Sounding the depths- Assessing Cadet Knowledge of Engineering Ethics

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Abstract

The United States Coast Guard Academy (USCGA) is one of five Service Academies. USCGA has served the country for over one hundred years by educating and training generations of Coast Guard Officers. Like all service academies, USCGA's curriculum contains requirements for both officer training and degree completion. A course in Ethics is among the core curricular requirements.

Since the four USCGA Engineering Programs are ABET-accredited, all cadets majoring in engineering have additional coursework in Engineering Ethics. Over the past several years, Engineering Ethics has been taught as part of capstone design courses in each major. This is an alternative to teaching Engineering Ethics as separate course. Given that Ethics is a core requirement, the decision to teach Engineering Ethics as a module in capstone design courses, as opposed to a separate course, has not been in question. What has been a concern is assessing student knowledge of Engineering Ethics.

This paper will describe USCGA efforts to assess ethical knowledge of graduating cadets through interactive discussions at Ethics Luncheons and results of standardized testing. In addition to outlining past and current USCGA efforts to assess ethical knowledge, this paper will propose a different, ABET-based approach to assessing ethical knowledge.

Introduction

The United States Coast Guard Academy (USCGA) is one of five Service Academies training and educating future officers for service. USCGA offers eight majors, with four of the eight in Engineering (Civil, Electrical, Mechanical and Naval Architecture and Marine Engineering). USCGA seeks accreditation for all programs, including ABET accreditation for its Engineering programs.

Prior to the last ABET visit in 2007, three of the four engineering programs had very short plans for addressing 3f. [1], [3], [4] Electrical Engineering had a more robust plan, but the faculty were uncomfortable with many of the items included in the assessment because the program had no control over most the items. [2] The problem was relying on other departments and divisions to support Engineering Programs when and if changes need to be made. It is much easier to only include assessments in courses controlled by the programs.

The Need to assess Ethical Knowledge

Institutions seeking ABET accreditation for Engineering Programs must publish and document student success at mastering student-specific outcomes. Table 1 outlines ABET's list of required student outcomes. As noted by ABET, student outcomes should lead to program graduates attaining the program's educational objectives. Each degree program should list and prepare documentation for each outcome (a-k). If a program has additional student outcomes, they should be included. Notable among the student outcomes is Criteria 3f- an understanding of professional and ethical responsibility. Different institutions and programs interpret 3a-k differently. This is accepted as part of the ABET accreditation process, and allows institutions and programs to address its interpretation and approach to addressing these outcomes .

Table 1: ABET Criterion 3 Outcomes [5]

Criterion 3. Student Outcomes
(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Since the latest ABET Criteria allows each program to define its own performance indicators for these outcomes, every institution struggles to define their approach to developing outcome measures- USCGA is no exception. Some ABET Criterion 3 requirements are easier to document than others because they are measured at several points, so there are many more opportunities to assess these skills. For example, Criterion 3a- an ability to apply knowledge of mathematics, science and engineering, can be assessed in any number of Math, Science and Engineering courses. Proving an institution or program prepares students to solve various problems using their engineering, science and mathematics knowledge can be as simple as having standardized examination questions on several exams in different classes. How does a program measure its students' understanding professional and ethical responsibilities? What does it mean for a student to demonstrate understanding versus an ability to do something?

Bloom's Taxonomy of the Cognitive Domain may prove helpful in addressing these questions. Bloom's Taxonomy was developed by a group of educational psychologists to classify cognitive skills. In short, Bloom's Taxonomy is guide for measuring how well someone has learned some subject matter. Table 2 outlines Bloom's Revised Taxonomy.

Table 2: Bloom's Revised Taxonomy [6]

Cognitive Skill	Expectations/Objectives	Verbs for Objectives
Remember	Shallow processing, drawing out factual answers, testing recall and recognition	Choose, describe, define, identify, label, list, locate, name, recite, select, state
Understand	Translating, interpreting and extrapolating	Classify, defend, demonstrate, distinguish, explain, express, extend, indicate, infer, match, judge, paraphrase, present, restate, rewrite, select, summarize
Apply	Knowing when to apply; why to apply; recognizing patterns of transfer to situations that are new, unfamiliar or have a new slant for students	Apply, choose, explain, generalize, judge, organize, prepare, produce, select, show, sketch, solve, use
Analyze	Breaking down into parts, forms	Analyze, categorize, classify, compare, differentiate, distinguish, identify, infer, survey
Evaluate	Evaluation based on some set of criteria, and state why	Appraise, judge, criticize, defend, compare
Create	Combining elements into a pattern not clearly there before	Choose, combine, compose, construct, create, design, develop, do, formulate, invent, make, make up, originate, plan, produce, tell

By applying Bloom's Taxonomy to ABET's Criterion 3f, an understanding of professional and ethical knowledge would be a lower level cognitive skill. The expectation may be that students are not able to resolve all ethical dilemmas presented to them, but at least be able to recognize dilemmas, understand why the dilemmas exist, and know where to seek help to resolve those dilemmas.

In assessing student understanding, faculty can use Bloom to develop an assessment of a higher cognitive skill to measure a lower one. For example, cadets' understanding could be measured by having them read cases and write a judgment as a board of ethical review, based on an engineering code of ethics (ASCE, ASME, IEEE, NAME or NCEES). In this exercise, cadets would have to be able to recognize dilemmas, understand why the dilemmas exist, and based on an engineering code of ethics, decide if the action taken by the engineers in the case were acceptable.

Can, May and Should

Figure 1 is an attempt to graphically capture the education cadets to which cadets are exposed. Science teaches what can be done, Law teaches what may be done, and ethics teaches what should be done. As part of the core curriculum, cadets take courses in Martine Law Enforcement, Criminal Justice and Morals and Ethics. In addition to coursework, cadets participate in ethics training provided through the Cadet Division. This training includes the Ethics Forum, which is a day-long series of Ethics addresses by individuals with Military, Medical, Philosophical and Engineering backgrounds.

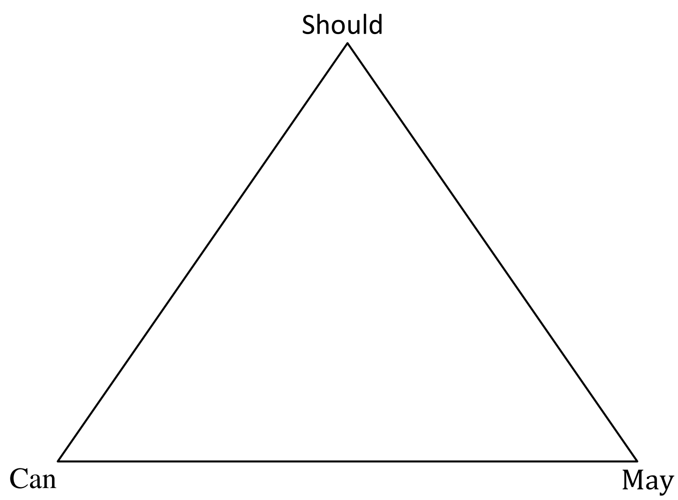

Figure 1: Cadet Education and

The combination of academic coursework, military experiences such as Cadet Honor Concept, Cadet Honor Board and Ethics Forum give cadets a big-picture understanding of where the lines between legal/ illegal and ethical/unethical behavior are. The introduction of profession-specific ethics (ie- Engineering Ethics) is included in senior level courses. A proposal was offered previously to modify the Morals and Ethics course to include a section on profession-specific ethics. The proposal called for 85-90% of Morals and Ethics to be taught by Humanities Faculty, and the remaining portion of the class to be taught by faculty from the majors. This proposal would have required major-specific sections of Morals and Ethics, as well as identifying faculty that could absorb additional teaching load. The proposal failed.

The Engineering Department has also used an Ethics Luncheon as a method of exposing cadets to Engineering Ethics. The Ethics Luncheons were designed to have faculty discuss Ethics with cadets in a casual roundtable setting. The luncheons were held every semester, with First Class Cadets required to attend three of the four luncheons offered during the semester and write a paper discussing the ethics of a particular case. The first year, the Luncheon was very successful. First Class Cadets enjoyed the informal Ethics discussions with faculty. As the Luncheons were modified, the amount work increased, and as faculty members rotated to new duty assignments, interest in continuing the program waned.
A course in Engineering Ethics could be developed and offered very quickly. The course would extend exploration of topics covered in Morals and Ethics, and then focus on engineering-based ethics and case studies. To add this course to the curriculum would require the loss of the only free elective cadets in engineering majors currently have. According to the current course catalog, two of the four engineering majors only have one elective- the free elective. The other two majors have either one free and two major electives, or two free electives. [7] Given the amount of coursework and training devoted to the subject of Ethics, keeping Ethics in Capstone Design and Construction Management is probably the best choice.

Measuring an Understanding of Ethics

As programs have settled on when assessments will be done, rubrics have been developed to measure understanding. Both ABET 3c and 3f have Ethics as a component. Two rubrics currently under development attempt to measure an understanding of ethics as well as the ability to design with constraints including ethics. The rubric addressing 3c is in Appendix 1- ED03 and the rubric addressing 3f is in Appendix 2- ED06.

Rubrics for outcomes 3c and 3f were developed using "silent brainstorming" and "grouped affinity" activities. Outcome 3f was judged to be sufficiently general such that all four of CGA's engineering programs could reasonably share common performance indicators and levels of performance. Therefore, the rubric for outcome 3f was developed by a department-wide assessment committee for use by all four programs. However, outcome 3c, which deals with design, was judged to be program-specific, and accordingly, the development of the rubric was best addressed by the respective program faculty.

Both rubrics are structured as analytic rubrics. The rubric for outcome 3f features two performance indicators: (1) awareness and understanding of the code of ethics, and (2) Ethical Judgment, including problem recognition and solution description. The first performance indicator is structured to exactly meet the minimum requirements for "understanding;" the first is actually structured to assess mere awareness or knowledge of any professional society's engineering code, as is actually focused at the "remember" level of achievement (a level below "understanding") to determine if awareness itself is potentially a contributing factor to a hypothetical cadet's failure to achieve the desired level of this outcome. This was deemed important because, as mentioned above, cadets receive extensive exposure to ethics, exposure which include rigorous academic preparation and practical training exercises in the course of their military duties. However, this training is either general in nature or tailored to the Coast Guard profession, which means it is not necessarily tailored to the engineering profession specifically. The "awareness" line of the rubric, then, provides a means to assess if the existing four-year program of study adequately exposes the cadets to professional society codes of ethics.

The "ethical judgment" performance indicator actually exceeds the minimum level of "understanding" and instead specifies problem recognition and problem solving as the minimum levels of performance. As such, this performance indicator actually specifies a level of performance in excess of that required by ABET. However, considering the mission of the institution and the objectives of the programs, which include successful service as a US military officer, the higher level of attainment was deemed appropriate and necessary to enable ultimate achievement of these objectives.

This higher level of attainment is also evident in the performance indicators associated with outcome 3c. Here the causal relationship between objective and performance indicator is not as obvious. Specifically, outcome 3c defines the "ability to design...within realistic constraints such as ...ethical..." This raises the question: what level of attainment of ethics is necessarily to allow its consideration as a design constraint? Is this "understanding," or a higher level on Bloom's taxonomy?

The program faculty considered this carefully and decided that to include ethical considerations in design actually involved the application of ethics--in other words, a level of attainment on Bloom's taxonomy above "understanding." The performance indicators for this rubric (which is also an analytic rubric) address "awareness" (much as for the outcome 3f rubric)--but extend the concept of attainment in the ethics performance indicator to include "end use." This performance indicator implies that the level of attainment of an engineer for ethics needs to be at the "application" level...above the "understanding" specified in outcome 3f.

The tie between the level of performance expected of an individual in ethics at the US Coast Guard Academy is therefore driven by two factors: (1) A level of performance that includes "application" that is driven by the institution's mission and the objective of military service for its graduates, but also by (2) a level of performance that is driven by the ability to "apply" ethics to design...an expectation of "application" that is driven by the program objective of producing an "engineer."

Therefore the level of achievement of "ethics" for an engineer at the Coast Guard Academy needs to be at the "application" level for two reasons: (1) to prepare the cadet for service as a Coast Guard Officer, and also (2) to prepare the cadet to perform as an engineer capable of considering ethics as a realistic design constraint. Significantly, even without the military mission of the Academy, reason (2) still implies that the all engineers should be capable of applying ethics to their designs, which implies that the wording of outcome 3f is such that the level of expected attainment ("understanding") is set too low."

The Engineering Department at the United States Coast Guard Academy is in the early stages of creating assessments to measure ABET's 3c and 3f Criteria for Ethical knowledge. With the creation of two rubrics, the department has the ability to start gathering data. The next step is to validate the rubrics. After validating the rubrics, the next step is to create other assessments that would allow the programs and department to triangulate data.

References

[1] Civil Engineering Summer 2009 Program Review, United States Coast Guard Academy Department of Engineering

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[4] Naval Architecture and Marine Engineering Summer 2009 Program Review, United States Coast Guard Academy Department of Engineering

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[6] Bloom's Taxonomy "Revised" Key Words, Model Questions and Instructional Strategies, http://www.stfrancis.edu/content/assessment/BloomRevisedTaxonomy_KeyWords.pdf, University of St. Francis Assessment Council, accessed 27NOV2010.

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Biography

RICHARD W. FREEMAN has served as a lecturer in the U.S. Coast Guard Academy's Electrical Engineering Section since 2008. Prior to joining the faculty, he taught fulltime for eight years. He also worked in the Telecommunications Industry for eight years. He earned BS and PhD degrees in Computer Engineering from Iowa State University and a MBA from Southern Methodist University. He is pursuing his Professional Engineering License.

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Group/Project Name ________________________ Item Assessed ____

ED03: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

A. Economic		
Unsatisfactory	**Satisfactory**	**Excellent**
1. Time value of money Does not consider time value of money concepts in design or when making design decisions	Computes and considers time value of money calcs—such as cash flow diagram, Present Worth (PW), Future Worth (FW), annualized amount (A), and rate of return(ROR)—when making design decisions	Computes and considers time value of money calcs (such as cash flow diagram, PW, FW, A, ROR) AND performs cost/benefit analysis, decision calculations for multiple projects of unequal life
2. Budget Designs incorporate components, processes, or materials that consume too much of the budget—other components are left under-funded	Designs incorporate components, processes, or materials that whose cost allows other components to be fully funded	Designs incorporate components, processes, or materials that result in significant cost savings relative to existing available technology

B. Ethical		
Unsatisfactory	**Satisfactory**	**Excellent**
1. Intellectual Property Awareness Cannot recognize or answer copyright, patent or license questions	Recognizes need for answers to copyright, license and patent question	Conducts patent searches independently, recognizing and seek proper/sufficient answers to copyright, license and patent question.
2. Intellectual Property Use Makes use of copyrighted, licensed or patented material w/o permission and/or attribution	Properly makes use of copyrighted, licensed or patented material with permission and/or attribution.	Properly makes use of copyrighted, licensed or patented material with permission and/or attribution
3. Ethical End Use Designs processes, technology or devices intended or clearly capable of being used to circumvent the letter and spirit of laws, regulations, or ethical guidelines	Designs processes, technology or devices that are not intended or clearly capable of being used to circumvent the letter and spirit of laws, regulations, or ethical guidelines	Designs processes, technology or devices that improve upon either the enforcement or ability of others to follow the letter and spirit of laws, regulations, or ethical guidelines

C. Safety		
Unsatisfactory	**Satisfactory**	**Excellent**
1. Safety in Design Designs do not consider all realistic failure modes or fail apply a suitable factor of safety to each.	Designs are analyzed for all realistic failure modes, and a suitable factor of safety is incorporated into the design for each mode.	Designs are analyzed for multiple simultaneous failure modes or “cascading casualties.” Fail-safe features in the design limit negative effects.
2. Safety in Manufacture Designs systems, components or processes that require fabricator to circumvent safe practices.	Designs system, component or processes for which the prototype and final product may be constructed meeting all safe practices	Designs system, component or processes for which the method of manufacture contributes new technology/technique that improves existing safe practices
3. Safety of product use Use of final system, component or process exposes personnel or machinery to unacceptable risk	Use of final system, component or process does not expose personnel or machinery to unacceptable risk of injury.	Use of final system, component or process improves upon the safety of current technology or practices.

D. Manufacturability		
Unsatisfactory	**Satisfactory**	**Excellent**
1. Manufacturing Capability Design cannot be manufactured using existing technology in available facilities	Design may be manufactured using existing technology and available facilities	Designs systems, components or processes that extend or enhance the manufacturing capabilities of existing facilities
2. Manufacturing Efficiency Design process did not consider material, machine time, or labor cost	Design process considered waste. Re-design took place to reduce amount of waste relative to original design.	System, component, or process is optimized to minimize waste in one or more ways (material, machine time, or labor)

E. Social, Political, Environmental, Sustainable		
Unsatisfactory	**Satisfactory**	**Excellent**
Designs increase net pollution, negatively disrupt quality of human life or institutions, or accelerate consumption of non-renewable resources.	Designs are pollution neutral, have little impact on human life or institutions, and do not accelerate consumption of non-renewable resources	Designs reduce net pollution, positively impact human life or institutions, and retard or eliminate the consumption of non-renewable resources

Please include your candid comments. Use the back of this sheet if needed.

Assessors Name ______________________ **Date** ___________________ **Title**______________ **Org.** ___________________

Group/Project Name ________________________ Item Assessed ____

ED06: An Understanding of Professional and Ethical Responsibility ("Ethics")

F. Code of Ethics		
Unsatisfactory	**Satisfactory**	**Excellent**
3. Awareness		
☐ Unaware of Engineer's Code of Ethics	☐ Aware of Engineer's Code of Ethics	☐ Aware of Engineer's Code of ethics and can name several key components from memory
4. Understanding		
☐ No understanding of Engineer's Code of Ethics	☐ Understands key portions of Engineer's code of ethics	☐ Can explain inter-relationship between components of code

G. Ethical Judgment		
Unsatisfactory	**Satisfactory**	**Excellent**
4. Problem Recognition		
☐ Fails to recognize the ethical problems with a given situation	☐ Recognizes key ethical problems (honesty, fairness, conflict of interest) in a given situation	☐ Recognizes key ethical problems and other related ethical issues, and can articulate the trade-off between apparently conflicting ethical positions.
5. Solution		
☐ Fails to describe an ethical solution to even the simplest of problems	☐ Can describe an ethical solution to problems involving one ethical dimension	☐ Can describe an ethical solution to problems involving multiple or apparently conflicting ethical dimensions

Please include your candid comments. Use the back of this sheet if needed.

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Assessors Name ______________________ **Date** ___________________ **Title**______________ **Org.** ___________________