Integrating Ethics into Modeling Courses in Engineering

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1. Models and Modeling

From an engineering perspective, a model can be defined as a representation of an object, system or an idea in some form other than itself. Models can be classified using a spectrum ranging from physical (exact) to mathematical (abstract). Physical models are actual "mock ups" of objects such as cars and planes. Scaled models are reduced version of physical objects such as dams and building used generally for the purpose of testing. Analog models use substituted properties of reality. Examples of analog models are gages and blueprints. Simulation models include computer simulation models and role playing games. Computer simulation models useful for analyzing dynamic situations in manufacturing or service industries, and role-playing games are useful for exploring scenarios of problem situations. Information models or data models represent information that will be stored in a database system and knowledge models capture expert knowledge for use in an expert system. Mathematical models are abstract models such as linear programming models or statistical models. In the engineering field, models are generally used for understanding, analyzing, predicting, or solving problems.

Modeling is the process of designing and developing a model. The process often rests in the hands of "modelers" knowledgeable in the process and familiar with the problem domain. The conceptual nature of the modeling process and its dependence on modelers and users give rise to numerous ethical issues. As compared to other engineering techniques, modeling may appear to be directly unrelated to the five fundamentals canons of the Code of Ethics for Engineers [1] due to the conceptual and inexact nature of the modeling process. Models are generally used for decision-making and the conclusions derived from models can have a significant impact on the safety, health, and welfare of the public. Even though a modeler may be knowledgeable in a particular modeling technique, he/she may not be competent in every problem domain and may not be aware of all the techniques that are applicable to solving problems in all problem domains. All modeling projects require reporting and documentation of results in a truthful and objective manner and modelers have to interact with clients or model users on matters related to the design, development, testing, and use of models. Modelers and their employers may be tempted to solicit modeling projects that are not in their areas of competence or offer their services for modeling projects that do not warrant their particular modeling expertise. Therefore, the fundamental canons of the Code of Ethics do directly apply to modeling. The requirement by ABET2000 to include ethics in the engineering curricula and the fact that an entire workshop on Ethics in Modeling [15] was conducted in 1989 signify the importance of this topic.

Engineering students learn in various courses a variety of modeling techniques and their applicability to solving particular problems. Engineering curricula generally focus on the

techniques and problem solving and not the ethical issues involved in applying the techniques. Engineering educators have an obligation to prepare students not only in the various modeling techniques and their application, but also increase their awareness of the ethical issues involved in modeling and help them deal with such issues responsibly in their professional careers. In this paper, integration of ethics into modeling courses in engineering is addressed and the experience gained from integrating ethics into modeling courses in engineering is presented.

2. Ethical Issues in Modeling

The traditional model building steps give rise to numerous ethical issues. A majority of the issues are applicable to various modeling techniques across disciplines and problem domains. The issues arise mainly from the murky nature of the modeling process, reliance on human skill, judgment, and interaction, and the dynamic nature of real-world problems. The following paragraphs highlight some of the significant ethical issues that can be encountered in modeling.

Selection of a modeling methodology - The selection of a suitable modeling methodology for a particular problem situation is often a difficult task due to modelers' bias for certain techniques they are familiar with and the ethical issues involved in this are quite obvious. Allison et al. [2] mention that the use of different methodologies to solve the same problem without giving consideration to differences in representation and interpretation of results can lead to contradictory conclusions and defeat the intended purpose. Waterman [16] mentions that the methodological problems that exist in expert systems include defining the correct problem space, choosing the appropriate expert, using the proper tools for knowledge engineering, developing an appropriate representation, and managing an interaction of these factors. One of the common problems in simulation models is its abuse. Naïve modelers often suggest simulation, due to its ease of use, as the technique for solving problems even though other techniques may be suitable.

Selection of modelers - Compared to other occupations, *modeling is not a certified profession*. Selecting modelers for solving a particular problem that has not been fully understood is often a difficult task and can easily give rise to some ethical issues directly related to the second fundamental canon in the Code of Ethics. Walker [14] mentions that "identification of modelers is impossible and certification of modelers is unreliable and inefficient." Further, a model may be constructed by a group of modelers with the help of clients over a period of time, and therefore, identifying and policing them will be very difficult. Gass [7] emphasizes the need for ethics education in operations research, which deals with mathematical and statistical models, and questions why there is no code of ethics for operations research.

Model construction - The construction process involves analyzing a problem and translating it to a representation using one or more chosen modeling techniques. But the process itself has not been well understood. Little [8] exclaims where models come from is often difficult to answer but concludes that models certainly favor the prepared mind. But how one analyzes a problem and identifies a representation is itself not clear [12]. For the purpose of modeling, modelers can simplify a problem using certain assumptions and relax them later when appropriate. Modelers and their clients can also influence the values incorporated in a model through the variables defined and the assumptions included in a model [9]. Mulvey [10] mentions how computerized decision procedures can be harmful to the public when ethical considerations are not addressed by the procedures and that competing choices for modeling a problem must be explored.

Data collection and analysis – This is one of the important steps in the modeling process since the data used in a model have a direct impact on the conclusions derived from the model. This step involves identifying data to be collected, designing data collection mechanisms, and analyzing the data collected for use in the model. This includes deciding which data to include or omit and what to do when the data available is insufficient or unusable. Bird et al [4] mention that the precision and accuracy of data collected can also be crucial to the success of the modeling effort. These decisions are left to the modelers and clients, and if they do not apply correct judgment, the data collection and analysis step can have a drastic impact on the conclusions derived from a model.

Model validation and verification –In the case of computer models, such as simulation models or data models, these steps can be very tedious and time consuming. Modelers have a professional obligation to validate and verify a model before it is turned over to the client or used for deriving conclusions about a problem situation. Carrier and Wallace [5] mention that naïve modelers who do not understand the underlying assumptions of a model and fail to validate them fully can commit the Type III error, that is, arriving at a wrong solution because an inappropriate empirical method was selected for the problem [13].

Interpretation of model results – Barabba's Law is "Never say the Model says" [3]. Models by themselves will not provide the answers necessary for making decisions about a problem situation. The modeler or a qualified user will have to analyze and interpret the results into valid conclusions. Deriving conclusions about a problem without analyzing the results properly can lead to erroneous conclusions. The values applied in interpreting the results can also impact the health, safety, and welfare of the public [9]. Modelers or model users who interpret results without conducting the necessary analysis will be negligent in their professional responsibilities.

Model delivery – It is the professional responsibility of the modelers to instruct the clients in the proper use of a model before turning the model over to them, and it is the clients' responsibility to follow such instructions. Ross and Harris [11] mention that failing to provide clients with adequate documentation and training can destroy the clients' confidence in the model and may also destroy confidence in decisions made using the model's results.

Model maintenance – Each model has a life of its own. This is due to the dynamic nature of real-life problem situations and the eventual obsolescence of the data used in constructing a model. It is the modelers' responsibility to inform the clients the conditions and assumptions under which a model must be used and beyond which it should be revised or discarded. It is also the clients' responsibility to follow modelers' instructions and recognize when a model has become obsolete and discontinue using it or revise the model to suit the modified situation or data. Otherwise, continuing to use an obsolete model to make decisions can have a significant impact on the safety, health, and welfare of the public.

The eight issues mentioned emphasize the need for addressing ethical issues at the various stages of the modeling life cycle. Engineering students may not readily recognize these ethical issues in modeling since the process itself appears to be inexact. Further, they may not also see the direct impact of models and modeling techniques on the safety, health, and welfare of the public as compared to tangible topics that deal with materials, product testing, etc.

3. Ethics in Modeling Courses

Numerous books and articles exhort the need for integrating ethics into engineering curricula and suggest various pedagogical approaches for doing so. However, ethical considerations are seldom taught as part of the methodology in modeling courses. This could be partly due to the lack of (1) emphasis placed on ethics by the instructors or knowledge about the topic, (2) understanding of how to go about integrating ethics in their courses, or (3) room in the course to do justice to the topic. The author addressed all three issues before attempting to integrate ethics into his modeling courses. He educated himself first on the fundamentals of engineering ethics by attending numerous seminars on engineering ethics at various ASEE conferences, attending a colloquium on engineering ethics presented by Professor Heinz C. Luegenbiehl of the Rose-Hulman Institute of Technology, participating in a week-long workshop on Ethics Across the Curricula offered by NSF and the Illinois Institute of Technology, and reviewing the relevant literature. He also acquired and/or reviewed numerous videos on ethics published by various engineering societies and the numerous web sites that contain useful information on engineering ethics. Before the semester began he prepared the lectures and course activities to include ethics at the appropriate places during the semester and also designed surveys to assess the impact of his efforts to introduce ethics in his courses.

During fall 1997, the author began to experiment with integrating ethics into his undergraduate "IENG370 Operations Research" and "IENG480 Simulation Modeling and Analysis" courses. In the operations research course, lectures on mathematical programming topics were augmented with ethics-related lectures, video presentations, and group discussions. One whole lecture was devoted to fundamentals of ethics, ethical issues in operations research, and the code of ethics. Students were taught the ethical decision making process suggested by Davis [6]. A video and a class discussion followed the lecture. Students' awareness of ethical considerations in mathematical modeling was raised through a six-part case study that addressed the first six of the eight issues discussed in Section 2 of this paper and students were required to solve this case study in teams. The last two issues, namely, model delivery and model maintenance were not included in the case study since those issues had not been covered in the course when the case study was assigned to students. The case study described a linear programming problem and the various ethical dilemmas related to the problem a modeler could encounter in real-life. The final examination also included an ethics question related to one of the topics covered in the course.

In the "Simulation Modeling and Analysis" course students were introduced to foundational concepts on ethics and the basic steps involved in conducting practical simulation studies. Similar to the operations research course, lectures, discussions, video, and handout material were used to integrate ethical considerations into this course. The eight issues that were mentioned in Section 2 of this paper were fully emphasized in this course since the course topic was ideally suited for doing so. Students were assigned a case study specifically designed to highlight ethical dilemmas in simulation modeling and analysis. The case study was based on a real-life situation encountered at a Nabisco manufacturing plant in California and reported in the news during 1996. The situation addressed the lack of adequate restroom facilities for women employees at the plant and the health problems that ensued as a result. The realistic aspect of this case study was quite effective for emphasizing the need for addressing not only ethical issues in simulation modeling, but also gender equity issues in facility design. To respond to the case study, students were encouraged to simulate the situation before analyzing the ethical dilemmas.

On the last day of the semester, students were surveyed on the effectiveness of the ethical issues included in the two courses using a comprehensive survey designed for this purpose that required students to respond to multiple choice questions and also provide written responses.

4. Conclusions

In this paper, the need for integrating ethics into modeling courses in engineering and the various ethical issues that arise in modeling topics were discussed. The approaches used for integrating ethics into two modeling courses in engineering offered at Northern Illinois University were discussed. On the whole, the experience was positive and the instructor was able to integrate ethics into these courses without sacrificing any of the course topics. The impact of the efforts on students was assessed using surveys that required students to respond to multiple choice questions and also provide written responses.

Out of the 44 students who responded to the survey 91% indicated that the coverage of ethics in the courses was adequate, 95% indicated that the resources used for conveying the ethical issues were useful for learning the concepts, 91% indicated that the discussions on ethics gave them definite tools and techniques to deal with ethical dilemmas in their careers, and 84% indicated that the assignments and discussions were sufficient to exercise the concepts on ethics covered in the course. Students' written comments indicated that the course activities raised their awareness of ethical issues in modeling, the need for modelers to exercise professional responsibility, and how tactfully one may have to resolve ethical dilemmas in real-life situations.

The experiences gained from this effort can be summarized in the form of the following recommendations for those interested in integrating ethics into their modeling courses:

1. It is necessary to plan ahead to integrate ethics into a modeling course without sacrificing course topics, design course activities that highlight ethical considerations, and assess the effectiveness of the integration attempt.
2. Ethical issues must be addressed as when an opportunity arises in the course and not address ethics at the end of the semester or through just one concentrated lecture on ethics. By including ethical consideration when discussing a topic, students will be able to include ethical consideration as part of the topic and not as a side issue to be addressed at the end.
3. Actual examples of ethical dilemmas related to the course topic experienced by the instructor or reported in the news must be discussed in class. Discussing the Challenger disaster or the Hotel Walkway collapse in Kansas City are useful but not sufficient to reinforce the ethical issues related to a course topic.
4. Ethics related assignments must be integrated with the course material so that students will learn to associate ethical issues as part of engineering concepts covered in the course and not treat ethical problems separate from the concepts covered in the course.
5. Real-life problems are not clear-cut, multiple choice problems and engineers have to deal with ambiguity, uncertainty, and face the consequences after pursuing a course of action. Therefore, as Whitbeck [17] suggests open-ended ethical problems must be assigned for students to analyze and recommend solutions that are both ethical and pragmatic.

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