Incorporating Ethics Education into an Electrical and Computer Engineering Undergraduate Program

Ms. Mahsa Ghorbani, Colorado State University

Mahsa Ghorbani is a PhD student in Program of Systems Engineering at Colorado State University. She received her BSc in Industrial Engineering from University of Yazd, Yazd, Iran in 2009 and her MSc degree in Industrial Management from University of Tehran, Tehran, Iran in 2012.

Dr. Anthony A. Maciejewski, Colorado State University

Anthony A. Maciejewski received the BS, MS, and PhD degrees in electrical engineering from Ohio State University, Columbus in 1982, 1984, and 1987, respectively. From 1988 to 2001, he was a professor of electrical and computer engineering at Purdue University, West Lafayette. He is currently a professor and head of the Department of Electrical and Computer Engineering at Colorado State University. He is a fellow of IEEE. A complete vita is available at: http://www.engr.colostate.edu/ ˜aam.

Dr. Thomas J. Siller, Colorado State University

Tom Siller is an associate professor in civil and environmental engineering at Colorado State University. He has been a faculty member at CSU for 30 years.

Prof. Edwin K. P. Chong Ph.D., Colorado State University

Edwin K. P. Chong received his B.E.(First Class Honors) from the University of Adelaide, South Australia, in 1987; and his M.A. and Ph.D. in 1989 and 1991, respectively, both from Princeton, where he held an IBM Fellowship. He joined the School of Electrical and Computer Engineering at Purdue University in 1991, where he was named a University Faculty Scholar in 1999. Since August 2001, he has been a Professor of Electrical and Computer Engineering and of Mathematics at Colorado State University. He coauthored the best-selling book, An Introduction to Optimization (4th Edition, Wiley-Interscience, 2013). He is an IEEE Fellow and was President of the IEEE Control Systems Society in 2017.

Dr. Pinar Omur-Ozbek, Colorado State University

Dr. Pinar Omur-Ozbek is a faculty in the Civil and Environmental Engineering Department at Colorado State University since 2009. She is involved with the College of Engineering's ethics education efforts through sessions and discussions on engineering ethics concepts and case studies.

Dr. Rebecca A. Atadero, Colorado State University

Rebecca Atadero is an associate professor in the Department of Civil and Environmental Engineering at Colorado State University, specializing in structural engineering. She conducts research on the inspection, management and renewal of existing structures, and on ways to promote diverse, inclusive, and equitable engineering degree programs.

Work in Progress: Incorporating Ethics Education into an Electrical and Computer Engineering Undergraduate Program

Introduction

Instruction in ethical considerations is an important part of every engineering discipline. In many programs, a student's exposure to ethical issues is delayed until the capstone senior design experience. For example, in the past we have included lectures devoted to ethics in our Electrical and Computer Engineering senior design program that start with an introduction to the National Society of Professional Engineers (NSPE) and Institute of Electrical and Electronics Engineers (IEEE) codes of ethics, and then is followed by a discussion of various ethical case studies. While this is common in many programs, surveys of our students have revealed that they do not value this instruction to the same level as the technical content that they acquire. To address this issue, our department is exploring ways to integrate ethics education throughout the curriculum as part of our NSF-sponsored RED (Revolutionizing Engineering and Computer Science Departments) project.

The core goal of our RED framework is to provide a holistic education, where we view our program as an integrated system that is a collaboration among faculty and students. Our new organizational model emphasizes knowledge integration at many levels and includes three key threads that extend throughout the curriculum, namely: foundations, creativity, and professionalism. The professional formation thread is designed to convey the importance of professional skills in the development of engineers, so that they are prepared to enter the workplace. One critical component of this thread is exposing students to ethical considerations that they may encounter in their professional careers and preparing the students to deal with them.

This paper discusses the process by which we have identified how to deconstruct the components of a traditional delivery of ethics education and integrate them throughout the instruction of technical content. A well-established method to raise the perceived relevance of ethics education in engineering is to provide discipline-specific case studies and industrial scenarios [1], [2]. By crafting case studies to the technical material that the students are currently studying, we aim to have the students make the explicit connection that ethical considerations are part of the engineering design process and not a component that is tacked on at the end. In addition, because the same faculty who are presenting the technical material are also involved in the discussion of the ethical issues that arise, we believe students will make the implicit correlation that these issues should be valued as much as the technical material. Finally, by reinforcing the ethical content at multiple touch points throughout the curriculum, we hope to see an increased sophistication of ethical analysis as the students move through our program.
The rest of this paper is organized as follows: In the next section we provide an overview on ethics education in engineering. Then we provide a background on the way we integrate technical content into knowledge integration activities and how we plan to integrate ethics into that framework. Finally we talk about a method to assess the effectiveness of our study.

Ethics Education in Engineering

One of the major thrusts in engineering education is to develop students' professional skills that go beyond the traditional technical curriculum [3]. Ethics education is a very important part of any engineering program. ABET requires that all programs seeking accreditation must demonstrate that their graduates have an understanding of professional and ethical responsibility [4].

Integrating professional skills into the technical content of engineering curriculum has always been a challenge [5]. Teaching ethics in engineering is problematic because the content may be considered too ambiguous or philosophical to the students [2]. In general engineering students are more receptive if the material is presented though case studies because it is easier for them to recognize and appreciate the relevance, rather than simply discussing abstract ethical theories [6]. However, it is essential to provide some ethical foundations. Haws (2001) recommends a combination of theoretical grounding and case studies to optimize engineering ethics instruction [7]. An additional problem can occur if the case studies used are too simplistic, i.e., there is not sufficient ethical complexity and all students converge on the same solution to the ethical dilemma [1]. Well-designed case studies are those that make students realize that in real-world ethical challenges, there will be different factors and tradeoffs to consider.

In our proposed framework for teaching ethics, we prepare case studies that are specifically relevant to the technical material in the formal curriculum, making it easier for the students to relate to the problem. In each case study, some background and general information is presented with reference to current real-world cases. This is done to make sure that students are aware of different aspects of the problem and how it is connected to other factors, such as cost analysis, existing and missing law and regulations, citizens' rights, and cultural differences. A specific scenario is presented to the students where they will make decisions as a professional facing an ethical dilemma.

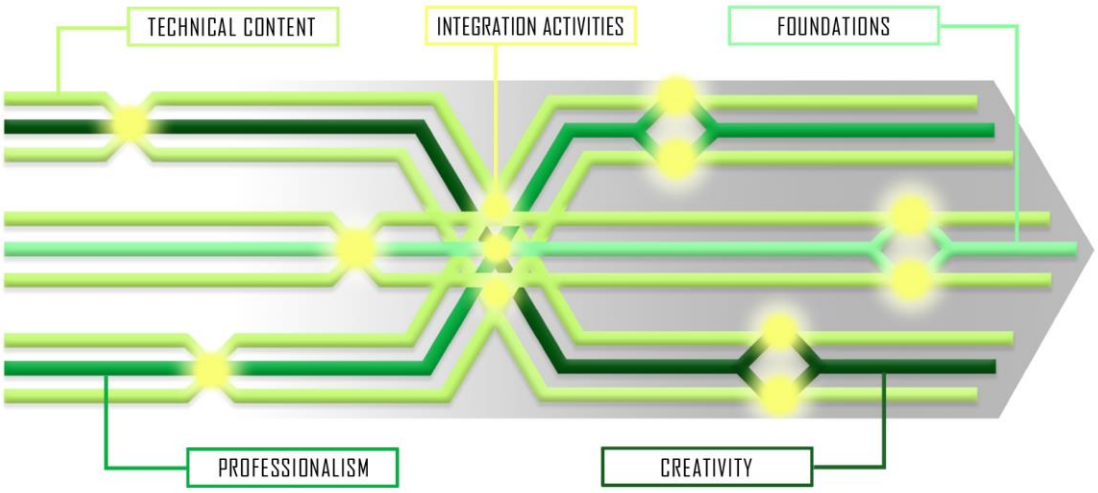
Knowledge Integration Activities and the Building Blocks for Ethics Education

As part of the RED project, our team of educators in the department of Electrical and Computer Engineering have designed a framework that treats the undergraduate curriculum as a complex integrated system. A set of knowledge integration (KI) activities are created to illustrate how different anchoring concepts can come together and be applied toward solving a real world problem. The new educational model in our department recognizes the fact that students learn abstract concepts better in the context of a set of familiar applications [8]. Using familiar applications such as cell phones, we connect the dots between the topics that they have already learned, helping them understand why they are learning the material and how they will use those concepts to solve the real-world problems. KI activities provide an ideal mechanism for adding professional skills to the curriculum. The new approach to redesigning the undergraduate curriculum is described in details in our papers "A Holistic Approach to Transforming Undergraduate Electrical Engineering Education" and "Mastering the Core Competencies of Electrical Engineering through Knowledge Integration" [9], [8].

The faculty in our ECE department emphasize the development of professional skills of our students. The professionalism thread includes five major skills: communication, cultural adaptability, ethics, leadership, and teamwork, which are aligned with the skills required to be a professional engineer in the 21st century [10], [11]. Our current method of ethics education was developed more than 10 years ago in collaboration with an IBM executive. Ethics workshops are presented to our students through the Professional Learning Institute (PLI). Although we value this approach, the mechanism for delivering ethics lectures is not well received by our students which motivates us to integrate the ethics component into the technical curriculum using KI activities.

We design the new ethics education framework to encompass all parts of the curriculum. Figure1 shows how different threads, already embedded in technical content, all come together in integration activities. Because knowledge integration activities illustrate how different technical content relates together, they provide an excellent opportunity to provide real-world ethical dilemmas closely related to the application discussed in the KI activities, for example cellphones. This shows our students how ethical difficulties can arise in their professional career and to improve their ethical reasoning skills.

Figure1. Graphical representation of RED philosophy in our department



To illustrate how we plan to integrate ethics into KI activities, Table1 shows the general schedule for three KI activities and the corresponding anchoring concepts for the second half of our junior year curriculum in spring 2018. Each KI activity is a 75-minute session run by one of the faculty members who teach the related anchoring concepts throughout the semester.

For each KI activity, a document including a set of questions on corresponding topics is sent out to the students five days prior to the KI session. Students are asked to complete the pre-work and submit their work before going to class. Our plan is to prepare a set of ethics case studies directly aligned with the anchoring concepts covered in each KI. The case studies, along with some

questions and background information will be added to the pre-work. The last 15 minutes of each KI session will be reserved for ethics discussion on that specific case.

Table1. KI activities for spring 2018

Linear Systems Analysis	Electronics Principles	Electromagnetics	KI Activities
Anchoring Concepts			
Complex-frequency spectrum analysis of continuous-time signals and systems (Laplace-transform)	CMOS Single-Transistor Circuits	High-Frequency Electromagnetic Field	KI Activity 4
Spectrum analysis of discrete-time signals and systems (Z-transform)	CMOS Output Drivers	Plane Electromagnetic Waves	
Filtering and modulation	CMOS OTA and OpAmp Design	Wave Reflection and Transmission	KI Activity 5
Computing for spectrum analysis	Circuit Frequency Response	Transmission Lines and Waveguides	
Noise	Feedback and stability	Circuit Analysis of Transmission Lines	KI Activity 6
	Noise		

As an example, KI activity 4 is a vehicle to help students better grasp the commonality and correlations between concepts covered in three ECE classes: signals, electronics, and electromagnetics. In this KI module, students concentrate on the back-end of signal transmission in a radio system where they discuss amplification of a base band signal that is mixed with the carrier signal and then radiated through the antenna. This allows the faculty to discuss the spectrum analysis of the various signals and the desired operations that are implemented using the electronics circuits they discussed in the corresponding anchoring concepts. Finally this is also related to the electromagnetic fields anchoring concepts and the design of different types of antennas, their radiation patterns, and their properties. This is a perfect time to introduce a case study on health effect of radio magnetic fields as described in the next section.

Sample Proposed Case Study

A good candidate case for a discussion on ethics aligned with KI activity 4 is the debate on electric and magnetic fields (EMF) and their effect on human health. Concerns about whether EMF could adversely affect human health were raised initially by epidemiologic studies reported in the late 1970s, and since the 1980s, findings on EMF have been widely publicized in the popular press [12]. A majority of studies have focused on cancer, particularly leukemia and brain cancer, among other health effects. Although associations have been observed in some studies, there remains considerable uncertainty about the validity and meaning of these associations [13]. As part of the pre-work for KI activity 4, a one-page introduction to the problem will be provided to the students along with a table including a list of some selected scientific findings and policy actions over the years of debate on EMF human health effects. A short case study is written inspired by the case “Risk Communication and Electromagnetic Fields (EMF)” from the Center for Ethics in the Professions at the University of Puerto Rico. In this case, a health professional

must consider his own beliefs as well as current research to decide how to communicate the potential risk of a navy project to the public. A controversy has arisen over a project by the United States Navy to build a radar facility at a site near Lajas, Puerto Rico. Much of the debate is concerned with the right of the local community to participate meaningfully in this decision. And a concern has arisen over the possibility that the facility could generate EMFs that could cause harmful health effects, namely, forms of cancer [14]. In our modified version of this case study, the professional facing the ethical dilemmas is an electrical and computer engineer. We also provide similar cases such as a case from National Society of Professional Engineering to help facilitate the discussion [15].

This case study would be tied to the technical content of the KI4. As part of the pre-work for this activity, students answer questions on electromagnetic concepts such as electromagnetic waves attenuation, radiation patterns, antenna configurations for different radiation patterns, and order of magnitude for different carrier frequencies. As part of the discussion on radiation patterns we introduce an ethics discussion on the effects of electromagnetic fields on public health.

The pre-work for the ethics module of the KI activity requires students to read through the material and answer the follow up questions, stating what they believe is the ethical responsibility of the mentioned professional in such a situation and what the rights of the community are as a stakeholder in making the decision. Submitting the pre-work before going to class ensures that students are ready to participate the class discussion, where the instructor would guide the session to make sure all aspects of the problem are covered. To assess the improvement in our students' ethical reasoning skills through the new ethics educational framework, our students are asked to participate in a survey that is described in next section.

Assessment

The most commonly used survey to measure ethical reasoning skills is the Defining Issues Test Version 2 (DIT-2). In this survey, respondents are asked to read five moral dilemmas and then rank a series of statements in terms of their moral importance [16]. When it comes to engineering ethics education, one of the drawbacks of DIT-2 is that the scenarios mainly focus on general moral development rather than ethical situations in engineering practice. Inspired by the structure of DIT-2, a new survey has been developed at Purdue University in collaboration with other schools for an engineering program that is based on projects [17]. The Engineering Ethical Reasoning Instrument (EERI) involves dilemmas that students might potentially expect to encounter in an engineering student project. Similar to the DIT-2, in each scenario students are asked explicitly what action they would take. Students are then asked to rate a series of items [18]. In its current form, there are 6 scenarios: Housing Quality, Racing Car, International Aid, Flood Control, Nurse Schedule Software, and Water Quality. Students rate 12 items in terms of importance with five response alternatives: great, much, some, little, or no. The rating process makes students reflect upon each item. Similar to DIT-2, the most important metrics are P (Post-conventional) and N2 scores where higher score values indicate higher ability to participate in complex moral reasoning.

To assess the effectiveness of our proposed ethics education framework, we obtained permission from the EERI developers to use this instrument. EERI will be used as a pretest-posttest to

evaluate the level of students' ethical reasoning skill level before and after participating in the KI activities. As we are interested in the development of students' ethical reasoning skills throughout the curriculum we have also developed a system for longitudinal tracking of students' performance on the above survey as they progress through the curriculum. Using our learning management system we developed 'course sections' that persist beyond the typical semester schedule. This allows for the storing of student work on professional skills during their entire undergraduate program. This will allow both the students and the faculty to observe the skills development over time.

Summary and Next Steps

This paper described our efforts in integrating ethics education into our technical curriculum as part of the professionalism thread. By including relevant case studies in knowledge integration activities, we help our students to realize the importance of ethical considerations and to develop their ethical reasoning skills. Our approach is founded on integrating ethics instruction with technical content and directly engaging the faculty with the ethics instruction. Others have recommended both of these approaches as being effective pedagogies for ethics instruction [19].

Our next step would be identifying appropriate ethics case studies for all KI activities. For example for the next two KIs, we are developing case studies on privacy issues in cellphones, and noise jamming. We are also planning to do a survey to evaluate students' satisfaction of this method of delivering ethics education and compare it to the results from the survey on students' satisfaction on ethics workshops from PLI.

In the future we are also planning on developing an electronic portfolio framework to replace our current approach using the learning management system. While the current approach allows for students to track their development it separates the documentation of professional skills performance from the technical content. Using electronic portfolios will allow students to also integrate artifacts showing their technical skill performance next to their professional skills development.

Acknowledgement

This work was supported by the National Science Foundation, IUSE/Professional Formation of Engineers: Revolutionizing Engineering and Computer Science Departments (RED) under Grant EEC-1519438.

References

[1] M. Hoffmann and J. Borenstein, "Understanding Ill-Structured Engineering Ethics Problems,'' *Science and Engineering*, vol. 20, no. 1, pp. 261-276, 2014.

[2] E. Alpay, "Student-Inspired Activities for the Teaching and Learning of Engineering Ethics,'' *Science and Engineering Ethics*, vol. 19, no. 4, pp. 1455-1468, 2013.

[3] T. Siller, A. Rosales, J. Haines and A. Benally, “Development of Undergraduate Student’s,’’ *Journal of Professional Issues in Engineering Education and Practice*, vol. 135, no. 3, pp. 102-108, 2009.

[4] ABET Engineering Accreditation Commission, “Criteria for Engineering Programs: Effective for Evaluation during the 2016-2017 Accreditation Cycle,’’ 2015. [Online]. Available: www.abet.org. [Accessed 10 10 2017].

[5] L. J. Shuman, M. Bestereld-Sacre and J. McGourty, “The ABET ‘Professional Skills’ - Can They be Taught? Can They be Assessed?’’ *Journal of Engineering Education*, vol. 94, no. 1, pp. 41-55, 2005.

[6] K. M. Passino, “Teaching Professional and Ethical Aspects of Electrical Engineering to a Large Class,’’ *IEEE Transactions on Education*, vol. 41, no. 4, pp. 273-28, 1998.

[7] D. R. Haws, “Ethics Instruction in Engineering Education: A (Mini) Meta-Analysis,’’ *Journal of Engineering Education*, vol. 90, no. 2, pp. 223-229, 2001.

[8] T. W. Chen, A. A. Maciejewski, B. M. Notaros, A. Pezeshki and M. D. Reese, “Mastering the Core Competencies of Electrical Engineering through Knowledge Integration,’’ in *American Society of Engineering Education Annual Conference*, New Orleans, 2016.

[9] A. A. Maciejewski, T. W. Chen, Z. S. Byrne, M. A. De Miranda, L. B. Sample Mcmeeking, B. M. Notaros and A. H. Rosales, “A Holistic Approach to Transforming Undergraduate Electrical Engineering Education,’’ *IEEE Access*, vol. 5, pp. 8148-8161, 2017.

[10] D. Fisher, “Fostering 21st Century Skills in Engineering Undergraduates through Co-Curricular Involvement,’’ in *American Society of Engineering Education Annual Conference*, Indianapolis, 2014.

[11] American Society for Engineering Education, “Transforming Undergraduate Education in Engineering, Phase I: Synthesizing and Integrating Industry Perspectives,’’ Arlington, 2013.

[12] L. I. Kheifets, R. S. Greenberg, R. R. Neutra, G. L. Hester, C. L. Poole, D. P. Rall and G. Lundell, “Electric and Magnetic Fields and Cancer: Case Study,’’ *American Journal of Epidemiology*, vol. 154, no. 12, pp. S50-S59, 2001.

[13] L. I. Kheifets, G. L. Hester and G. L. Banerjee, “The Precautionary Principle and EMF: Implementation and Evaluation,’’ *Journal of Risk Research*, vol. 4, no. 2, pp. 113-125, 2001.

[14] W. J. Frey, “Risk Communication and Electromagnetic Fields (EMF),’’ Center for Ethics in the Professions at the University of Puerto Rico Mayagüez, 2010. [Online]. Available: http://www.uprm.edu/etica/engcases.html. [Accessed 5 11 2017].

[15] National Society of Professional Engineers (NSPE), “Recommendation Regarding Mitigation of Electromagnetic Field (EMF) Exposure," 2010. [Online]. Available: https://www.nspe.org/resources/ethics. [Accessed 8 10 2017].

[16] J. R. Rest, D. Narvaez, S. J. Thoma and M. J. Bebeau, “DIT2: Devising and Testing a Revised Instrument of Moral Judgment," *Journal of Educational Psychology*, vol. 91, no. 4, p. 644, 1999.

[17] Q. Zhu, C. B. Zoltowski, M. K. Feister, P. M. Buzzanell and W. C. Oakes, “The Development of an Instrument for Assessing Individual Ethical Decisionmaking," *American Society of Engineering Education Annual Conference*, Indianapolis, 2014.

[18] C. B. Zoltowski, P. M. Buzzanell and W. C. Oakes, “Utilizing an Engineering Ethical Reasoning Instrument in the Curriculum," in *American Society of Engineering Education Annual Conference*, Atlanta, 2014.

[19] A. Colby and W. M. Sullivan, “Ethics Teaching in Undergraduate Engineering Education," *Journal of Engineering Education*, vol. 97, no. 3, pp. 327-338, 2008.