Developing Community and Research Experience In A Freshman Mechanical Engineering Programming Course

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Abstract

In this paper, group research projects in a freshman Mechanical Engineering programming course are examined as a method to better integrate and engage first-generation students and to generate interest in research and research careers. First-generation students have been found to have an achievement gap, possibly due to social isolation and a lack of cultural capital. Creating project groups that maintain connection and interaction within the course was found to be important in a survey of students in supporting their learning. Adding a research-based project to this group work has been designed to further engage these students in campus life and introduce them to potential academic and career options.

Keywords

Programming, First-year, First-generation, Research

Introduction

The first year of an engineering career is an important phase of a student's education. In these first courses, fundamental skills are learned that will be used in many downstream classes. Students learn to navigate the expectations of college coursework. Students also develop the study skills they need to succeed in their downstream classes. In particular, this is the time when students form support communities of peers that can help each other.

For first-generation students, forming communities and understanding expectations can be particularly challenging. An estimated 15-40% of college students are first generation, defined here as a student whose parents have not received a 4-year college degree [1]-[3]. These students have been shown, both nationally and in our own courses, to have an achievement gap relative to their continuing-generation peers in terms of degree completion and continuation in engineering [4]-[5]. These students may also be disproportionately from underrepresented racial and ethnic groups [6]. Previous research has identified several factors that impact the performance in first-generation students including a lack of cultural capital (inside knowledge of the best ways to succeed in a university) and social isolation [1]-[3].

These students are also less likely to reach graduate school, impacting our ability to recruit diverse students beyond the undergraduate degree. It has been shown that research experiences during undergraduate careers increase the likelihood of undergraduate degree completion and continued participation in the scientific workforce [7]. As such, integrating research into the freshman engineering experience could be powerful in engaging diverse students early in a fruitful career.

Introduction to Digital Computing Methods in Mechanical Engineering (ME 208) is an introductory programming course required of first year students in Mechanical Engineering at the University of Kansas. In this course, we are working to address these issues by engaging students in group projects that create community, integrate course objectives, and improve understanding of scientific research. Through these projects, students are encouraged to develop communities with fellow students to reduce social isolation and improve sharing of cultural capital.

Course Structure

The course, ME 208, focuses on programming Arduino microcontrollers in the C++ programming language for 8 weeks followed by Matlab programming for 7 weeks. Class size is typically between 50 and 100 students and the course is taught in both the Fall and Spring semesters. The students each purchase the Sparkfun Inventor's Kit 4.1 (Sparkfun, Niwot, CO) which contains an Arduino Uno style development board as well as a breadboard and an assortment of sensors, motors, and other elements. Each weekly module starts with tutorial videos. A one hour class on Mondays reviews this material in an active-learning style, where students sit in their project groups to complete exercises. Each week has a 2 hour laboratory in which an individual programming assignment is competed followed by a homework assignment due the following week. The course has 3 individual exams, the first in week 4 on Arduino C++ programming, the second in week 8 on Arduino C++ programming, and the third during finals week on Matlab programming.

Projects

In parallel with the individual work, groups are created with 5-6 students within discussion sections of the course. As much as possible, first-generation students are paired with continuing generation students, while efforts are made to include at least two women in any group that contains women. These groups sit together for active learning assignments during the Monday lecture period and also work together on three collaborative projects. The groups meet via Microsoft Teams for 15 minutes each week with a graduate teaching assistant and/or the professor during their registered discussion section time. Each project has weekly deliverables and a final report. Microsoft Teams is used to support the groups work. Within the software, students are able to send chat messages, share files, and organize video meetings.

The first 3-week project allows the students to get to know each other and develop their communication and teamwork skills. This project focuses on using LEDs and a piezoelectric speaker from their kits to create a sound and light display such as flashing lights to a sports team theme song. The group is asked to create a unified plan and code, but each student must then implement the project on their own device and create an individual demonstration video. The group is also asked to produce a short report.

In the second project, the students are asked to do a creative project that integrates at least one sensor and one motor from the kit. These sensors include a temperature sensor, an ultrasound distance sensor, a potentiometer, buttons, and switches. The kit comes with two types of motors: a microservo motor and two gear motors. The group comes up with a unified plan and code, but each student must then implement the project on their own device and create an individual video.

The group also produces a short report. Some of the projects that have been done for this second project include an automatic flusher for a toilet, a light following platform, and a collision detecting car.

For the last 6 weeks of the course, a third project focuses on scientific research. The project asked the group to:

1. Develop a hypothesis that can be tested using one of the available sensors.
2. Use the Arduino-board and at least one sensor to collect data.
3. Use Matlab to analyze the data including either a t-test (are two samples statistically different from each other) or linear regression (do two variables correlate with each other).
4. Create graphics within Matlab to represent the data. These could include plots of the data, bar graphs, or histograms.
5. Create a group research poster and presentation to present at the university's undergraduate research showcase.
6. Write a final group report for the project.

The project starts after the second Arduino exam, at the same time the course transitioned to Matlab programming.

Each weekly deliverable for this third project helps the team to develop a better understanding of the research process and how to develop tools for research. During the first week, the students watch a video on the research process, investigate potential sensors (including those from the purchased kit as well as others made available to them including a load cell, anemometer, accelerometer, and wheel encoder), and brainstorm ideas for a testable hypothesis. During the second week, the group is asked to contact and interview a researcher on campus about their research. In addition, the group is asked to select a hypothesis and beginning to prepare the hardware setup for the experiment. In week 3, the students are asked to collect some sample data and work on code to analyze their data in Matlab. By this stage, we have introduced some basic statistical analysis methods during the lecture and lab (a t-test and linear regression). In weeks 5 and 6, the groups are asked to complete their data collection and analysis and to draft a research poster for a university undergraduate research showcase. Group posters are graded using a project grading rubric where meeting project requirements, researcher interview, research question, methods description, results, graph, visual communication and spelling/grammar are rated as expert, proficient, apprentice, or novice. Group members also completed peer evaluations of the team members using the CATME.org software.

Results

In Fall 2020, prior to the current form of the third research project, students were surveyed to assess what elements of the course students found most supported student learning (with university human subjects committee approval). It was found that students rated their project

group members, more than all other surveyed classroom elements, as the most important resource in supporting learning (Table 1). In this same survey, it was also found that first generation students had greater family and work responsibilities presenting obstacles to their learning.

	Very Important	Slightly Important	Not Important
My Project Group Members	61%	35%	3%
TA Office Hours or Direct Communication	58%	26%	16%
Arduino.cc	48%	26%	26%
Dr. Wilson's Office Hours or Direct Communication	42%	42%	16%
Other Classmates Not in Group	42%	29%	29%
Mathworks.com	42%	26%	32%
Other Internet Sources	32%	32%	35%
Other	11%	6%	83%
Undergraduate Teaching Fellow	11%	29%	61%
People Outside of This Class	10%	42%	48%

Table 1. Fall 2020 survey of students found group members were of the highest importance as resources in supporting learning in the class. [5]

These findings support the belief that this group work is critical to overcoming social isolation and supporting student learning.

Discussion

Many of the student groups formed connections that extended beyond the required interactions. When the course was taught in-person, these group bonds also extended to student interaction in the classroom, leading to more efficient active-learning work and a better sense of community within the classroom. The group project meetings also provided a space for the professor and graduate teaching assistants to interact in an informal way with the groups—answering questions, facilitating group and individual work, monitoring progress, and interacting informally with students even when the course was not meeting face-to-face during the pandemic. Group projects were particularly important in creating a sense of community and connection among students in the course during the early stages of the pandemic. In Spring 2020, after shutdowns, students had just completed the last Arduino exam and were moving to working with Matlab. Given the difficulties of the early weeks of the pandemic, attendance at Zoom lectures was optional (sessions were recorded), and often focused on answering student questions. While coordinating group projects proved difficult, several students also found them helpful for preserving a sense of connection and community in a difficult semester.

The research focused project was introduced in Fall 2021, replacing a game design project. This coincided with students returning to being predominately on campus. A goal of this effort was to encourage students to engage in on-campus activities through introduction to the research enterprise and how skills developed in the course could be used in those endeavors. It has been observed that, over the pandemic, interest in graduate school from our student population

dropped. While this could be due to many factors, it will be interesting to see if downstream undergraduate engagement in research and subsequent graduate enrollment increase in this student cohort. We have already seen an increased engagement in student organization such as ASME (which may again be due to many factors including this course).

In conclusion, group project work has been found to be important in overcoming social isolation in freshman, both first-generations students and student experiencing isolation during the pandemic. It is hoped that including an introduction to research work in the third project will further entice our students to consider getting involved in research and considering research careers. For those interested in replicating this work, resources for implementing a similar research-focused, mechatronics project (including sources for equipment, assignment structure, and grading rubrics) have been made available through the Science and Education Research Center at Carleton College, Teaching Computation With Matlab site [8]. This type of assignment could be modified for students with less programming experience by providing them with working instrumentation and Arduino code. It could also be expanded for students with programming experience prior to a course.

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