuring student performance is to use realistic ethical problem scenarios students are likely to face as future engineers and allow them to address the issues presented. Such a measure would require students to examine all aspects of the problem and develop a tenable solution, an approach which showcases critical thinking and problem-solving skills. It is important for researchers to create assessments that minimize the effect of the testing method on the test results 'rather than relying on tests that can be easily scored, or simply calculating differences in grades among sections' [16].

CONCLUSION

We have offered ideas about research designs and how to conduct research in order to examine the impact of cases on student learning and conceptual understanding of ethical dilemmas. However, we do not see these research models as being prescriptive and faculty should see what works best for them. We agree with Berliner's view that education research is the 'hardest science of all' and the context is what matters in research [21].

It is our hope that this paper stimulates faculty who use cases and/or researchers conducting investigations in this area into thinking about how they might assess the effectiveness of case-based instruction. This would not only allow them to make informed decisions about what works, but also build a research base. We also wish to encourage engineering faculty to collaborate with others, especially educational psychology, to create stronger research teams. In engineering education we need to think about whether cases have a long-term impact on students, and if case-based instruction impacts on their decision-making process when faced with ethical dilemmas during their career. Research also needs to be conducted to determine if engineering students are able to transfer their learning from cases to other situations.

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