

# Incorporating Ethics in Engineering Education

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**Abstract:** Ethics and ethical behavior are typically not discussed in the classroom and made an integral part of engineering education. However, there is an awareness in the engineering profession that academic dishonesty in undergraduate and graduate education is very likely to lead to similar behavior in professional practice. In this paper, a case is made for incorporating ethics as an integral part of any course and curriculum, and setting up a framework to promote and handle ethical behavior in institutions of higher learning. Examples involving traditions and practices at Arizona State University (ASU) help illustrate author's views on ethics and ethical behavior.

**Keywords:** Ethics, engineering education.

## 1. Introduction

Engineering is defined as a profession that helps solve societal problems while engineers participate in this endeavor as creative problem solvers. Often, while the focus of students and educators is narrow involving the contents of a specific course, the science and engineering knowledge, the tools used to solve problems in the classroom and in engineering practice, and the realities of running a business and earning a livelihood, need to be examined in the context of a wider audience - societal values, role played by educational institutions, professional or organizational approaches to problem solving, and the political climate and system under which the engineering profession operates. This complex problem has several facets - education and the role of assessment in education (K-12 and beyond), an individual's decision making perspective that evolves with time, an organization's framework to define, practice and enforce appropriate decision making, and the political systems that lay the foundation for regulations and laws governing society and countries.

A person's exposure to ethics starts early with elementary school education and the role of assessment in education. Sometimes students and parents cite unreasonable amounts of reading and writing work, and unrealistic level of expectation as the two major factors that encourage cheating. While one hears similar statements at all levels of the educational ladder, one would expect that assessment instruments are rigorously discussed and refined, and

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then implemented in the classroom. Student evaluations should "be ethical, fair, useful, feasible, and accurate" [JCSEE, 2003] and it is a challenge to create and administer ethical assessment practices [Felder, 2002; Green et al., 2007]. With competition to gain placement in any country's leading engineering, business, law, and medical schools, today's students and their well-wishers all over the world are under extraordinary competitive pressure to perform well [McCabe et al., 2001; CBS News, 2013; Fu, 2013; Rao and Borwankar, 2016]. It is important that discussions involving ethical behavior start early in a person's career path [Mathur and Corley, 2014]. In this paper, the authors discuss the topic of ethics in the classroom and "offer suggestions, grounded in education literature, for addressing ethics explicitly and for developing a critically reflective perspective toward ethical decision-making". Interestingly enough, they contrast one view of public education - "... to improve the financial condition of individuals and to advance the prosperity of the nation. Hence students should do well on standardized tests, get into good colleges, obtain well-paying jobs, and buy lots of things. Surely there is more to education than this?" [Noddings, 2003] with their own view - "...to contribute to the person's journey toward responsible selfhood."

At institutions of higher learning, engineering ethics education plays a significant role in the formation and reshaping of the engineer's ethics [Hamad et al., 2013]. In their review, the authors look at attributes of ethical engineers, contents, logistics and pedagogy of engineering ethics, and assessment of engineering ethics. While there is consensus that engineering ethics and engineering ethics education are important, they argue that it is difficult to create and integrate engineering education curricula for a number of reasons. Billington [Billington, 2006] explores using history to discuss in the classroom "uniquely engineering situations" that challenges engineers to act responsibly. Newberry [2004] points out that scholarly work on engineering ethics follows three investigative paths - "What should engineering students know to have an understanding of professional and ethical responsibility? By what methods is that knowledge to be imparted? And, how is that understanding to be measured?" Newberry concludes that the systemic barriers that prevent thorough discussion of ethics in the classroom include student's lack of emotional engagement with ethical issues, and "lack of expertise and role modeling by faculty".

And finally, the ethical issues at the professional level continue to garner attention. Giges [Giges, 2012] cites the large number of recent advisory opinions issued by the Board of Ethical Review of the National Society of Professional Engineers as involving such diverse issues as conflict of interest, expert witnesses and accepting gifts and other payments.

Rather than tackle the entire spectrum of ethics-related topics, the focus of this paper is narrow. The rest of the paper is divided into three parts. In the next section, a case is made for incorporating ethics in the context of a rich engineering curriculum where there are courses and outside-the-classroom opportunities that address different aspects of the ethical problem mentioned earlier including an introspective look at ethical dilemmas in profession-related scenarios. This is followed by a detailed examination of how to practice ethics in the classroom. The next section deals with an institutional framework for handling academic integrity cases within the institutional framework. Finally, the last section summarizes the paper.

## **2. Incorporating Ethics in the Engineering Curriculum**

Incorporating ethics in the engineering curriculum requires that all concerned - administrators, faculty, staff, professionals, accreditation agencies, and the students, participate in setting the direction in all educational institutions. There are several approaches to incorporating ethics in the curriculum with two more popular approaches being a course dedicated to engineering ethics and an approach where different aspects of engineering ethics are an integral part of a course. At most universities, the second approach is the preferred route mainly because there is no room for a dedicated course and because of the lack of training on part of the faculty to deal with a wide variety of engineering ethics topics.

In the civil engineering degree program at ASU, the freshmen level students take FSE 100 - Introduction to Civil & Environmental Engineering in which they are taught the importance of ethics in engineering practice. At the sophomore level, students take CEE 300 - Engineering Business and Practice. In this course, concepts of problem solving, ethics, and professionalism are addressed in the context of civil engineering applications. Finally, at the senior level, students have the option of taking an elective CEE 481 - Civil Engineering Project Management where

quality control, quality assurance, intellectual property, ethics, and safety are discussed. Clearly, there is room for improvement and for a more holistic treatment of the topic of engineering ethics.

Drawing on observational case studies of engineering education and site visits at eleven undergraduate engineering programs at seven US engineering schools, Colby and Sullivan [2008] offer five suggestions to strengthen the preparation of undergraduate students for the ethical-professional dimensions of their work. First, they suggest using the codes of engineering ethics to help the students understand the ethical and professional responsibilities and help inculcate in the students a lasting view "that engineering competencies, a commitment to high quality work, and a drive to keep learning throughout one's career are inseparable from other aspects of professionalism." Second, realizing that there is no room in most curriculum, they suggest that "if students are to begin developing the full range of competencies that a broad conception of professional responsibility implies", then other activities such as EPICS and similar activities can be used. Third, they recommend the use of practice-based education to develop professional responsibility in engineering. While some engineering programs require an internship or co-op program, courses that deal with engineering design are perhaps the closest to giving students a look at professional and ethical development opportunities. Fourth, they state that without an engaged faculty it is not possible to integrate ethics and professional responsibility throughout the curriculum. And lastly, they argue that students' moral and civic educational experience works best where there is institutional support for multi-faceted initiatives right from freshmen year to senior capstone projects.

In the two courses that the author teaches - an undergraduate course on structural analysis and design, and a graduate course on computer programming for finite element analysis, an effort is made to discuss practice-oriented ethics. Case studies make the discussions more relevant. For example, in the structural analysis and design code, the discussions center around grey areas where engineering judgements need to be exercised during the course of modeling, analyzing and designing structural systems - approximations in structural models, computation of loads, variability in material properties, uncertainty in boundary conditions, etc. Links are drawn to examples of engineering failures

where incorrect judgements have led to catastrophic failures - Tacoma Narrows Bridge failure that took place because aeroelastic flutter during wind loading was not accounted for, the failure of I-35W Mississippi River Bridge failure in Minneapolis due to inadequate design of the gusset plates and overloading of the bridge during rehabilitation and repair, and the Hartford Civic Center roof collapse whose analysis and design did not include large deformations and eccentric connections. During team projects where a part of the grade is assigned for the efficiency and total cost of the design, attention is drawn to ethical problems in competitive bidding.

In the graduate course, the discussions are once again tailored around the course contents. Some of the discussions deal with intellectual property - why it needs to be protected, how it can be protected, and the role that open source software plays in stimulating innovation and research. Other discussions deal with the role of software in modern society and the importance that must be given to understanding the strengths and limitations of software (and hardware), quality assurance tests, dissemination of software, considerations for the end user and so on. Attention is drawn to ACM's Software Engineering Code of Ethics and Professional Practice - "Software engineers shall commit themselves to making the analysis, specification, design, development, testing and maintenance of software a beneficial and respected profession. In accordance with their commitment to the health, safety and welfare of the public, software engineers shall adhere to the ... eight principles - public, client and employer, product, judgement, management, profession, colleagues and self" . The link between software engineering and structural engineering is drawn through an analysis of development and use of finite element software for structural analysis and design, something that is perhaps more difficult to do in a purely software engineering (or, computer science) class.

### **3. Practicing Ethics in the Classroom**

Understanding engineering ethics should start with practicing ethics in the classroom. There are several actions that faculty can take to encourage academic integrity within and outside of the classroom. Some institutions have adopted honor codes that are defined as "a set of rules or ethical principles governing an academic community based on ideals that define what constitutes honorable behaviour within that community. The use of an honor

code depends on the notion that people (at least within the community) can be trusted to act honorably." While it is universally accepted that the mere existence of honor codes does not solve the cheating problem, "many of the principles on which such codes are built can be implemented on any campus" [McCabe et al., 2001]. An example honor code used in the Schools of Engineering at ASU can be found at <https://engineering.asu.edu/integrity/>. Research has shown that the effects of using honor code are mixed, much like passive ways of combating cheating. In a study involving 695 students from six colleges and universities only half of which had incorporated honor code systems, researchers [Arnold et al., 2007] found that - "(a) Even though no significance was found in the difference in the level of academic dishonesty between institutions with or without honor code systems, a significant difference was found in the perception of student cheating between the two types of institutions. (b) Students from honor code institutions perceived that the amount of academic dishonesty at their institutions was lower. (c) No significant difference was found in the level of student cheating regarding the size of the institution. (d) However, the study found that students from the large-sized universities perceived that they were more likely to get away with cheating than students from the small and medium sized institutions." Some claim that honor codes should be dropped since they "stifle collaboration and encourage cheating" [Greenberg, 2015]. Others argue for the use of pre-task warnings over traditional honor code since they are easy to implement, especially in online examinations and are more effective [Corrigan-Gibbs et al., 2015]. It has been the experience of the author that honor code must be used in conjunction with an involved discussion of the repercussions of cheating, to be an effective deterrent tool.

In the rest of this section, discussions will be centered around integrity-related framework within Arizona State University. First, it is important that the institution incorporate ethics in all policies and procedures documents. For example, a typical educational institution should have written documents addressing policies and procedures governing academic affairs, environmental health and safety, facilities construction and management, financial services, purchasing and business services, research and sponsored projects, managing assets, student services, campus police department, and faculty and staff (<http://www.asu.edu/aad>). These written documents should not only be readily

available but should be reviewed and modified periodically in a transparent manner that involves and solicits input from all constituents. At the second level, each unit of the institution, e.g. schools or colleges, should create their own academic integrity guidelines that supplement the institution's overall policies and procedures. In ASU's Schools of Engineering, this support is provided by the Dean's Office. In order to address specifically the issues relating to academic integrity policies, the Vice Dean and an Assistant Dean work with the School's faculty, staff and students. For example, general guidelines are provided to the faculty to promote academic integrity in all degree programs [Skromme, 2012]. At the third level, each academic unit should formulate, promote and practice its own guidelines and policies. Typically, these are formulated by the faculty assembly and promoted and practiced by individual faculty. Finally, at the ground level, the individual instructors and their assistants teaching the courses are responsible for academic integrity issues within the framework of the course that they teach.

It is possible to mitigate the effects of course-related cheating by following common sense guidelines. Here is a list that the author has formed and refined over the years.

(1) Every instructor should discuss the student's performance expectations for the course at the beginning of the course. It helps that both the instructor and the student understand what the course objectives and expectations are and work towards common goals. For example, in the undergraduate course that the author teaches every semester [Rajan, 2015], the grading philosophy is described in one section of the course syllabus - "There are several prerequisites to this course including Statics, Dynamics, Deformable Solids, Linear Algebra and Numerical Analysis. I expect that you are comfortable with the use of material from these courses that form the foundation of material in this course. An A+ student is one who is comfortable interpolating and extrapolating material discussed in the class, and can with minimal guidance, self-learn new material - a rare, extraordinary trait. An A/A- student is very comfortable with vast majority of the material and can perform structural analysis/design with relative ease. The student has demonstrated effective and creative thought processes. A B+/B/B- student can demonstrate on their own, mastery of more than half of the structural analysis/design concepts. The performance is clearly above average. A C+/C student

is one who is performing satisfactory work and with the help of the instructor can demonstrate a satisfactory understanding of structural analysis/design. A D student is one who has demonstrated unsatisfactory but passing work."

(2) Very clearly state the ethical policy for the course. The policy should be unambiguous as to what constitutes ethical and unethical behavior, and what the penalties are for unethical behavior. For example, in the courses that the author teaches, a simple rule that is followed is explained in the class - If an assessment item has the name of a single student, then the entire work must be done solely by the student with no outside help except the help that the teaching assistant and the instructor provide the student in understanding the assignment. Similarly, for team projects where there are several individuals working as a team, the entire work must be done solely by these individuals with no outside help except, once again, those provided by the teaching assistant and the instructor. This is necessary since different instructors have differing ethical policies.

(3) Recognize the students by name and interact with them inside and outside of the classroom. Encourage them to discuss ethical issues so that they recognize when they need to ask for clarifications. Create a positive and rich learning environment where students learn from each other when appropriate and know when not to cross that boundary.

(4) In-class assessment work: This assessment work is the easiest to control. With increasing class sizes in most institutions, it makes sense to create multiple versions of an exam that are printed on different colored paper so that it is easier to see what version of the exam each student is working on. In addition, one can create a seating chart so that students who typically study together do not sit close to each other. Recognizing that students complain that there is too much of information to recall during a quiz or exam, assessment in engineering courses should be based on application of knowledge, not on regurgitating material discussed in the class. In all the courses that the author teaches, students are allowed to use the textbook or electronic notes during the quiz or exam. Furthermore, one should avoid repeating questions from previous exams or those discussed earlier in the class so as to discourage students from memorizing solutions or solve problems simply as the lowest form of "pattern matching" exercise. The use of technology poses new challenges. Should cell phones, smart

watches and computers (laptops, tablets) be banned during a quiz or exam?

(5) Out-of-class assessment work: When appropriate, the weightage for such assessment items should be minimal simply because unsupervised work cannot be adequately assessed for authenticity. With the ready availability of resources on the internet, it is a challenge to police the work. However, when important and challenging assessed work needs to be done under unsupervised conditions, one should use technology to one's advantage. At ASU, the Blackboard learning management system is used. The system has a SafeAssign tool [BlackBoard, 2016] "...to review assignment submissions for plagiarism potential and create opportunities to help students identify how to properly attribute sources rather than paraphrase. SafeAssign is effective as both a deterrent and an educational tool. SafeAssign compares submitted assignments against a set of academic papers to identify areas of overlap between the submitted assignment and existing works." Similarly, when students write and submit software, a system like MOSS [MOSS, 2016] can be used. "Moss (for a Measure Of Software Similarity) is an automatic system for determining the similarity of programs. To date, the main application of Moss has been in detecting plagiarism in programming classes. Since its development in 1994, Moss has been very effective in this role." There are many other online tools that can be used to detect plagiarism.

(6) Train teaching assistants and graders to recognize unethical behavior. Make these individuals a part of the classroom environment so that they are aware of the classroom discussions involving ethical behavior and how to handle these situations.

(7) The institution should have a centralized system for all instructors to report the violations in their course. At ASU, all violations are reported to the Dean's office. The Vice Dean interviews the student and provides an opportunity for both sides of the incident to be heard. The two-strike policy puts the student on notice after the first incident and readily tracks repeat offenders while protecting student confidentiality.

The author has implemented the items in the list in two courses mentioned earlier. The undergraduate course has a large enrollment (approximately 100 students/class) with a very diverse student population in terms of skill sets. About 35-30% of the students

have taken the pre-requisite courses at other institutions. The weightage for outside-of-the-class individual assessment items and for team projects is about 15% of the total grade. The rest of the grade involves in-class assessment work in the form of quizzes and exams. The author has found this to be an equitable way of gaging the individual mastery of the students over the course objectives with the highest level of confidence in the assessment process and the limited resources available for carrying out the assessment (a teaching assistant and 2-3 undergraduate teaching assistants help in course instruction).

A different assessment philosophy is used in the graduate course where the assessment must involve work that is substantial and must be carried out over a longer period than is available in the classroom. The class enrollment is, from a historical perspective, quite high - between 35 and 40 students. A majority of the students are international (non-US) students. About 55% of the grade is made up of project work that is conducted outside of the classroom. This work primarily involves writing C++ code in the context of linear algebra, numerical analysis and introductory finite element analysis [Rajan, 2016b]. The rest of the grade is composed of in-class quizzes and class participation.

#### **4. An Institutional Structure for Handling Academic Integrity Cases**

It is important that institutional leaders first acknowledge that systemic cheating exists and that they must address the destructive effects of cheating. "Acknowledging student cheating as corruption rather than as simple misbehavior will generate strategies that are less about managing cheating and more about institutionalizing academic integrity. This willingness to direct attention to the negative and address student cheating within the current system is the essential precondition to strategic planning." [Gallant and Drinan, 2006]. This type of thinking makes it possible to address various facets of this problem at all levels of the institution.

Addressing this problem at ASU starts at an early stage in some courses and programs where first year undergraduate and graduate students are required to review ASU Academic Integrity Policy (<http://provost.asu.edu/academicintegrity>). The violations cover five broad areas that include but are not limited to cheating on an academic evaluation or

assignment, plagiarizing, academic deceit such as fabricating data or information, aiding academic integrity policy violations and inappropriately collaborating, and falsifying academic records. To raise awareness of such broad areas, classroom discussions need to take place with specific examples connected with the course being taught. Some academic programs take this one step further by requiring the students to review ASU's policy, write a one-page paper on how each student would maintain academic integrity during their education, and take a web-based test on plagiarism. It should be noted that it is a challenge to maintain a high ethical standard unless a vast majority of courses reinforce the concepts and enforce the standards uniformly.

When a case of academic integrity violation is detected, ASU Student Academic Integrity Policy stipulates the steps that must be taken to resolve the allegations. The first item addresses student obligations and defines what academic dishonesty is in terms of fourteen broad actions, e.g. "Refers to materials or sources or uses devices (e.g. computer disks, audio recorders, camera phones, text messages, crib sheets, calculators, solution manuals, materials from previous classes, or commercial research services) not authorized by the instructor for use during the Academic Evaluation or assignment", "Signs an attendance sheet for another student, allows another student to sign on the student's behalf, or otherwise participates in gaining credit for attendance for oneself or another without actually attending", etc. The second step deals with the details of the allegations. A stipulated procedure must be followed to discuss and resolve the allegations and proposed sanctions, and the "procedures are designed to encourage a fair and appropriate response to allegations of academic dishonesty". The student is then given an opportunity to appeal the allegations and sanctions. Each school/college then appoints an ad hoc board to conduct the review or may have a standing board to hear such cases. The board conducts the hearing and forwards its recommendations to the Dean or Director. A student may seek to have a Dean's or Director's decision reviewed by the University Hearing Board only if the final decision imposes a sanction of suspension or expulsion from the university, revocation of admission or revocation of a degree.

#### **5. Concluding Remarks**

As discussed in this paper, without imposing undue

burden on an educational institution and its faculty, staff and students, it is possible to incorporate ethics and ethical behavior in engineering education. The effectiveness of such a system is dependent on certain key components - institutional support with buy in from administrators and faculty, documents that clearly state what the institutional and individual policies are, enforcement of the policies, and finally peer pressure to ensure that all those involved (administrators, faculty, staff, professionals, accreditation agencies, and the students) abide by the stated rules and regulations and make an effort to see that the rules and regulations are enforced. A data analysis to examine the effectiveness of the practices in ASU (or any other institution) and specifically, in the classes taught by the author is difficult to conduct for a number of reasons. Since student information is confidential, administrators are reluctant to release data that can be used for a reasonably thorough analysis (aggregate data is usually available but not details of the violations, e.g. course number, nature of the integrity violation, number of students involved in each violation etc.). From the author's experience in the two courses, the number of cases of cheating has certainly declined ever since focused classroom discussions on ethics and ethical behavior have been integrated into the courses.

The sporting world provides us with very powerful examples that illustrate how imperfect society is. Peer pressure is a double-edged sword - peer pressure can push an athlete to cheat in the same way as peer pressure (stigma?) can make an athlete think twice before resorting to unethical means to win at any cost.

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