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An Introductory Course in Electrical Engineering: Lessons Learned and Continuing Challenges

Dr. Melinda Holtzman, Portland State University

Melinda Holtzman received her Ph.D. from the University of Nevada, Reno. She is a Senior Instructor in the ECE department at Portland State University.

Prof. Branimir Pejcinovic, Portland State University

Branimir Pejcinovic received his Ph.D. degree from University of Massachusetts, Amherst. He is a Professor and former Associate Chair for Undergraduate Education at Portland State University, Electrical and Computer Engineering department. In this role he has led department-wide changes in curriculum with emphasis on project- and lab-based instruction and learning. His research interests are in the areas of engineering education, semiconductor device characterization, design and simulation, signal integrity and THz sensors. He is a member of IEEE and ASEE.

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Work-in-Progress - An Introductory Course in Electrical Engineering: Lessons Learned and Continuing Challenges

Melinda Holtzman and Branimir Pejcinovic
Portland State University, Electrical and Computer Engineering Department
holtzman@pdx.edu, pejcinb@pdx.edu

Abstract - **A three-quarter freshman sequence in electrical engineering was designed to provide design and teamwork experience, introduce programming, stress communication skills, and attract and engage more students, especially from under-represented groups, into electrical and computer engineering. While successful in some aspects, we see problems with retention and student success in the later courses. This paper focuses on the first course in the sequence, and how it could better prepare students for the more rigorous coursework ahead. We look at two areas. First, the introduction of an alumni mentor program to connect students with recent graduates working in local industry. While promising, students did not engage in the program as much as expected. Second, continuing efforts to assess students' lack of math and problem-solving skills. We are currently working on math, logic and algorithmic assessments to detect and address these problem areas early on, and researching the correlation between these assessments and student outcome in the courses. So far, we have found little correlation between tests on specific math skills, from algebra to calculus, and success in the courses. However, we do see a correlation with overall math GPA. In addition, there is some promise in using a logic and algorithmic assessment. We are exploring the correlation between this logical-thinking test and student success, and also improvement in students' logic ability as evidenced by pre- and post-test comparisons.**

Index Terms - electrical engineering, mentors, problem-solving skills, retention

INTRODUCTION

Nine years ago our Electrical and Computer Engineering (ECE) department designed a three-quarter freshman sequence to address these goals: (i) give students an early experience in design and teamwork, (ii) introduce programming and specifically MATLAB early in our program, (iii) stress communication skills, and (iv) attract and engage more students, in particular from under-represented groups, into ECE [1]. While we have had some successes – popular and engaging team design projects, hands-on lab experience, and an alumni mentor program – we still have problems with retention and student success. Specifically, the first quarter in the sequence has been a fun and inviting gateway course, but has not prepared students well for more rigorous coursework in the next two classes in the sequence.

In this work-in-progress paper, we will describe some of the continuing challenges with this three-quarter sequence, with particular emphasis on the first quarter. We will look mainly at two aspects: (i) the alumni mentor program, which we believe is promising but has so far not lived up to expectations, and (ii) efforts to address student lack of problem-solving skills. A common belief is that students struggle in engineering courses due to lack of math skills. We find that students lack not just basic math skills, but also problem-solving ability, as evidenced by poor performance on a simple logic/algebra test. We will discuss our continuing assessment efforts and some ideas to address this issue.

BACKGROUND

When we replaced the existing college-wide introductory engineering course with our own three-course sequence, specifically designed for ECE students, we based the course design on feedback from employers and alumni. The feedback identified four main issues: (i) students had insufficient programming skills, (ii) students had weak communication skills, (iii) students were not introduced to design until upper-division courses, and (iv) we needed to attract and retain undecided and traditionally under-represented groups of students. The overall goals were to include project design and teamwork experience, introduce programming earlier, stress "soft skills" such as communication, ethics and student success, and to improve student engagement.

In the first course in the sequence, ECE 101, students do a quarter-long hands-on project such as building a Rube Goldberg machine, to learn the design process and teamwork skills. They do lab experiments to learn basic equipment and components, and speakers from both the faculty and local industry present an overview of different fields and career opportunities in electrical engineering. In the second course, ECE 102, students learn to develop algorithms and apply computational software tools (mainly MATLAB) to solve primarily simple electrical engineering problems. They do a project using MATLAB programming for data acquisition and control. In ECE 103, they learn software design, algorithms, data structures, and computation using the C programming language. They write C programs to solve intermediate-level engineering problems, and write control code for hardware interfacing projects.

We designed these courses to be engaging and to help students be well prepared for future ECE courses, not to "weed out" underperforming students. However, we see a large percentage of drops and fails, especially in ECE 102 and 103. In order to improve retention and success, we need to understand our students and why they do not succeed – is the problem preparation, motivation, college skills, or something else? Some of the challenge stems from our non-traditional student population: (i) roughly 60% of upper-division students transfer from community colleges, (ii) roughly 50% work on average 20 hours a week, (iii) around 20% are international students who, in spite of passing an intensive language program, still struggle with English, and (iv) students do not follow our advising plans. For example, the number of credit hours required to graduate in ECE is 180, but the average number at graduation is about 230.

To illustrate diversity of student backgrounds, Figure 1 shows the admission status of students taking ECE 101 and 102 from 2014–17. There is an increased percentage of transfer students for the latter, which is due to the historically flexible substitution policies for ECE 101. As a result, many transfer students are required to take ECE 102 but not 101.

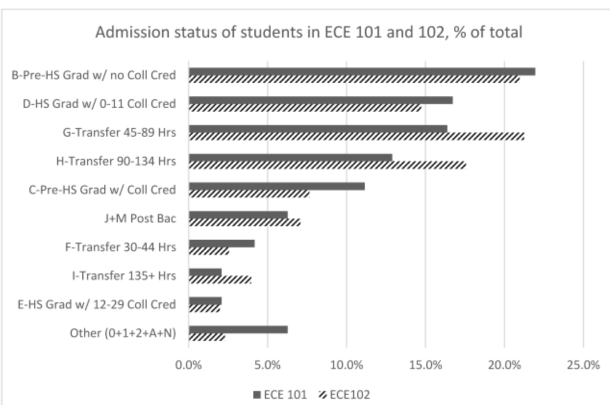

FIGURE 1. ADMISSION STATUS OF STUDENTS IN ECE 101 AND ECE 102 COURSES. DATA FOR FALL 2014- TO SPRING 2017.

In the past year, we have made several changes to ECE 101, including introducing significantly more math content, developing new labs that reinforce the math content [2], and starting an alumni mentor program to connect students with recent graduates working in local industry [3]. These changes will be discussed in the next sections.

ALUMNI MENTOR PROGRAM

In this program, each project team of 4–6 students is assigned an alumni mentor – a recent graduate working in local industry. The mentors do several things: (i) come to class and speak about their job experience, (ii) meet with their teams early in the term to help them get started with their projects, (iii) provide a job or internship description to which the students apply by providing resumes and letters, then giving feedback, and (iv) being available by email or other means to answer questions throughout the quarter.

The program was met with enthusiasm by the mentors, who were excited to meet with their teams. We were especially pleased to have several female mentors to provide positive role models for our underrepresented female students. The students, however, were not as engaged with this program as expected. They seemed happy to meet the mentors when they came to class, and most submitted resumes and cover letters when it was a graded homework assignment, but they otherwise did not reach out to the mentors with email questions or any other kind of contact.

We still feel this program has great potential, and are considering how it can be more effective. We need to be cognizant of not asking too much time of our working alumni, but also want to encourage more interaction between students and mentors. Expecting freshman to reach out to professionals may be too intimidating, so we are considering more structured meetings between students and mentors, such as asking mentors to come to class a second time, or requiring online or phone meetings. We feel students have much to gain from this interaction, and would like them to appreciate the benefits of having an industry contact and the valuable advice and feedback being provided. However, this might not be as much a priority for freshman as for students further along. Another idea is to adopt this program in the sophomore year, when students are more likely thinking about internship possibilities.

MATH AND PROBLEM-SOLVING SKILLS

One definition of problem solving is "any goal-directed sequence of cognitive operations" [4]. In the last few years, we have tried several ways to assess math and problem-solving skills in both our freshman and sophomore students, and to investigate the utility of these assessments as predictors of student success in ECE courses. Jonassen [5] divides problem solving into eleven categories. Our assessment tests generally fall into his first three categories: logical, algorithmic and story. This work is ongoing, but we have had some limited success so far. Results are reported in more detail elsewhere [6], but are summarized below.

- Prior completion of Calculus I or similar math course showed weak correlation with ECE grades.
- Level achieved in online math assessment tool (ALEKS) also showed weak correlation with ECE grades. This assessment technique (an online, at-home test) could possibly be more valuable if administered in class, but that raises logistical and financial issues.
- Overall grade point average in all prior math courses shows somewhat better correlation with ECE grades. The $R^2 = 0.2$ factor is still weak, but this appears to be a better predictor than the previous two approaches.
- A simple math quiz given at the beginning of the sophomore year showed weak correlation with exam grades in the first quarter of the sophomore circuits

sequence ($R^2 = 0.05$) and no correlation at all with grades at the end of the second quarter. While this may be a useful tool to make students aware of gaps in their math preparation, it is not a predictor of eventual success.

- Students performed poorly on a simple logic/algebra test given in both ECE 101 and 102, with an average of about 65% across four sections. Given that roughly 65% of ECE 101 students and 80% of ECE 102 students have already passed at least Calculus I, we were surprised at the low results for a relatively simple and straightforward test. This may be due to students not transferring their math skills to new contexts, inadequate preparation, or lack of motivation for taking the test. There was no correlation between these test results and ECE 102 final grades. However, learning about student difficulties with even simple word problems was helpful knowledge.
- A Math-Algorithmic-Logic Thinking (MALT) test [7] in ECE 102 did show some weak correlation with final course grades ($R^2 = 0.12$.) This test was also given at both the beginning and end of the quarter to examine the extent of student learning during the course. The average improvement in score was around +2 points out of 12, and t-test confirmed significance.

DISCUSSION AND CONCLUSIONS

Student response to ECE 101 is generally positive. On a self-efficacy survey, students expressed confidence in their research and writing abilities, ability to perform simple lab experiments, and ability to complete a team project. However, students were much less confident in their ability to solve engineering problems. Among seven different class activities, students ranked labs, project and homework as most helpful in their learning. The last one is puzzling because we do not emphasize homework in this course.

Students enjoy and find value in the team project experience. The Rube Goldberg machine (with required electrical components) is creative, challenging and popular. In a recent class we also tried letting students choose a project that interested them. While daunting for some students, others rose to the challenge. Students also find value in being introduced to lab equipment in a less intense course than the sophomore circuits lab, which used to be our first lab course. For students with no prior electrical experience, the sophomore lab was a difficult hurdle. We feel both the project and lab portions of this course are quite successful. We believed the alumni mentor program would be an exciting positive addition. We are a bit disappointed with its implementation so far, but are working on improvements.

One lesson learned is that it is critical to express expectations clearly to both mentors and mentees. Where we did this, for example in asking the mentors to come to class and talk about their work experience, expectations were met. When we were less clear, for example regarding continuing contact after the class meeting, results were less successful. In addition to making expectations clear, we also need to collect data to assess the level of student engagement in the program. Our conclusion that few, if any, groups contacted their mentors beyond what was strictly required is based on the mentors' reports. In the future, records of contact will be kept to determine accurately the extent of engagement.

We are continuing to work on the challenge of student retention in ECE 102 and 103, and are concentrating efforts on student problem-solving abilities. It is puzzling that students who have successfully completed college level math courses, many including Calculus I or above, cannot solve relatively simple math, algorithmic or logical problems. This lack of problem-solving ability surfaces particularly in courses like ECE 102 and 103, where students have problems with programming and debugging. We are currently working on assessments to detect and address these problems early on, and researching the correlation between these assessments and student outcome in the courses. So far, we have found little correlation between tests on specific math skills, from algebra to calculus, and success in the courses. However, we do see a correlation with overall math GPA. In addition, there is some promise in using a logic and algorithmic assessment. We are exploring the correlation between this test and student success, and also improvement in students' logic ability as evidenced by pre- and post-test comparisons.

There are still issues related to our assessment of student skills and preparedness but we believe that the hardest issue is how to improve student problem-solving ability. A most promising approach seems to be "learning by doing." We have designed some new labs in ECE 101 that directly implement the math theory covered in class. For example, a MATLAB simulation of a robot arm uses trigonometry. While it is too early to assess the impact of these new labs, we feel it is a promising approach. We are also exploring the idea of two tracks in ECE 102. One would be at the same pace as the current course, but we would offer a second track spread over two quarters with more time for students to develop their programming skills. The issue of student problem-solving ability is not an easy one to assess or address, but is essential for engineering education.

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