Ethics and the Development of Professional Identities of Engineering Students

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ABSTRACT

How do undergraduate students in engineering conceive of themselves as professionals? How can a course on engineering ethics affect the development of an undergraduate student's professional identity? In this project, students responded to questions about the characteristics and responsibilities of professional engineers. The results indicate that students learn about professionalism primarily from relatives and co-workers who are engineers, and rarely from technical engineering courses. Even before they study engineering ethics, students put honesty and integrity on par with technical competence as an essential characteristic of engineers. In the course, students benefit from cases of actual incidents and from classroom activities that encourage diverse perspectives on moral problems. By analyzing cases in groups and by hearing different perspectives, students build self-confidence in moral reasoning. By the end of the course, some students understand professional responsibility not only as liability for blame but in a capacious sense as stewardship for society.

Keywords: engineering ethics, professional identity

I. INTRODUCTION

Since the late nineteenth century, academic programs have replaced apprenticeships in educating professionals, including engineers [1]. Consequently, academic programs now bear the primary responsibility for preparing students to become engineers. If we think of engineering education as socializing students to become professional engineers, then we can apply the standard four-stage model of role acquisition [2]. In the *anticipatory* stage, the student learns about the profession through contact with engineering practitioners and through the mass media. In the *formal* stage, the student learns the formal expectations of engineers, such as design processes, technical standards, and licensure requirements. In the *informal* stage, the student learns about unofficial expectations and everyday practices. Finally, in the *personal* stage, the student reconciles the social expectations for engineers with his or her personal identity. Perhaps only a few undergraduate students reach the final stage, at which being an engineer is integral to the student's identity. Nevertheless, during their undergraduate years, engineering students begin to develop their identities as professionals.

Studying the development of professional identities of law students, Floyd [3] determined that the overemphasis on analyzing legal opinions is "boring" for students. In law school, the valorization of analytical skills may discourage students from improving interpersonal skills, which are essential for professional practice. Similarly, in engineering education, Florman [4] called the overemphasis on solving technical problems "laborious and disagreeable." In engineering school, the inculcation of disciplined habits may socialize students in undesirable ways [5].

In the early 1960s, Perry [6] studied the intellectual and moral development of college students. His research subjects were undergraduate men and women enrolled at Harvard and Radcliffe. Since then, Perry's model has been tested with other populations of college students. Psychologists and philosophers have studied the development of moral identity [7–10]. But there has been little empirical work on whether and how instruction in ethics affects an undergraduate student's moral development, beyond improvements in moral reasoning skill [11, 12].

In this project, I focused on the effect of instruction in engineering ethics on the development of an undergraduate engineering student's professional identity. I addressed the following questions.

- During their studies, how do undergraduates in engineering develop their self identities as nascent professionals, particularly their understandings of engineers' ethical obligations?
- How can instruction in engineering ethics affect the development of a student's professional identity?

In an engineering ethics course, we cannot expect all students to develop their professional identities in the same way. Because students come to a course with a variety of backgrounds and developmental stages, different students internalize different ideas. In this project, therefore, I describe the profound insights and the significant changes in conceptions of professional identities experienced by some students—not necessarily by all or most students. Furthermore, I document which aspects of the engineering course inspired these insights and changes. In other words, I seek to identify the potential for deep learning in a course on engineering ethics.

From the data that I gathered from students during the 2003–04 academic year, I found that students learn about the characteristics and responsibilities of professional engineers primarily from observing relatives and co-workers who are engineers. According to students, the ideal engineer is honest, conscientious, and confident, as well as technically competent. In a course on engineering ethics, students became more confident about their moral reasoning skills, and they can develop a more sophisticated understanding of professional responsibility that includes awareness of social consequences.

A preliminary version of this paper was presented as a work-in-progress paper at the Thirty-Fourth ASEE/IEEE Frontiers in Education Conference [13].

II. Method

ECE 216*, Engineering Ethics, is an elective course for juniors and seniors [14]. ECE 216 has no formal prerequisite other than expository writing at the freshman level. ECE 216 carries three semester hours of credit. Although it is offered by the Department of Electrical and Computer Engineering, the course is cross-listed with the Department of Philosophy, and it satisfies the campus's general education requirements for advanced composition and for humanities and creative arts. ECE 216 requires five short papers of three pages each and a research paper of eight or more pages; each paper must be revised. In addition, each student writes two one-page reflection papers each week, usually on the assigned readings; these reflection papers are similar to learning logs and journals. There are no examinations.

The course emphasizes ethical issues in engineering at the level of individuals and organizations, rather than social policy. These ethical issues include professionalism, responsibility, confidentiality, conflict of interest, risk and safety, relationships between engineers and managers, loyalty, whistle-blowing, codes of ethics, licensing, and choosing a vocation. ECE 216 relates general ethical theory to concrete problems in engineering, using a textbook [15], additional readings, videotapes, short scenarios about everyday problems, and case studies about major events: the *Challenger* disaster, the BART (Bay Area Rapid Transit) case, and the *Citicorp Center* case. For their research papers, students study ethical issues in a contemporary controversy, such as stem cell research, mammalian cloning, genetically modified foods, nuclear weapons, and copyright laws for digital media. Most students in ECE 216 are in electrical engineering or in computer engineering, but some students are majoring in other engineering disciplines or in business.

During the 2003–04 academic year, the enrollments in ECE 216 were 39 students in the fall semester and 38 students in the spring semester, for a total of 77 students over the academic year. At the beginning of each semester, students provided information about their backgrounds, including their previous work experiences. Although they were traditional aged students (around 20 years old), nearly all had previously been employed. About half had had pre-professional experiences, usually as summer engineering interns.

As potential research participants, all ECE 216 students completed consent forms. These forms were sequestered until the end of each semester so that I would not know who had consented to participate until after I had submitted course grades. Most (59) of the 77 students consented to participate, including nine of the 10 women.

At the beginning of the fall 2003 and spring 2004 semesters, I required all students in ECE 216 to complete an initial essay assignment about the characteristics and responsibilities of professional engineers. I asked them to plan, compose, and write an essay of 400 or more words that responded the following questions:

- What are the characteristics of the ideal professional engineer? What are the engineer's most important professional responsibilities? Give specific examples. Explain your reasoning.
- What people and experiences have shaped your understanding of these characteristics and responsibilities? How have they done so? Describe specific incidents or actions you have taken. Possible sources could include relatives, friends, employment, courses, student organizations, etc.
- To what extent do you feel that you have these characteristics and are prepared for these responsibilities? Why or why not? How would you know that you are a professional engineer? Give specific criteria.

Students who were not majoring in engineering were invited to interpret the questions for their intended professions instead.

Students wrote this essay at a computer in approximately one hour. This method of collecting data is less labor-intensive than conducting and transcribing individual interviews. This method does not guarantee that students answer each question explicitly in detail, however.

At the end of each semester, for the final reflection paper, I asked the students how their answers to the questionnaire had changed as a result of taking ECE 216. For both the initial essay and the final reflection, students' responses were *not* graded for content; the final reflection paper received only a completion grade (*present* or *absent*). Students could express their opinions without concern about grades.

At the beginning of the spring semester, because of an oversight, I obtained copies of initial essays from only 12 students. I had 28 initial essays from the fall semester. Thus, in total, I analyzed 40 initial essays that responded directly to the questionnaire. Because some students did not submit the final reflection paper, I had 49 final reflections to analyze (27 in the fall, 22 in the spring).

III. Analysis

To analyze the students' initial essays and final reflections, my undergraduate research assistant and I used a simple coding scheme; we believed that we could gain insight into the students' responses without resort to sophisticated methods of textual analysis. We classified the students' responses into a small number of categories and looked for related words within each category. For example, students said that professional engineers should be ethical, using adjectives such as *honest* and *trustworthy*, and nouns such as *integrity* and *moral standards*. The details are specified in the appendix below.

Because the undergraduate research assistant had not taken ECE 216, she had no strong preconceptions about the intended outcomes of the course. She knew which documents were initial essays and which were final reflections—each had a name and a date. When we paired the two documents for the same students, we discerned no clear patterns. Therefore, in the sequel, I report only overall trends, with numerical frequencies. Despite the inclusion of numerical data, I want to emphasize the interpretation of the students' statements. In particular, statements from the final reflections can provide compelling evidence of deep learning.

The findings presented below may not generalize to other institutions, for three reasons. First, although the population of students who took ECE 216 in 2003–04 was reasonably diverse in gender, race, ethnicity, and pre-professional experience, there were other ways in which this population lacked diversity. Most students were majors in electrical engineering or in computer engineering; these

* In August 2004, this course was renumbered ECE 316.

engineering disciplines have weaker traditions of professionalism than, say, civil engineering, which has a long tradition of concern for the safety and welfare of the public. Second, the students who took ECE 216 may have had a stronger prior interest in professional ethics than other students. Third, the students' understandings of professionalism may have been affected by the particular content (readings, videos, topics, etc.), pedagogy (case discussions, role-plays, written assignments, etc.), and instructors for these offerings of ECE 216. The content, pedagogy, and instructors can not be duplicated exactly at other institutions.

A. Characteristics and Responsibilities of Professional Engineers: Initial Essays

Despite concerns about the detrimental effects of engineering programs [5], it appears that regular engineering courses influence the development of the student's professional identity much less than do people. In the initial essays, most students (28 of 40) reported that they learned about the responsibilities and characteristics of professional engineers primarily from relatives, co-workers, and friends who are engineers. Far fewer students (11 of 40) cited courses, professors, or student organizations as major influences; almost all cited professors were parents or had worked outside the academy. Subsequent interviews [16] corroborated these sources of students' understandings.

Students listed four kinds of characteristics of ideal professional engineers:

- *Technical competence:* technical knowledge, problem solving skills, creativity.
- *Interpersonal skills:* communication skills, effective teamwork.
- *Work ethic:* conscientiousness, diligence, persistence.
- *Moral standards:* honesty, integrity.

These characteristics are consistent with a similar survey by Pritchard [17]. According to practicing engineers [18], professional engineers require a variety of non-technical competencies, such as awareness of societal consequences, communication skills, and interpersonal skills.

Although the questionnaire did not mention ethics explicitly, students frequently (25 of 40) identified honesty or integrity as an important characteristic. In general, they conceptualized moral standards as honesty, but they meant more than truthfulness, candor, and avoiding deception; they implied other kinds of moral obligations such as fairness, keeping promises, trustworthiness, caring, and civility. For example,

> "The ideal professional engineer should, above all, be honest. Honesty in the engineering profession is very important as people often bet their lives on the safety of the engineers' products. For example, if you are driving your car down the street, you trust the certification by the engineers at Ford Motor Company that your wheel will not spontaneously detach itself from your car and roll down the street while you are traveling at forty miles per hour."
>
> —Male, junior, electrical engineering, initial essay

Besides honesty and integrity, in the initial essays, students cited technical competence as a key characteristic (18 of 40). Students also mentioned communication and teamwork skills (11 of 40) and the need for accuracy and precision (6 of 40). In both internships and engineering courses, students had worked in teams, and they had learned that accuracy and precision are valued highly in solving technical problems correctly.

> "Engineers should be team players and good communicators. Unlike the older days, when engineers mostly worked individually and were employed in the industry only for their technical skills, engineers today are frequently found in the upper levels of management and play dual roles as engineers/managers."
>
> —Male, senior, electrical engineering, initial essay

> "In class we as students are expected to turn in neat, organized homework. Our grade can sometimes reflect the neatness of the work.... Time and care is [sic] put into the work we turn into class now. As we enter the professional work, the time and care will be put into the projects we as engineers work on."
>
> —Female, junior, computer engineering, initial essay

Students stated that the ideal engineer should have persistence and self-confidence (16 of 40).

> "Every professional engineer has to be determined, because when designing and building a product it takes a lot of tries before coming to a design that is actually marketable. To be able to get through the many trials before reaching success takes determination. It is easy to get frustrated and want to give up, but engineers find it in themselves and take the challenge until they complete the task [making a successful product]. This not only takes determination but hard work. Engineers have to spend hours upon hours just tossing up ideas to solve problems they come across as they are trying to reach their goals."
>
> —Female, senior, bioengineering, initial essay

Students said that engineers should ensure the safety of products (16 of 40). Davis [19] claimed that engineers, unlike managers, seem to be "hard-wired" with a code of ethics that emphasizes professional responsibility for safety. I believe that the origin of this attitude is not a mystery, but arises organically from the values of engineering courses and engineering practice. Engineering students understand clearly that engineers have the power to create and to control complex objects such as cars and aircraft, and large interconnected systems such as computer networks and sewage treatment systems and electric power grids, which are intended to improve the lives of people. For these objects and systems to function properly, engineers must solve technical problems correctly, as emphasized by engineering courses, because people's lives depend on the proper functioning of objects and systems. Therefore, engineers are morally responsible for safety.

> "During my internship... I saw many environmental problems of varying degrees of intensity. One case comes to mind which confirms my belief that safety of humans should come first. A plant had put a tank designed to hold hydrochloric acid into use without any testing. When the hydrochloric acid was put in the tank, it failed due to structural reasons. The tank's malfunction put the safety of hundreds of workers at this plant in jeopardy by exposing them to

> hydrochloric acid, a highly toxic compound. The company is currently suffering from financial aftershocks due to the expensive clean up. Also, the company has had to work extensively to improve a public image that has been tarnished by the spill of hydrochloric acid."
>
> —Male, junior, agricultural engineering, initial essay

Downey and Lucena [20] contended that in engineering courses, students are taught to "make the self invisible in problem solving." According to Downey and Lucena, students are expected to suppress their individual personalities, to ignore the social contexts of engineering problems in homework and examinations, and to solve these problems dispassionately. By contrast, the data that I collected indicate that many engineering students—even students who have not studied ethics—are acutely aware that engineers must solve problems correctly because they are personally responsible for the social consequences of their technical decisions.

In summary, although engineering students learn more about professional responsibilities from people than from courses, they learn from technical courses that engineers must solve problems correctly. The emphasis on correct solutions and accurate answers does not devalue the engineer's personal identity but rather arises directly from the engineer's responsibility for technical decisions.

B. Characteristics and Responsibilities of Professional Engineers: Final Reflections

> "I am a self-confessed 'pirate', who would not think twice about ripping off the next CD/DVD. The … article on intellectual property and the common good set me thinking hard about the fairness of my actions. While I do not claim to have had an 'epiphany' and changed my behavior, I can at least say that my ripping activities have somewhat mellowed."
>
> —Male, senior, finance/management information systems, final reflection

In their final reflections, most students cited the ECE 216 course as a major influence on their understandings of the characteristics and responsibilities of professional engineers. When students considered the outcomes of the course in their final reflections, they most frequently added responses in three categories: ethics, safety, and social responsibility.

First, in ECE 216, students learned about the specific ethical obligations of engineers. The proportion of students who cited the importance of ethics in engineering work increased from 25 of 40 in the initial essay to 37 of 49 in the final reflections.

> "Before taking ECE 216, I seldom considered ethics to be a large part of engineering. I am not sure whether I was ignorant or simply naive, but I now realize the extent to which ethics governs the behaviors of those within the engineering profession."
>
> —Male, junior, computer engineering, final reflection

> "The most important characteristic that I forgot to mention months ago is that an engineer should have ethical reasoning…. It may seem strange that ethical reasoning could be a more important characteristic than intelligence, but this is truly the case. Engineers may be brilliant, but if they are immoral people, they may pose a real threat to humanity. Engineers work with very hazardous equipment, and they have the potential to create extremely dangerous projects. People that have this much power must know how to think morally. They must decide what kind of products would be useful to society, and what kinds of things would hurt it."
>
> —Female, senior, electrical engineering, final reflection

For other students, ECE 216 did not change their basic beliefs about ethics. Some students had already begun the course with the conviction that honesty and integrity are key characteristics of engineers.

> "For the most part, my answers to the questions in the first response paper have not changed…. Although I may not have considered engineering ethics to any large degree before, I do not feel that the course has greatly influenced my preconceived notions of ethical behavior."
>
> —Male, senior, computer engineering, final reflection

ECE 216 gave students concepts for moral analysis and tools for moral reasoning. Students said that the course helped them gain confidence in reasoning about moral problems. Through the course, students developed the habits of looking for missing information, evaluating situations from multiple perspectives, and using the line-drawing and creative-middle-way methods for solving moral problems [15].

> "Having taken this class I have learned about different conflicts I may face as an engineer. I have also learned about different processes in making decisions when in a conflict. I have also heard many different perspectives on different ethical issues which has [sic] opened my eyes to different ways at looking at things."
>
> —Female, senior, bioengineering, final reflection

> "ECE 216 has given me a more confident attitude towards working in 'the real world.' The course has sharpened my insight and communication skills. I also have a more solid set of ethical beliefs and I am aware of the options I have if my ethical beliefs are ever in danger of being compromised. Though my ethical beliefs have been strengthened, I think I've also become a more flexible and open-minded individual."
>
> —Female, sophomore, electrical engineering, final reflection

Self-confident engineers might act courageously in morally challenging situations.

Second, in ECE 216, students learned the reasons for the engineer's special responsibility for safety. Consequently, the proportion of students who highlighted the responsibility for safety increased from 16 of 40 in the initial essays to 29 of 49 in the final reflections. Some students neglected to mention safety; for example, accounting students answered the questions for the accounting profession, in which safety is not a major concern.

Third, in ECE 216, students developed a deeper, richer understanding of professional responsibilities beyond completing tasks competently and conscientiously. The proportion of students who said that engineers have a general responsibility for the welfare of the public increased from 14 of 40 in the initial essays to 33 of 49 in the final reflections.

> "The engineer's most important professional responsibility should be to the public. An example of the failure to fulfill this responsibility is the Challenger accident. Engineers work on technical projects that require specialized knowledge. Since the average person does not have this knowledge, … [engineers should] not cheat their client because they do not know any better. Engineers also have a professional responsibility to their employer. For example, engineers should not reveal trade secrets … [At the beginning of the course,] I knew that engineers had to protect the welfare of the public and that engineers should have integrity, but other subtleties escaped me at that point. These subtleties were listed above."
>
> —Female, junior, electrical engineering, final reflection

After taking ECE 216, students felt empowered when they understood that engineering work can affect the world significantly. Students realized that because engineers have great power, they have commensurately great responsibilities for the good of society and for the quality of the environment.

> "I now realize that engineers have a larger social responsibility.… I now understand engineering as using technical knowledge to bring about a social change. As a computer engineer, this means creating something new, or improving something that will have an impact on how some part of the population lives their lives."
>
> —Male, senior, computer engineering, final reflection

C. Development of Professional Identities

> "I think that what will most likely happen is that I will be going through my college notes one day, come across this paper, read it, and realize, 'Wow. I am a professional engineer.' Alternatively, I will wake up one morning and come to the same realization as I brush my teeth or something similarly mundane like that."
>
> —Female, senior, aerospace engineering, final reflection

Students used three different kinds of criteria to determine whether they have become professional engineers.

- *Tangible markers:* has a B.S. degree, job title, P.E. (professional engineer) license, or own cubicle; receives a paycheck.
- *External approval:* receives a job assignment with major responsibility; enjoys recognition for technical expertise; is consulted for advice.
- *Internal qualities:* technical competence, work ethic, interpersonal skills, moral standards, personal virtues.

Students who cited internal qualities usually said that they would know they are professionals when they have the characteristics that they listed in their responses to the first question of the questionnaire.

> "I would consider myself a professional engineer when I embody the characteristics and qualities of an ideal professional engineer, as well as fully comprehend the responsibilities bestowed upon me."
>
> —Male, junior, computer engineering, initial essay

Some students used more than one kind of criteria.

> "A professional engineer seeks to apply their sound moral reasoning, technical competency, communication ability, and ethical behavior to all situations they are faced with, both on and off the clock. I will know that I am a professional engineer when other people see me as someone who possesses the traits I listed above."
>
> —Male, junior, electrical engineering, final reflection

This student sought external validation ("other people see me") of internal personal qualities. He would be a professional "both on and off the clock" because being a professional is integral to a person's identity: an engineer is a professional all the time, not just at the job site from 9 a.m. to 5 p.m. A few other students expressed the same sentiment:

> "You are always a professional, whether or not you're on company time. For instance, a doctor always has the responsibility of helping a person in need even though they [sic] are not necessarily at the office."
>
> —Male, senior, accounting, final reflection

At the end of ECE 216, several students (14 of 49) specifically mentioned that professional engineers need courage to make the right decision when confronted with an ethical problem, despite pressures such as cost, schedule, and managerial expectations.

> "I have been learning to think more about the impact of my decisions, and to be able to recognize when I am faced with an ethical decision. I am also trying to tell myself that when faced with an ethical decision, I should have the courage to make the right choice. One of the articles we read in class pertained to this. The writer stated, that it is easy to point out what an engineer should do when discussing the case in the classroom. The question is, is it as easy when the engineer is me, and my job is at stake?"
>
> —Female, senior, electrical engineering, final reflection

> "I believe there is one trait that is common to all professions. This trait is being true to yourself and standing up for what you believe to be morally and ethically right regardless of the personal suffering that may occur."
>
> —Male, junior, computer engineering, final reflection

One student connected the need for personal courage with the development of her professional identity:

> "I now know that behaving ethically in industry is a lot harder than I thought it would be, and I am more aware of possibly compromising ethical situations. I think compromising is essential, but compromising when faced with an ethical dilemma is wrong.… From the feminist ethics we studied in class, I agree that women approach ethics from a much more personal angle than men. I also think women and men are

> complimentary [sic] and work well together, and I think since women are scarce in engineering, I will have to be very solid in my ethics and standards, as my input may be more scrutinized as a woman among many men."
>
> —Female, junior, electrical engineering, final reflection

A few students internalized their social responsibilities into their professional identities.

> "Now, I understand how broadly engineers can influence society … But, with this power comes the ability to do harm as well. The professional engineer, as with all professionals, should consider the implications of their actions, especially with respect to the public…. Some of the most interesting and most influential articles we read were the ones that empowered me to be the best engineer I can be. This is not only because my parents influenced me to become an honest and hard working person, but rather because of the power and responsibility I will have when I graduate."
>
> —Male, junior, computer engineering, final reflection

In summary, students identified three major insights about their professional identities:

- an engineer may need moral courage to choose the right action;
- an engineer always has professional responsibilities, even when not at the office; and
- an engineer should understand the effects of technical decisions on the public.

D. Influential Course Activities

Clearly, ECE 216 influenced students' thinking about the responsibilities of engineers. In the spring of 2004, I gathered data about specific course activities that students found most influential. For the final reflection at the end of the spring semester, I asked students to identify the aspects of ECE 216 that significantly influenced their thinking about the characteristics and responsibilities of professional engineers.

As I had expected, different students reported that their thinking was influenced by different course activities, but two activities were mentioned most frequently. First, students benefited from cases (12 of 22), both the analysis of everyday scenarios and the lessons of major cases such as the *Challenger* and the *Citicorp Center*. Second, students benefited from diverse perspectives (10 of 22) in the classroom discussions, in large and small groups, about moral questions and moral problems.

> "The most influential part of the class had to be the case discussions. I have always believed that case studies are great tools to gain insight on relevant issues in the real world. Also, the discussions facilitate my thinking because other people bring up new viewpoints I never would have thought of."
>
> —Male, senior, accounting, final reflection

Students also considered multiple perspectives when they read articles with a variety of opinions and when they participated in role-playing exercises [14].

IV. Discussion

From the data that I have gathered, it appears that a course in engineering ethics reinforces the students' previous inclinations to act morally. Students expressed improved self-confidence in identifying and reasoning about moral problems. Students said that they benefited most from studying major cases and from hearing diverse perspectives. They understood clearly that engineering work has extensive social consequences, and that engineers are morally responsible for those consequences. Before taking ECE 216, a minority of students identified engineers' responsibility for ensuring the safety of the public explicitly. Those who stated this responsibility seemed to conceptualize professional responsibility as carrying out assigned tasks and as liability for blame when a disaster occurs. At the end of the course, most students accepted the responsibility for safety, and some articulated a capacious notion of professional responsibility that includes caring for the good of people and the environment. Broadening the student's understanding of professional responsibility to encompass social and global stewardship could be an important outcome of a course on engineering ethics.

These findings have several limitations. Because most students in ECE 216 were in computer engineering or electrical engineering, their responses might not be representative of all engineering students. Further, students' responses were influenced by the particular content, pedagogy, and instructors of the offerings of ECE 216 in 2003–04. Finally, students' self-reports about their improved self-confidence may not be completely accurate. We can not determine whether an individual student will act with courage in a real moral dilemma.

The limitations of this study suggest many directions for further research. To overcome limitations on the diversity of the students and the teaching of ECE 216, the study could be repeated with different students at different institutions. The results could be analyzed in finer detail, to identify carefully which pedagogies can produce which outcomes in which students. Interviews and focus groups could be used to gather other kinds of data about the development of students' professional identities. Our conclusions about the effect of ethics instruction on professional identities would be more convincing if they were supported by a variety of kinds of qualitative data.

In this study, few students provided explicit, specific criteria for the key question about how they would know they have become professional engineers themselves. Therefore, I have followed on this project with interviews of selected individuals—both students who took ECE 216 and students who did not. The interviews reveal how students think about their professional identities and whether, in a difficult situation, that identity will give them the courage to choose the action that they have determined is right [16].

Acknowledgments

I thank the students in ECE 216 for allowing me to use their papers in this project, and Professor Philip Hillmer for collecting data from students in his section of ECE 216 in each semester. Undergraduate researcher Golnaz Hashemian coded the data to enable me to quantify my qualitative statements, and she wrote detailed comments on previous drafts of this paper. Students Ryan Chmiel, Caroline Fabbrini, and Bharath Krishnan pilot-tested early versions of the questionnaire.

I am honored to receive the support of the Carnegie Foundation for the Advancement of Teaching for this project through the Carnegie Scholars Program. I am indebted to my fellow Carnegie Scholars for their wise advice. Curt Bennett provided steadfast encouragement. Bill Cerbin, Mary Huber, and Kathleen McKinney referred me to the social science literature. Tracey Patton recommended that I emphasize the actions that students would take as professionals, and she reminded me to quote "unsuccessful" students too.

My work is also supported by the National Science Foundation under Grant SES-0138309. I take full responsibility for the views, opinions, and conclusions of this paper, which are not necessarily those of the Carnegie Foundation, the National Science Foundation, or the University of Illinois.

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Appendix

We used a simple coding scheme that classified students' responses in the following categories:

Characteristics of engineers

- *Technical competence:* creativity, innovation, intellect, intelligent, resourcefulness, techniques, solve problems, education in math and science, complete tasks, scientific knowledge, technical knowledge, knowledgeable.
- *Work ethic:* conscientious, dedicated, determination, diligent, efficiency, patience, persistence, hard work, thorough, do the best job possible.
- *Accuracy and precision:* concerned with details, no tolerance for errors or mistakes, attention to detail, meticulous, careful.
- *Communication and teamwork:* leadership, collaborate, cooperate, present ideas clearly, work well with others, friendliness, relations between people, diplomacy, social skills.
- *Confidence and courage:* stand up for ideas, brave, pride, independence.
- *Moral standards:* accountable, beyond reproach, candor, character, conduct, honest, honesty, impartiality, integrity, loyal, morals, respect, sense of right and wrong, tolerance, truthful, trustworthy, values.

Responsibilities of engineers

- *Safety:* should not harm the general public, public safety, protect the public.
- *Social responsibility:* welfare of the public, responsibility to the community, understand impact of solution on the community, decisions for the public good, social conscience, social awareness, improve society, betterment of society, serve the public interest.

Sources of understandings

- *Relatives and co-workers:* father, mother, parent, uncle, friend, peer, supervisor, manager, boss, engineers.
- *Academics:* course, professor.

Criteria for determining a professional engineer

- *Internal qualities:* can solve a difficult problem, embody these characteristics and qualities.
- *External approval:* recognized for expertise, consulted for advice, projects assigned to me, others see me, respect of peers.
- *Tangible markers:* P.E. license, pay, degree, job title.