AC 2012-4913: THE LONG-TERM OUTCOMES OF AN ENGINEERING COURSE FOR STUDENTS OUTSIDE ENGINEERING

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The Long-Term Outcomes of an Engineering Course for Students Outside Engineering

Introduction

Assessing the state of engineering education within the larger community of educators, the National Science Foundation has highlighted the need for an understanding of engineering in fields outside of engineering and "attention to STEM literacy for the public at large"[1]. In the 1995 NSF report *Restructuring Engineering Education: A Focus Change*[2], one of the suggestions to address such a need was to offer engineering courses to non-engineering students. Consequently, in the late 1990's and early 2000's, engineering departments slowly began to offer courses for students who did not plan to major in engineering. Because few such general education courses were offered in the past, little is known about the long-term student outcomes of these courses. Moreover, what we know about the outcomes of general education engineering courses for non-majors was collected through end of semester surveys. To address this gap in our knowledge and in our research methods, this study aims to investigate the long-term student outcomes of a general education engineering course on digital information technologies at a large research university using qualitative research methods to gather and analyze data.

Previous Research

Prior to this study, the long-term impacts of general education courses on students have not been widely examined. In a recent study of the contributions of general education to student learning[3], researchers surveyed faculty and instructors in 109 colleges and universities using the Faculty Survey of Student Engagement (FSSE). The FSSE contains questions about what faculties expect of students and how faculties dedicate their time to various activities in the classroom. One of the key findings from this study is that faculty teaching general education courses focus more on acquisition of intellectual skills, such as critical thinking, than do faculty teaching non-general education courses. Although acquisition of intellectual skills may not be a primary objective of a general education course in engineering, it is certainly a desired outcome. One of the primary course objectives of general education courses in engineering may be increased awareness and appreciation for engineering as a profession.

Researchers who have assessed engineering courses for non-majors, through the use of quantitative surveys, have found that students who took such course felt empowered and took on meaningful job-related positions because of the course[4], had an increased confidence in their performance of basic engineering problems[5,6], and an increase understanding of engineering outside of the academic environment[4,6]. Unlike previous studies, we are examining long-term impacts and outcomes, and we are employing qualitative research methodologies for data collection and analysis.

In addition to engineering general education courses for non-majors, there is some literature on computer science courses for non-majors that is relevant to our study. A study[7] about what factors affect how well non- computer science students learn to program in an introductory

computer science course found that students' perceived self-efficacy increased substantially over the course of the semester. As cited in their study[7], perceived self-efficacy is "concerned not with the number of skills that you have, but with that you believe you can do with what you have under a variety of circumstance." A separate study[8] on a media computation course for non-majors found that after completing the course, students reported seeing the applicability of computer science and found computer science interesting.

Although the findings of previous studies on engineering courses for non-majors are similar to computer science courses for non-majors, long-term student outcomes of these courses have not been previously studied. Moreover, because almost all of these studies used quantitative methodologies, they neglected the lived experiences of students. In our study, we address both the literature gap and the research methodology gap to better understand the long-term effects of ECE 101, a general education course in electrical and computer engineering.

ECE 101 Background

In 2003, the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign began offering ECE 101, a course that introduces students to selected technical aspects of digital information technologies. To help students understand the information technologies they use every day, ECE 101 covers some of the scientific and mathematical principles that underlie the operation of information technologies, and the engineering processes by which the technologies are created. In particular, ECE 101 shows students how engineers negotiate tradeoffs as they design devices to meet social needs. Intended for students outside the College of Engineering, ECE 101 meets the campus's general education requirements in physical sciences and in quantitative reasoning.

In each semester, the enrollment in ECE 101 ranges from forty to sixty students, mostly freshmen and sophomores. Each week, students in ECE 101 attend two 50-minute lectures taught by the instructor and one two-hour laboratory session led by a graduate teaching assistant. In the laboratory, students learn HTML and Javascript, construct digital filters to process music and images, and create digital logic circuits using Transistor-Transistor Logic components. ECE 101 explicitly introduces students to the "engineering approach," namely, the application of mathematics and science to design products that solve problems. Students learn that engineering solutions are not unique, because engineers must consider tradeoffs between cost and performance. In laboratory assignments, students find multiple engineering solutions as they develop, test, and refine their Javascript programs, digital filters, and logic circuits.

Methodology

In this study, we address the question, *What are the long-term impacts of ECE 101?* Long term was defined as one to six semesters after the participants took ECE 101. Using a phenomenographical approach, we seek to describe the long-term student outcomes holistically. One of the reasons we use phenomenography in this study is to have a better understanding of the students' lived experiences in ECE 101. Our goal is not to determine "what works" in achieving learning outcomes, but instead to characterize "what is" the experience of the non-engineering student who takes an introductory course on engineering.

Following Institutional Review Board approval, in the spring of 2011, semi-structured, individual interviews were conducted with twelve students who had completed ECE 101 between the fall semester of 2007 and the fall semester of 2010. Each interview lasted between 25 and 45 minutes. The interviewed students were prompted to recall important ideas and significant experiences in ECE 101 and in one other memorable general education course. Students chose to discuss general education courses in psychology, in Latin American studies, in animal science, and in other fields.

The authors used inductive data analysis to classify and categorize the interview transcripts independently[4]. Each author created a set of categories or codes and met to negotiate and re-negotiate codes. A negotiated, final code list was used to apply to all interview transcripts; the last set of coded transcripts was used to create a list of larger categories or themes that described the students' experiences and outcomes of ECE 101. We sent a draft of the report to each participant to receive feedback on how their interview responses were interpreted; three of the twelve participants responded and they felt they were accurately represented.

Sample

All 150 students who had completed ECE 101 in the targeted semesters were invited via e-mail to participate in individual interviews. All students who responded to the e-mail message were interviewed. The students were of traditional age, and they lived on our residential campus. The students were compensated with $10 for their time. Table 1 shows the demographic characteristics of the twelve interviewed students.

Table 1: Participants Demographics

Female	6
Male	6
Freshman	2
Sophomore	1
Junior	8
Senior	1

Results

The results presented in this paper are organized in four sections. The section "Before the course" explains how the students learned about ECE 101 and their initial perceptions of the course. "During the course" refers to how students experienced ECE 101 during the semester, and the content they remembered. Finally, "After the course" refers to the experiences that students described as they thought about how they used the material they had learned. The "Other general education courses" section compares ECE 101 with other general education courses. The quotations presented below are representative of the salient ideas and experiences that students talked about in the interviews. We refer to the participants interviewed as "students" for clarity.

Before the course

Prior to enrolling in the course, students learned about ECE 101 mostly through the university's course catalog. The majority of students selected the course because it fulfilled one of their curricular requirements. Some students registered for the course because they learned about it from other students.

We asked students to recall their initial perceptions and expectations of the course. Some students expressed apprehension when they registered for the course because they lacked proficiency in math and science. Moreover, early in the semester, the students with weak skills in math and science seriously considered dropping the course.

> *I wanted to learn about logic and things like that … I love math and engineering stuff, I'm just not that good at it, it was never my strong point so when I have time I try to sneak in some of those classes that are interesting to me and ECE 101 was interesting just by its description*. (Student 2)

> *I hate math and I hate science, and this is a math and science gen ed course so I expected to get those out of the way as fast as I could. I didn't expect to like it because I don't like those things and it's not something I'm really good at, so I expected to struggle*. (Student 7)
> *Well I knew that it was meant to be for non-majors and I knew that in fact even learning that majors who took the class wouldn't get credit for it, it made me feel a lot more comfortable about delving into this field that's been known to be really tough for someone for who didn't go into it for those reasons, I suppose, because I didn't think that I would be able to go into that. So my expectations, because I'm really interested in this stuff and I really wanted to learn more* (Student 3)

During the course

Although most interviewed students found the course difficult and involved, some aspects of the course encouraged them to continue. Students may have been motivated to continue by the instructor and teaching assistants. The instructor and teaching assistants had a noticeable, positive influence on the way the students experienced the course. This influence may have contributed to students' enthusiasm they maintained during the course regardless of how challenging they found it. The quotation below is representative of how the students remembered the ECE 101 instructor and teaching assistants,

> *He was a great guy, he was a great professor and the TAs were great, during the first few weeks and I didn't want to drop it because as soon as I communicated with him then he'd help me out through the class, so that's why I didn't drop it*. (Interviewee 5)

In addition, some students showed improved self-efficacy with regards to being involved with technical projects. Self-efficacy[5], how confident a person feels in their abilities to do something, is used here to describe situations where students emphasized learning something about themselves through the course that showed improved self-efficacy.

As much as I disliked this class and it was a struggle for me, I did well when all was said and done and I realized that even though I … don't see myself as someone who is good at these things, I can do them when push comes to shove and math and science aren't these scary things I can't do. (Student 7)

The HTML that we did cover was very simple, you know like making a paragraph that is formatted with a heading, that is different then the paragraph, but it shows you where to go to improve upon that, which was really nice. It gave you the skills to just kind of start on your own. (Student 8)

I like all the math and stuff but I know that's not my strong point. And I know I need to be heading towards writing, public speaking, administration, things like that, political science, but I do have this passion for this other area. (Student 2)

When prompted about what they learned in the course, some of the students described situations where they demonstrated persistence.

Even though a course may seem difficult, especially an engineering course, just stick with it because sometimes it just takes your interaction with a professor or TA, just communicating with them that you have a problem, ask questions, you know, stuff like that. You can get through it. (Student 5)

The third one I would say is to keep trying, the information is out there and it is not always like crazy hard or whatever cause I usually I think about computer people like crazy, smart people and way over your head. I think that like the idea that if you keep looking you will find the answers. Like for my project I had to do I had to keep looking, and looking, and looking and it was fruitful. (Student 11)

After the course

A key outcome of ECE 101 for a lot of students was learning to take on and overcome challenges. After the course ended, some students worked on tasks that related to ECE 101 in some ways, but that were not specifically taught in the course. Moreover, the students described feeling satisfied with themselves after accomplishing these challenging tasks.

I also improved on like hardware stuff. Recently I learned how to fix my fan on my MacBook which saved a lot of money for me. I wouldn't even have done that unless I didn't have some previous background in doing hardware in which we did in class... I was able to like fix my fan not because they taught me that but because they really broke it down so that you could understand that a lot of things are just that you take it a step at a time. (Student 11)

I had a Game Boy game, Pokemon Silver, I love it. And the battery ran out on the game which doesn't allow you to save any more. And I was very unhappy about this…. So I Googled up why this was happening, what was going on, and it said there was an internal battery inside this game pack that's dying. So what I did was unscrewed this back piece, found a solder, went out and bought a battery and soldered that battery, the new battery, into

the back of the game and it works perfectly now. That was pretty cool. I learned all that from ECE 101. I had no idea how to solder before that or anything. (Student 2)

I've fixed my computer a couple of times with stuff the professor has taught me. That's pretty nice. It's died twice now and I've brought it back twice. (Student 4)

Whether students had completed ECE 101 recently or three years ago, when asked to recall the ideas, concepts, and principles from the course, almost unanimously, the students mentioned HTML and JavaScript. Often they perceived these Web development skills as knowledge they could use in their future professional endeavors,

I am pretty sure if I got into business that I will need to like make forms, and in order to make forms I would need to use my knowledge of like HTML and like java script. So like to contact people and send out email about how I could apply all of that. (Student 9)

Well because webpage construction is a pretty handy skill to have nowadays. So knowing HTML and Javascript is a pretty handy bonus, I'm actually trying to use it to get an internship this summer. (Student 4)

They also perceived HTML and Javascript as practical skills they used in subsequent classes or personal projects,

I have to build a webpage in four or five other courses next semester so that was pretty handy. Other than that most of the time, I made a website too for one of my Spanish classes. We made a basic website and everyone was all "We don't know how to make websites!" and I went "That's okay, I know." (Student 4)

My dad has a business and I am currently working on his business website using CSS and the other languages to design it. (Student 6)

On my down time, I would use the programing skills to build websites and I know me and my friend wanted to start a website too but that never happened. And I remember teaching it to my sister, so it helped in a way. (Student 10)

Other general education courses

When discussing ideas, concepts, or principles from general education courses different from ECE 101, students mostly remembered isolated facts. Below is a representative example of a student who recalled an activity in his psychology class about hearing deterioration over time.

We did a class activity, we all got up and [the professor] started [the sound] so that everybody could hear regardless of age and then slowly the [sound] got higher and higher and people started sitting down when they couldn't hear it. And the thing is because you're older, you damage your ears more, you can't hear as high of frequencies as other people. (Student 6)

Only sometimes did students remember "big ideas" from their general education courses different from ECE 101. By big ideas we mean those that encompass the overall teaching goal of the course. For instance, the student quoted below talked about the idea of a place being "a center of multiple things" which she learned from a Latin American studies course.

> *Well we always went over how a place can be a center of multiple things. It can be a political center, or a population center, cultural center, economic center, I suppose that a place can be multiple things*. (Student 4)

In comparison with ECE 101, more students recalled big ideas in other general education courses different than ECE 101.

Conclusions

Understanding the long-term impacts of general education courses in engineering can help us better design engineering courses for non-major students. This study investigated the experience of twelve non-engineering students who took ECE 101 between the fall of 2007 and fall of 2010. The results suggest that the students improved their self-efficacy toward technical projects, learned to take on and overcome challenges, and demonstrated persistence in the course. Perhaps not surprisingly, our results regarding self-efficacy agree with previous studies on engineering and computer sciences for non-majors[5,6,7] in that the students who completed ECE 101 seemed to have improved their self-efficacy. The pace of the class as well as the positive influence from the instructor and teaching assistants may have helped the students build a positive self-efficacy towards the course. As a consequence, although many students felt uneasy about the course and did not feel they had a strong math and science background, they nonetheless completed the course. The improved self-efficacy also agrees with our result of overcoming challenges in that after taking the course, and thus improving self-efficacy, the students were more open to taking on challenging tasks that related to ECE 101.

Throughout the course, the students showed persistence, another characteristic of individuals with improved or high self-efficacy. Although the objectives of ECE 101 do not focus on the development of general intellectual skills, as other general education courses might, improved self-efficacy towards technical tasks may be an important outcome and a long-term impact of ECE 101 on students.

Faculty teaching engineering courses for non-majors may need to help students make connections between the details and "big ideas." Although the teaching methods and learning objectives of ECE 101 differ from other general education courses, it is interesting to note what ideas, principles, or concepts students recall from the two courses. From ECE 101, students seemed to recall specific skills such as HTML and Javascript, whereas from other general education courses students remembered isolated facts and sometimes big ideas. It could be non-majors become immersed in the details and technicalities of the engineering course, rather than perceiving the overarching ideas, because the material is new and perceived as difficult. One of the goals of ECE 101, however, is to introduce students to a variety of topics about digital logic and in doing that, practical skills such as HTML might stand out above "big ideas" such as engineering design tradeoffs. Faculty can aid students in making a habit of refocusing back to

"big ideas" throughout the course by intentionally making connections between smaller and bigger ideas. For instance, in the design of a project, the assignment might ask students to run a cost-benefit or design tradeoff analysis as part of a report. Additionally, students can find real life engineering projects in newspapers or online articles and reflect on how the skills they are learning in the classroom present themselves outside of the academic realm[6].

Limitations

One of the limitations in this study is in the nature of the course. Although ECE 101 follows a pre-defined syllabus and has had similar course objectives over the years, like any other course, it may have changed over the years. Depending on what semester the students took the course; they may have experienced a slightly different version of the course. However, the same instructor has taught the course over the targeted years and the core content has remained the same. A second limitation is that the participants are self-selected students who had completed ECE 101. Thus, we are not studying experiences of students who dropped or did not complete the course. We are perhaps studying the experiences of students who may have felt positively towards the course, as they were eager to share their experiences in the interview. Part of this limitation might have been mitigated by the $10 compensation.

Future Work

This study is part of a larger investigation on the impacts of diversity harnessing in ECE 101[11]. Diversity harnessing refers to the process of incorporating current students' personal interests, educational backgrounds, and career interests into the content of ECE 101 as it runs during the semester. The semi-structured interviews presented in this paper were conducted as a baseline assessment of students' outcomes of ECE 101. The students interviewed took ECE 101 before diversity harnessing was implemented in the fall of 2011. Starting in the spring of 2012, we plan to conduct longitudinal interviews with students who took the course after diversity harnessing was implemented.

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