AC 2011-1045: LINKING STUDENTS' INTEREST IN ELECTRICAL ENGINEERING TO THEIR CONCEPTUAL UNDERSTANDING

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Linking Students' Interest in Electrical Engineering to Conceptual Understanding

Background

Significant emphasis has been placed on understanding what factors impact students' decisions to pursue engineering majors and their persistence in the field. The broader goal of our NSF-funded study is to better understand if and how students' interest in the field of electrical engineering is linked to their conceptual understanding of engineering material. In the work discussed here, we examine the relationship between students' course and concept inventory performance and their reasons for studying engineering and experiences in the engineering coursework.

Previous work on students' understanding of signals and systems has focused on their conceptual understanding of the content.[1,2] This work has found that interactive pedagogy has a positive impact on students' learning of the content as measured by the Signals and Systems Concept Inventory (SSCI), which is described in further detail in the methods section.[3] In previous work, we have examined how students use different types of language (formal and informal) when describing their solutions to signals and systems problems and how language use is related to students' understanding of the material. This study extends that work by examining students' interests and perceptions of electrical engineering in relationship to their understanding of the course content.

In this study, we consider the following two research questions. First, what are students' long-term interests in engineering? In particular, what are their plans following graduation with a BS in electrical engineering? Second, how do students' interests in engineering relate to their understanding and learning of the content? We focus on the signals and systems area within electrical engineering. The signals and systems class we study is an upper-level course, and hence students enrolled have typically committed to an engineering major. However, students may envision careers outside engineering even though they are pursuing an engineering degree.

Students' interest in engineering is impacted by a variety of factors. Seymour and Hewitt, and others, point to the connection between interest and content delivery.[4,5,6] Seymour and Hewitt also indicate that the culture of engineering education is critical in students' decision-making about remaining in an engineering program. More recent studies have examined the value that students place on engineering as a program of study generally or the role of faculty.[6,7] Students in Case's study indicated that in-class problem solving was motivational to them, but she did not investigate the phenomenon in detail.[5] In existing studies, there is a challenge in linking the content to students' interest or the classroom environment to their retention in an engineering program.

Methods

Data for this study were collected from students in a required electrical engineering course at George Mason University. The course, ECE 320 – Signals and Systems II, is the second in a series of two signals and systems courses in the electrical engineering curriculum and focuses on discrete-time signals and systems. Students enrolled in the course are typically at the junior or senior level. The data collected for the study included students' concept inventory (SSCI) scores, course grades, end-of-semester survey responses, and interview transcripts. Data were collected during two semester offerings of the course, though not all types of data were collected in each semester. Thirty-five students participated in the study in semester A; students' concept inventory scores and course grades were collected, and semi-structured interviews were conducted with a small number of the students. Nineteen students participated in the study in semester B; students' concept inventory scores and course grades were collected, as well as end-of-semester survey responses.

In both semesters, students completed the discrete-time Signals and Systems Concept Inventory (SSCI) at the beginning and end of the term. The SSCI is a twenty-five question exam designed to measure students' conceptual understanding of signals and systems. Each multiple-choice exam question includes distractors (incorrect answers) that represent misconceptions commonly held by students. Topics covered by the exam include convolution, impulse and frequency response, pole-zero analysis, and filtering.

All members of the semester A offering of ECE 320 were invited to participate in individual interviews after the term had ended. Six students participated in interviews and were given a $30 gift card as compensation. Semi-structured interviews were employed; the interviewer had a basic list of questions but then prodded the interviewees for more details or additional information as needed. The interview included both a technical component and a general component. The technical component consisted of open-ended sample problems from signals and systems. It was followed by a set of questions regarding students' interest in electrical engineering and experiences in the electrical engineering coursework.

An end-of-semester survey was administered to students in the semester B offering of ECE 320. The survey was made available online during the last week of the term. Students were given a small amount of extra credit for completing the survey, and hence it was not anonymous. The survey questions were open-ended and focused on what students found most difficult and important in the course, what students liked most and least about the course, and students' future plans and if/how their experience in ECE 320 had affected those plans. Responses to questions about future plans and their relationship to signals and systems were analyzed in this work.

Analysis of Interview Data

Of the 35 students enrolled in the semester A offering of the course, six were interviewed in the months following the end of the course. The interview participants represent a range of ability levels and interests in electrical engineering. For this study, we have focused on students' responses to the general questions about their interest in engineering, their experiences in engineering courses, and any changes in interest/plans that have occurred during their academic career. The following questions were asked to each student interviewed:

Why did you decide to become an engineering major?
Why did you select electrical engineering specifically?
What are you planning to do when you graduate? Why?
What did you hope to learn during your engineering coursework?
What has surprised you the most about engineering?

Following the interview, students' responses were transcribed and categorized by question. They were coded based on a framework that emerged from the data (a typical procedure for qualitative studies that explore complex phenomena). While this is a small sample of students in a qualitative study, the small sample has informed theories about a larger sample that could be addressed in future work.

Table 1: Interview Participants' Post-Graduation Plans

Student	Post-Graduation Plan	Relationship to Signals & Systems
Amy	A less technical career (management, law, systems engineering)	Some
Beth	Graduate school in electrical engineering	Close
Charles	Graduate school in mechanical engineering	Some
Diane	Currently working for an engineering company using electrical engineering	Close
Edward	Job in industrial robotics or consumer electronics	Close
Frank	Job using signal processing or computer software skills	Close

The interview participants came from a range of backgrounds and experiences. Three female and three male students were interviewed. One male student had experience in electronics on the job and was coming back to school to study engineering. One female student had already graduated and was working for a large engineering company. Three students specifically mentioned graduate work in engineering as a goal following their undergraduate degrees. Since the objective of the study is to understand their conceptual knowledge in relationship to their interest in engineering, we present their post-graduation plans and their scores on the SSCI. Students' interest in electrical engineering varied. Some had come to engineering in general and then electrical specifically. For one student, the decision to pursue electrical engineering was motivated by the available programs at George Mason combined with an interest in robotics and vehicle design. Their plans post-graduation are summarized in Table 1. Pseudonyms are used to protect students' identities.

Table 2 shows the students' scores on the SSCI at the beginning of the term and at the end of the term. The test has 25 questions and students received one point for each correct answer. All students improved their scores after completing the course. The table reveals that the students represent a range of abilities and knowledge about signals and systems. The mean score for the interview participants was 13.5 on the pre-test and 20.3 on the post. For the class overall (N=37), the pre-test mean was 12.7 and the post-test mean was 17.6. So, while the sample scored slightly higher than the class overall, there scores are representative of the class distribution.

Table 2: Interview Participants' Scores on the SSCI

Student	Pre-Test Score	Post-Test Score
Amy	12	18
Beth	9	21
Charles	13	20
Diane	13	21
Edward	16	19
Frank	18	23

Themes in the Interview Responses

The students repeatedly mentioned an interest in knowing more about applications of signals and systems. Having applications presented as part of the class was useful. Students also wanted to know more about applications of the content in order to be prepared for their work as professional engineers. They pointed to applications of content and the integration of content (e.g., applying concepts from multiple courses in their senior design projects) as a difficulty and a challenge in the program. Students were also currently enrolled in various types of design courses that required them to integrate and to apply knowledge and concepts they had learned in previous courses. They pointed to this as challenging and interesting. At this upper-level stage of their engineering program (or having graduated), they were most interested in the concepts for which they could see a purpose. The mathematics-heavy concepts were singled out as difficult to understand and too difficult to apply in their design work and in their careers.

Related to real-world applications, four students pointed to the design of physical objects either as their reason for becoming engineers or as an activity they were now enthusiastic about doing in upper-level coursework. Related to the design of physical objects was software implementation. In other cases, being able to "tinker" with an object was an appealing aspect of electrical engineering or a rationale for entering an engineering program. In a few cases, they were finally achieving their goal of being able to take everything they had been learning in class and building a car, robot, or other device. In one case, a student identified signal processing as too theoretical, and her interest in bioengineering stemmed from the applied nature of the courses (e.g., more laboratory experiences and real-life problems). Students' responses about difficult and important concepts was consistent with previous interviews that have been conducted as part of the SSCI development work.[1,8] Consistent with the other theme related to applications, important concepts were identified by how well the students could see the application to real world problems or to other courses.

While the students who participated in the interviews represent a small sample from the course, there are some patterns that are worth pursuing in continuing work. Amy identified herself as having weak knowledge of mathematics, and she had the lowest post-test score on the SSCI. She was also non-specific about her future plans in engineering. She was interested in something "less technical" and had been exploring bioengineering as a possible option. Edward also identified himself as low-performing (he mentioned in the interview that he was taking the course for a second time). His interest in engineering was related to the design and building of electronics. So, he was specific in his future goals, but also interested in hands-on, building of tangible objects rather than in the theoretical elements of engineering.

On the other end of the spectrum, Frank had the highest scores on the SSCI and was very specific about his future plans, which were more theoretical in nature (e.g., software design and signal processing). Another high-performing student on the SSCI, Diane, was currently working for an engineering firm and applying her knowledge of signals and systems. However, her job did not require her to build or to design. Her work was more analytical in nature. A third high-performing student on the SSCI, Beth, also identified graduate school in electrical engineering as an objective, and she made the most gain on the SSCI from pre-test to post-test.

Analysis of Survey Data

Students from the semester B offering of ECE 320 have not yet participated in individual interviews, but they did complete an online survey at the end of the term in which they took the course. Among the questions asked in the survey administered to the students in the semester B offering of ECE 320, we considered the two related to future plans and the effect of the signals and system course on future plans. Specifically, the questions of interest were:

1. After graduation, I'm considering working/studying in the field of.....
2. Has this course affected your future career/education plans? If so, how?

Sixteen of the nineteen students enrolled in the course responded to the survey.

Students' responses to question one above were analyzed to determine how closely (if at all) their planned field of work/study related to signals and systems. Each response was coded as having a close relationship to signals and systems, some relationship to signals and systems, or little or no relationship to signals and systems. For example, a career in satellite communications has a close relationship to signals and systems, while a career in medicine has little to no relationship to signals and systems. Table 3 shows how many of each code appeared in the responses and the associated grade distribution for each code. Note that one student completing the survey did not answer this question.

Table 3. Summary of Graduation Plans and Course Grades

Response Code	Frequency	Associated Course Grades
Close Relationship	3	A A D
Some Relationship	10	B+ B B B C C C D D F
Little to no Relationship	2	A B+

Of the responses received, three were coded as being closely related to signals and systems. While two of the students with closely related focus areas earned A's in the course, the third did not earn a passing grade. The majority of the career/study responses fell in the *some relationship* category. This was in part due to the fact that many of the responses were not sufficiently specific to identify a strong relationship, e.g. a response of "electrical engineering." If non-specific responses are removed from consideration, three *some relationship* responses remain. The grades associated with those are B+, C, and C. Finally, two responses fell in the *little to no relationship* category. This is perhaps the most interesting category to consider, as the associated grades were quite high. The areas students provided that fell into this category were business and medicine.

One theory explaining why students with largely unrelated career plans did particularly well in the course is that they had focused career aspirations that motivated their studies. To explore this theory, we coded career plans according to specificity without considering relationship to signals and systems. Of the fifteen responses, eight were coded as specific and seven as non-specific. The course grades associated with the specific responses were A, A, A, B+, B+, C, C, and D. The top five grades earned in the course fall in the group that gave specific career/study field responses, indicating that a focused plan for the future may correlate positively to students' academic performance.

We also examined the relationship between students' responses to survey question one and their scores on the SSCI. We used students' SSCI scores at the end of the course (rather than at the beginning) as a measure of their conceptual understanding. Table 4 shows students' SSCI scores as a function of the closeness of the relationship between signals and systems and their planned field of work/study. Grade distributions are also included for reference. Recall that the best possible score on the SCCI is 25, and the worst possible score is 0. The table shows that students' SSCI scores are strongly correlated to their course grade, and hence the conclusions drawn about the relationship between course grade and interest in signals and systems as a field of work/study hold here, as well.

Table 4. Summary of Course Grades, SSCI Scores, and Graduation Plans

Response Code	Frequency	Course Grades and SSCI Scores
Close Relationship	3	A A D 22 21 13
Some Relationship	10	B+ B B B C C C D D F 21 21 20 20 19 15 9 12 12 N/A
Little to No Relationship	2	A B+ 23 19

Using the survey responses to question two above, we analyzed the degree to which the course impacted students' career and/or education plans. Analyzing the effect of this course on future plans is particularly relevant to studying the relationship between conceptual understanding and career plans because the course was taught with an emphasis on conceptual elements of signals and systems. Assignments included in-class group problems, traditional exams, and application-focused projects, all of which were designed to emphasize conceptual questions, e.g. those focused more on understanding the "why" of a topic and less on procedural mathematics.

We have coded the responses to survey question two into one of three categories: positive effect, little or no effect, and negative effect. Table 5 shows the number of responses in each category and the associated grades.

Table 5. Course Grades and Impact of Course on Plans

Response Code	Frequency	Associated Course Grades
Positive Effect	5	A B+ B B D
Little or No Effect	9	A A B B C C D D F
Negative Effect	2	B+ C

The limited data available does not indicate a correlation between course grade and effect on future career/education plans. It is worth noting that this relationship is somewhat difficult to analyze, since students who were already planning a signals and systems-focused career did not necessarily indicate that the course affected their plans, but it may have reinforced them.

Discussion and Future Work

The results of this study identify a variety of open questions to be addressed as areas for future work. The analysis of interview data indicated a relationship between students' future plans (analytical work/graduate school vs. design-and-build work) and their conceptual understanding of signals and systems. This relationship should be further explored using a larger group of students and data from both interviews and surveys. Examining similar relationships in more applied courses would also be informative. At a broader level, the results indicate that a study of the relationship between application-based classroom activities and conceptual understanding is warranted. Specifically, students whose interest was more in "tinkering" and design/build applications appeared to have more difficulty with conceptual understanding. One question to be answered in future work is whether incorporation of more application-based and hands-on (tinkering) activities could improve conceptual understanding for these students.

Analysis of the survey data raised questions about if/how students' career plans change over the duration of a course. Students in the semester B offering of the course filled out a survey only at the end of the semester. Asking students to respond to career plans and interests questions both at the beginning and at the end of the semester would provide a means for measuring how their focus changed during the academic term. An additional area for examination is students' perceptions of the usefulness of conceptual course material and if/how these perceptions change. Students who had strong conceptual understanding often showed an understanding of the links between signals and systems theory and real-world applications. Can the effect of course structure on these perceptions be measured? This question is likely related to the above question about the link between applications-focused instruction and conceptual understanding.

The work presented here represents a part of a larger ongoing study, and the questions brought forth by these results will be further explored as the study continues. In particular, future work will focus on increasing the number of students interviewed and surveyed, as well as extending the data collection and analysis to other courses in the electrical engineering curriculum.

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