Social, Ethical and Global Issues in Engineering

Efrain O’Neill-Carrillo, William Frey, Luis Jiménez, Miguel Rodríguez, David Negrón
University of Puerto Rico-Mayaguez

Abstract - The College of Engineering of the University of Puerto Rico-Mayaguez (UPRM) adopted an ethics across the curriculum (EAC) strategy in 2005. EAC is based on the combination of faculty development workshops, a stand-alone course in ethics, and ethics learning modules integrated at various levels of the engineering curriculum. In 2006 the EAC strategy was expanded to include social and global issues in engineering. A Coordinator for Social, Ethical and Global Issues (SEGI) in Engineering was appointed in the College of Engineering to coordinate and support activities related to these areas at all engineering departments. Such a position is valuable in demonstrating the commitment to educating integral engineers that are both technically capable and socially responsible. This SEGI work presents a more integrated curriculum to students through activities that link liberal arts courses and topics to engineering. The position also serves as a liaison with other Colleges in these matters, and supports the achievement of eight of the learning outcomes from ABET’s criterion 3. This paper describes the various activities of the coordination of the SEGI work, and its relationship to the general education component of engineering curricula.

Index Terms – Social impact, global awareness, ethics, liberal arts, general education, EC 2000

INTRODUCTION

The student learning outcomes of the University of Puerto Rico-Mayagüez (UPRM) state that by the time students graduate they will be able to:

a. Communicate effectively
b. Identify and solve problems, think critically, and synthesize knowledge appropriate to their discipline
c. Apply mathematical reasoning skills, scientific inquiry methods, and tools of information technology.
d. Apply ethical standards.
e. Recognize the Puerto Rican heritage and interpret contemporary issues.
f. Appraise the essential values of a democratic society.
g. Operate in a global context, relate to a societal context, and demonstrate respect for other cultures.
h. Develop an appreciation for the arts and humanities.
i. Recognize the need to engage in life-long learning

Within UPRM’s College of Engineering, these institutional outcomes are met by each Engineering program through the attainment of ABET’s Criterion 3. From the eleven a-k outcomes, eight are directly related to skills, abilities or knowledge that go beyond “purely” engineering courses: multidisciplinary teams, professional and ethical responsibility, effective communications, impact of engineering solutions in a global and societal context, lifelong learning, contemporary issues. These basic skills, or the so-called “soft skills” are necessary for a successful practice of the engineering profession. The attainment of these “soft outcomes” represents what a “liberal education” should help students accomplish. A liberal education providing these outcomes empowers individuals, cultivates social responsibility, and is the best preparation for the interconnected, global workplace of the 21st century. On the other hand, the engineering major should deepen the skills and knowledge provided in the general education courses in the context of the engineering profession. The major should be a complex context in which students communicate to multiple audiences, evaluate ethical implications and connect with other disciplines [1].

Until recently, many UPRM engineering students took blocks of courses without understanding the relationships among courses from different fields of study. There was no general education overarching goal or framework at UPRM, other than the student learning outcomes listed earlier. Each UPRM College had the responsibility of developing programs and curriculum aligned with the learning outcomes. That changed with EC 2000 and the revised accreditation guidelines from Middle States. Re-accreditation efforts presented a challenge and an opportunity to create links and improve the connectedness of general education and major areas within UPRM.

This was part of the context in which an ethics across the curriculum (EAC) strategy was adopted in UPRM’s College of Engineering in 2005. EAC refers to the practice of incorporating ethics in a holistic and interdisciplinary manner through academic programs [2]. By integrating ethics into the engineering curriculum as an integral and central component, EAC dramatizes the importance of ethics in practical affairs and emphasizes it as more than just a curriculum requirement. Ethics must be integrated into the actual training of the engineering and science students and not seen as something extraneous to science and engineering practice [2]. As such, ethics instruction should not be left only as an external course taken in the Humanities Department, but rather as an intrinsic part of engineering education and profession. Nevertheless, the adoption of EAC did not occur by chance, there was a long tradition of ethics
instruction at UPRM that eased the way for this holistic view of engineering instruction.

**HISTORICAL BACKGROUND**

This section describes the necessary conditions that made possible the adoption of EAC in UPRM’s College of Engineering. The instruction of Engineering ethics began at UPRM with the development of a course in the early 1980’s followed closely in 1985 with the publication of Ética Profesional para la Ingeniería [3] by a UPRM professor. This textbook, the first of its kind in Puerto Rico, consisted of three parts, the first devoted to engineering ethics, the second to the philosophy of technology, and the third to the theology of technology. The engineering ethics section reflected the issues present in the 1985 code of ethics of the Puerto Rico State Society of Professional Engineering and Land Surveying or the CIAPR (according to the Spanish acronym). This section treated issues like public wellbeing, faithful agency (the engineer/client relationship), and a historical account of and engineering’s journey into professionalism. As is consistent with the micro ethics perspective, this section explores engineering ethics from the standpoint of the individual engineer. On the other hand the other two sections (the philosophy and theology of technology) broaden the inquiry into such macro ethical issues as the social and global impacts of the technologies developed in engineering activity. This approach comprises the first stage in teaching engineering ethics at UPRM.

In the second stage, the philosophy of technology separates out from engineering ethics as macro ethics splits from micro ethics. Different courses (engineering ethics and philosophy of technology) explore these different ethical dimensions. While nearly a quarter of UPRM engineering students take one or the other course, most engineering students graduated without exposure to engineering ethics in either its macro or micro form. Part of the reason for this was that engineering ethics was not recognized during this period as a distinct discipline warranting focused study. Engineering ethics was subsumed by philosophy and humanities courses. For example, faculty from philosophy taught engineering ethics as the special application of philosophical ethical theories (utilitarianism, deontology, and virtue ethics) to cases that pertained to engineering such as Ford Pinto, McDonnel-Douglas DC-10, Three Mile Island, and BART. The assumption was that a general exposure to humanities, philosophy or ethics was sufficient to equip engineering students to deal with the ethical problems that arose in their discipline. Most notably, engineering codes of ethics were looked down on as ways of acquainting students with ethical issues in engineering practice. Along the lines laid down by John Ladd, codes interfered with moral autonomy because they gave rise to the misconceptions that good behavior could be reduced to rules grounded in the authority of a professional elite. Fear of losing autonomy by embracing the teaching of professional ethics using codes [4].

An ethics across the curriculum approach (see Figure 1) eventually replaced this pedagogy of applied philosophy in the late 1990’s. Engineers and ethicists, working in small groups in a series of workshops and retreats, identified ethical issues in engineering practice, developed short cases to present these issues, and designed classroom modules (micro interventions) to introduce this material into the mainstream engineering curriculum. This ethics across the curriculum approach promised to help students anticipate and face the ethical issues in likely to arise in engineering practice. It also made it possible to reach more students. Since micro interventions could be designed for insertion across the engineering curriculum, this approach allowed for reaching more students and for better integrating ethics naturally into the engineering curriculum [1]. A hybrid approach also made it possible to combine the best aspects of micro interventions and freestanding courses. The cases and modules designed by faculty in workshops could be tested and refined in freestanding engineering ethics courses. Then they could be integrated as modules into mainstream engineering courses. Engineering faculty could be empowered to teach these micro interventions in their own classes through a “train the trainers” approach. It is this hybrid approach that dominates the current scene in engineering ethics instruction at UPRM. The EC2000 criteria increased the significance of engineering ethics at UPRM, with its strong emphasis on professional and ethical responsibility, as well as the impact of engineering solutions in a global and societal context. There are also references to the effectiveness of interventions across the curriculum over teaching a single course in engineering ethics [5].

![FIGURE 1](image)

**STRUCTURE OF UPRM’S ETHICS ACROSS THE CURRICULUM [11]**

Workshops organized by UPRM’s Center for Ethics in the Professions led by Dr. William Frey empowered and encouraged engineering faculty to develop their own modules for integration in their courses. Very positive examples are available in literature on these initial efforts by engineering faculty [6-10].

**EAC ADOPTION**

In the Fall of 2005, the College of Engineering appointed Dr. Luis Jimenez as Coordinator for Ethics in Engineering.
The main objective was to establish an Ethics Across the Curriculum (EAC) strategy that integrates ethics exercises and modules developed by engineering faculty into their engineering courses. The purpose was to ensure the timely integration of ethical reflection into strategic points of the engineering curriculum in order to help students understand that ethics is a central, not a peripheral, component of engineering education. A pilot program was initially developed, implemented and validated at the Electrical and Computer Engineering (ECE) Department [8-9]. It was also implemented in the Materials and Engineering Sciences Department in courses taken by all engineering students such as Engineering Graphics. At this moment a series of ethical themes and values are to be promoted among students. The column at the left indicates the courses where this theme or value is to be discussed in the engineering curricula. Table I shows the work done in this first phase of EAC work at the ECE Department.

<table>
<thead>
<tr>
<th>COURSE</th>
<th>EAC MATRIX: WHAT WE'RE DOING, GAPS AND OPPORTUNITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETHICS THEMES</td>
<td>ETHICS THEMES</td>
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<tr>
<td>Basic Concepts</td>
<td>Professional Integrity</td>
</tr>
<tr>
<td>Academic Integrity</td>
<td>Engineering Codes &amp; Engineering Design</td>
</tr>
<tr>
<td>Yr 1: Graphics for Engineers</td>
<td>1 to 2 hours module</td>
</tr>
<tr>
<td>Yr 5: Capstone or Engineering Design Experience</td>
<td>2 to 3 hours module</td>
</tr>
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Other important accomplishments of this first phase of EAC were the establishment of an EAC Committee in the College of Engineering, the development of initial assessment tools and data collection methods, Faculty Development Workshop for Engineering Graphics Faculty, Publications on peer review conferences based on the assessment findings, and the development of a Research Ethics module to students and faculty that participates in the Research Project on Material Science at the General Engineering Department. An ethics module for engineering laboratories is being developed for delivery in the third year of engineering studies at UPRM.

**FROM EAC TO SEGI**

In the Fall of 2006, the EAC strategy was expanded to include social and global issues in engineering. A Coordinator for Social, Ethical and Global Issues (SEGI) in Engineering was appointed in the College of Engineering to coordinate and support activities related to these areas at all engineering departments. Such a position is valuable in demonstrating the commitment to educating integral engineers that are both technically capable and socially responsible. This SEGI work presents a more integrated curriculum to students through activities that link liberal arts courses and topics to engineering. The position also serves as a liaison with other Colleges in these matters, and supports the achievement of eight of the learning outcomes from ABET’s criterion 3. The ultimate goal of this work is to show students and faculty, that engineering is not practiced in isolation, but rather, on a social context with ethical implications and in many occasions with global dimensions.

The SEGI philosophy is to present a more integrated curriculum by creating thematic areas in socio-humanistic elective courses (listing existing courses by areas) and presenting the engineering profession as one that deals not with “technical” systems, but rather socio-technical systems. The objective is to have a facilitator role at the College of Engineering to gather current efforts, document, disseminate and help adapt them in other courses/contexts. Thus the effort has a “bottom-up” approach in order for it to be sustainable within each department. For example, the Mechanical Engineering Department has had Dr. William Frey as a presenter of ethics in engineering for the last 15 years in the ME capstone course. Dr. Frey has agreed to continue on this role, and is currently collaborating with the SEGI Coordinator to analyze the data Dr. Frey has collected in the last semesters in terms of assessment of mechanical engineering students with regards to ethics. In other programs, such as Industrial and Civil Engineering, the SEGI Coordinator has delivered the Ethics in Engineering Design Module developed and tested in ECE Capstone Courses.

Although the focus of the work has been on the delivery and assessment of the ethics module for engineering capstone courses [8], other SEGI activities include:

- Development of modules on the History of Engineering, Liberal Arts, Global Awareness and International Engineering and Economic Analysis
- Draft course on Social, Ethical and Global Dimensions of the Engineering Profession (Brief history of engineering, global and interdisciplinary dimension of engineering, social responsibility and engineering design, professional ethics, public policy and the engineering, sustainable development and engineering)
Courses as they see fit. The modules present a more coherent can make the modules their own, integrating them to their presented previously in [8-9].

The ethics module has been the fulfillment of a common goal. A brief description of four emphasis on developing a common “language” that allows the modules to students through an integrative perspective for the globalization, and point in some directions in terms of the preparation needed to deal with working in this global environment [12].

III. Global Awareness and International Engineering

The objective of this module is to expose engineering students to the global dimensions of the engineering profession. This includes impact of engineering decisions, opportunities and challenges of practicing in an international context. The module briefly presents reasons for the globalization, and point in some directions in terms of the preparation needed to deal with working in this global environment [12].

IV. Sustainable Engineering and Economic Analysis

This module presents sustainability as an option for engineering practice. A balance between the economical, social and environmental aspects of engineering decisions is proposed as a way of dealing with the reality of scarce resources and a growing local and global population [13]. It includes an introduction to life cycle analysis as a tool for sustainable engineering. Sustainability is presented as an example of an interdisciplinary area in which many of the professional skills are needed, and thus collaboration of many professionals is required.

Preliminary Assessment and Adaptability

An assessment test is given before and after each workshop, to test its effectiveness in increasing student awareness of the workshop’s topic. The instrument allows presenters to modify the workshop to address those areas in which participants still had problems as identified in the post-test. The assessment tool for the ethics module included the following questions:

1. All ethical norms are relative to the culture
2. As long as you act according to local laws, you are acting legally

3. You cannot act morally unless you are a religious person

4. A student copies a picture from a website and uses it on a report for an engineering design course. As long as the source is cited, there is no copyright violation.

5. Writing an article, a professor takes ideas from another professor without proper acknowledgement. Is this an ethical violation?

6. Professional codes of ethics provide all the professional help needed to be an ethical engineer

7. Although ethics problem solving shares some traits with engineering problem solving, the technological dimension of engineering does not allow full integration of ethical analysis in engineering decision making.

The ethics module is the one more broadly assessed, and has been delivered in all six engineering programs at UPRM. Assessment results are encouraging, and show the effectiveness of the module in introducing students to engineering ethics.

The strategy followed at UPRM is “train the trainers”. The College of Engineering coordinated EAC seminars by ethics experts that allowed Engineering Faculty to integrate ethics concepts in their courses. To adapt the EAC strategy in other programs would require similar training sessions since many engineering professors have not been exposed to formal ethics training. It is also important that programs value the time and effort needed to adapt these topics into engineering courses. At UPRM the College of Engineering provides academic release to the SEGI Coordinator to continue the “train the trainers” strategy and provide support to other engineering professors in their efforts to provide a more broad perspective of engineering ethics.

Nevertheless, besides the SEGI Coordinator at the College level, a professor from each program should act as “champion” for a SEGI-like effort, especially in large programs. At UPRM a faculty from each program, interested in SEGI activities, was identified and selected to be part of an EAC committee that is now a SEGI committee. Such faculty involvement is vital in order for the integration of social, ethical and global issues in engineering to be successful.

CONCLUSIONS
An ethics across the curriculum (EAC) strategy has been adopted at UPRM’s College of Engineering. It was made possible by a strong tradition of engineering ethics education from members of UPRM’s Center for Ethics in the Professions. The EAC strategy has been expanded to include the social and global dimensions of engineering. The main objective of the expanded strategy is to provide students with a more integrated perspective on their curriculum and the engineering profession. An important task is the development, delivery and assessment of instructional modules that help student apply and deepen the knowledge gained in general education courses. Faculty involvement and support from the Administration are vital in order to achieve a truly integrated perspective on teaching and learning engineering through the educational modules described in this paper.

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AUTHOR INFORMATION

Efraín O’Neill-Carrillo, UPRM Coordinator for Social, Ethical and Global Issues, College of Engineering, oneill@ece.uprm.edu

William Frey, Ethics Coordinator, UPRM Business Administration, freyuprm@yahoo.com

Luis Jiménez, Professor, Electrical and Computer Engineering Department, UPRM, jimenez@ece.uprm.edu

Miguel Rodriguez, Graduate Student, Electrical and Computer Engineering Department, UPRM, angelo_26@hotmail.com

David Negron, Undergraduate Student, Electrical and Computer Engineering Department, UPRM