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Work in Progress: Development and Implementation of a Self-guided Arduino Module in an Introductory Engineering Design Course

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Abstract

This Work in Progress paper discusses the implementation of an online module designed to teach basic Arduino programming skills to students enrolled in a first-year engineering design course. The learning objectives for students were (1) to learn the basics of Arduino programming through hands-on activities, (2) to connect with the numerous online resources available for creating their own projects for personal or class purposes, and (3) to gain a sense of curiosity about what types of challenges and problems they may be able to solve with their newfound skills. This module was deployed in the introductory design course beginning Fall semester 2017, and feedback from the initial module participants has been largely positive. Preliminary results suggest that module participants were able to expand upon the basic skills taught during the module to utilize the technology in their semester design projects effectively. In addition, participants expressed curiosity about ways they could use this technology in the future.

Introduction

This Work in Progress paper describes the development and implementation of a self-guided online Arduino module in a required, multidisciplinary design course for first-year engineering students. This introductory engineering design course is a project-based course required for all engineering majors on campus as part of the freshman engineering program. The course, which begins with a design challenge description and culminates with students demonstrating a working physical prototype by the end of the semester, serves as a first exposure to the engineering design cycle for many students. This project-based approach is used by numerous other first year engineering programs and is certainly not unique to this particular course, but it comes with both advantages and disadvantages [1], [2], [3], [4], [5]. On the positive side, students typically enjoy the hands on aspect of the course and are able to experience firsthand what it takes to design and build a product. However, most first year students have minimal prior experience with the tools required for design and fabrication, and this inexperience can severely restrict the types of design challenges that can be assigned. Development of meaningful design projects that are still approachable for a first year student can be difficult, and this challenge can be compounded by the limited instructional time and large student-to-instructor ratio.

In the case of this particular course, the assigned design projects have always had the option of a purely mechanical solution, as students were not required to have any prior knowledge of electronics, and teaching techniques such as basic circuitry and microcontroller programming was not the focus of the course. Most students ended up building purely mechanical devices using the woodworking shop available to course participants. There are always a handful of students each semester who utilize skills from past experiences such as high school robotics clubs or other programming activities to devise a solution that employs more than simple mechanics. These students' solutions are often more creative and require more critical thinking and troubleshooting. End of the semester feedback showed that students enjoyed the project overall, but felt that their lack of prior programming and electronics knowledge severely limited their projects, especially compared to other students in the course who had prior experience in these areas. The development of the Arduino module was motivated by four semesters worth of similar feedback from course participants indicating that basic microcontroller programming knowledge would have been valuable not only for completing the projects in the introductory design course, but also for use in upper level engineering courses and projects of personal interest. Not only were students eager to learn microcontroller basics, instructors also recognized that by introducing students to these skills, the resulting projects may be higher quality and the range of design challenges that can be assigned may be broadened.

Use of microcontroller technology in freshman level courses is not new, and these concepts have been taught through in-person laboratory instruction with positive results at numerous universities [2], [3], [6]. Additionally, multiple universities have employed a "flipped classroom" approach to teaching microcontroller basics with online instruction prior to in-class lab activities [1], [7], [8]. This work aims to build on these successful examples by developing and implementing a fully online and self-guided microcontroller module in the introduction to design curriculum. By designing the module for online instruction and support, the instructors were able to accommodate the large number of students, overcome lab space limitations, and minimize the required in-class time for the lessons.

This online module was developed and deployed in the course beginning Fall semester 2017. While a similar module could be developed for any microcontroller, instructors chose to focus on the Arduino UNO for this beginner level module, as it is cost-effective (approximately $25 per board), widely used, and open source, with an active community of educators and hobbyists sharing content online [9]. The fully online Arduino module has the benefit of having minimal impact on the overall course format, and it allows students to work at their own pace through the lessons, as there is likely a wide range of incoming knowledge for students in this first year course. As there have been urgent calls for post-secondary institutions to produce engineers who not only have a sound technical background but are also entrepreneurially minded and critical thinkers [10], [11], this module was designed not only to provide students with technical skills, but also to inspire curiosity about other ways this technology could be used and encourage students to engage with the online community and resources related to this technology. While the Arduino module is intended to equip students with skills that can be used in the classroom setting, it is also intended to give students a glimpse into the growing Maker Movement both on campus and worldwide [12]. With this in mind instructors designed the module to meet the following three learning objectives:

Learning Objective #1: Students will learn the basics of programming an Arduino Uno microcontroller board through hands-on activities.
Learning Objective #2: Students will connect with the numerous online resources available for creating their own projects for class or personal purposes.
Learning Objective #3: Students will gain a sense of curiosity about what types of challenges they may be able to solve using their new skills and connections to the online community.

This paper will discuss the development of this module, the preliminary results from the initial module deployment in Fall semester 2017 including student response and incorporation of microcontroller technology into the final projects, and the future work to be done to fully evaluate the effectiveness of the module at meeting its three learning objectives.

Course Overview and Arduino Module Implementation

Course Overview

The introductory engineering design course has an enrollment of nearly 600 students per semester and consists of one 50 minute lecture and one 50 minute lab session per week as well as an online software component administered through the Canvas learning management system. The lecture and laboratory content center around a semester-long team design and fabrication project. The design challenge is different each semester, with past projects including marble launchers, arcade game design, and Rube Goldberg machines. The first implementation of the Arduino module was in Fall 2017, and in this semester the design challenge required students to design a Rube Goldberg machine that could unlock a door in precisely 15 seconds using as many steps as possible. Teams of four students spent the entire semester learning the engineering design process through this hands-on project.

To complement the skills students learn in lecture and lab, the online software component of the course consists of five-week long self-guided modules that provide students with basic instruction in common engineering software programs that may be useful for their design projects and in their future engineering coursework. Prior to Fall 2017, students chose two of four options (MATLAB, AutoCAD, Microsoft Excel, or Siemens NX) to learn over the course of the semester. Because this software framework was already in place, the initial Arduino module was developed to be offered as a fifth option for students to choose from. This implementation gave a large number of students access to the module content with minimal changes to the overall course structure.

Arduino Module Development

Before the online module was developed, the concept was tested in a live presentation format during two “Pop-Up Courses” offered during the spring of 2017. 14 students participated in these non-credit workshops, and they provided valuable insight about which skills the students were most interested in learning and the appropriate level of difficulty and depth for the course material. With this initial feedback, a five-week module was developed as outlined in Table 1.

Table 1: 5-week Arduino Module Outline

Week	Instructional Content	Assessments
1	Video 1: Arduino Hardware and Basic Electronics (11 minutes) Video 2: Arduino Software (5 minutes)	Assignment, online quiz
2	Video 1: Writing Digital Signals (8 minutes) Video 2: Reading Digital Signals (8 minutes)	Assignment, online quiz
3	Video 1: Serial Communications (5 minutes) Video 2: Analog Signals (13 minutes)	Assignment, online quiz
4	Video 1: Libraries and Servos (10 minutes) Video 2: Review and Useful Resources (6 minutes)	Assignment, online survey
5	None	Comprehensive online quiz

While a wide variety of resources are already available for teaching and learning Arduino basics, a custom developed module was preferred for this course as it allowed instructors to deliver the content in a format that was consistent with the other software tutorials and to tie the concepts covered in the module to the course content to help students make connections between the skills they are learning and their team design project. The tutorial videos consisted of a combination of PowerPoint slides, still images of circuit schematics, and webcam video. The weekly content was broken up into two short videos (5-13 minutes in length) according to recommendations for improving student engagement [13]. In addition to introducing technical skills related to programming an Arduino UNO, the videos were designed to emphasize the numerous web-based resources available and encourage students to become involved with the active community of users working with open source microcontroller products and sharing content online on the Arduino [9], SparkFun® [14], and Adafruit ® [15] forums.

Although instruction was provided through online videos, the module was a hands-on learning experience for the students. The Arduino software is open source, so students were able to download it for free on their own computers and complete the lessons anywhere. Students checked out kits with either an Arduino UNO or SparkFun® RedBoard (Arduino UNO compatible board) and various other electronic components to use for the duration of the module. These kits cost approximately $40 and are reusable. Funding for the initial kit purchase was provided by an internal educational resource grant, and the kits were made available to the students free of cost. Kit checkout was handled by the instructors during weekly office hours. Equipped with this kit and a personal computer, students worked through the tutorials at their own pace over the five-week period. Because the tutorials and activities were self-guided rather than presented in a classroom setting, students were responsible for their own learning and could not immediately access an instructor for guidance. Students were encouraged to post questions and problems to a moderated online discussion forum or attend office hours for additional assistance.

Assessment of Student Learning

Learning Objective #1, for students to gain basic Arduino programming skills, was assessed through weekly assignments and quizzes that were designed to cover the main learning outcomes from each week. For the first four weeks of the module, the videos concluded with an assignment for students to complete on their own. Each weekly assignment required students to construct a circuit and write code to perform a specific task related to that week's lesson. Students submitted both their code file as well as a digital photograph of their circuit set-up through Canvas, allowing instructors to evaluate both aspects of their work and provide feedback. At the end of most weeks students also completed an online multiple choice quiz covering key concepts from the week's lesson. Students completed a longer, comprehensive quiz during the fifth week at the conclusion of the module.

At the end of the fourth week an anonymous online survey was administered, asking students for their feedback on the Arduino module. The survey was designed to gain insight about the students' motivation for choosing the module, their perceived learning, and whether this module made them curious about other ways this technology could be utilized (Learning Objective #3). The survey questions are detailed in Table 2.

The impact of the Arduino module on students' final design projects was also of interest in order to assess Learning Objective #2, for students to connect with the online resources available for creating their own projects. The five-week module was designed to give students confidence in basic skills rather than to provide specific project instructions. In order for students to utilize this technology in their semester project, they needed to draw upon additional resources to expand their skills. The semester-long design problem that students addressed in Fall 2017 could be solved using a wide variety of methods, and although students were not be required to incorporate an Arduino UNO microcontroller board into their design project, many chose to do so. The incorporation of this technology into the final project was recorded and compared between teams with one or more member who had completed the Arduino module and teams without. The quality of the projects produced by teams with member(s) who had completed the module and incorporated a microcontroller board into their design was also compared to the rest of the class by comparing average final project scores. Final project scores for the Rube Goldberg machines were assigned based on performance, complexity, and professional appearance. The performance score was based on how well the task was carried out and included points for the precision of the device's timing and for successfully completing the final step (unlocking the door). Project complexity was assessed by counting the number of different steps in the process from device activation to the door being unlocked. Finally, projects were expected to be professional in appearance with the team's name, logo, and theme clearly visible.

Table 2: Fourth week survey questions

Question	Response Options
What was your experience (if any) with microcontrollers before completing this module?	o No prior experience with any type of microcontroller o No prior experience with Arduino/RedBoard, but some experience with another type of microcontroller such as BASIC Stamp, Raspberry Pi etc. o Some experience with Arduino/RedBoard o Extensive experience with Arduino/RedBoard
Why did you choose to complete this module?	o General interest o To learn skills for a personal project o To learn skills for the class design project o Other
I gained a better understanding of Arduino/RedBoard from this module.	3-point Likert scale
I gained skills from this module that I can apply to this semester's project.	3-point Likert scale
I gained skills from this module that I can apply to projects in future courses or personal projects.	3-point Likert scale
This course sparked my curiosity about ways I can use this technology	3-point Likert scale
Provide any additional feedback you have	Free response

In this initial module deployment, collection of student feedback was somewhat limited in an effort to keep the module similar in workload and structure to the other software options. Not wanting to deter interested students during the pilot test of this module, the feedback was restricted to a single online survey at the conclusion of the module. In future semesters, instructors plan to survey students both before and after completing the module (weeks 1 and 4) to investigate changes in perceived knowledge and attitudes about the technology. In addition, students will be asked to complete a short reflection about their experience during the module, whether they consulted additional online resources and which resources were most useful, and why they did or did not choose to implement the technology in their design project. This additional feedback will further assess whether the three learning objectives for this module have been achieved.

Preliminary Results and Discussion

The Arduino module was first deployed in the introductory design class during the Fall 2017 semester, and while additional semesters will be required to refine the module, assess its effectiveness, and draw conclusions, the preliminary results and student feedback have been largely positive. During the pilot semester, 107 of the 564 enrolled students chose to complete the Arduino module as one of their two software choices. Of these 107 students, 99 (93%) completed the survey at the end of the fourth week of the module.

Based on the responses to the survey, students' past experience with microcontrollers was mixed. 56% of the students who responded to the survey indicated that they had no prior experience with any microcontroller, while 41% said that they had some experience with Arduino or another type of microcontroller. Only 3% of the students responded that they had extensive experience with Arduino. As this is a first-year course, it was hypothesized that most students would have little to no experience in the area of microcontroller programming and the module was designed to require no prior knowledge of the topic. Student responses indicate that this assumption was correct, and the beginner level module was likely appropriate for the majority of participants.

When asked about their motivation for choosing the Arduino module, the majority of students, (72%) stated that they chose the module due to general interest. 22% of respondents chose the module to learn skills for a personal project, and surprisingly few (4%) chose the module to learn skills for the semester design project. Two students (2%) listed other reasons for choosing to complete the Arduino module than those provided in the survey. It is interesting that only 4% of students chose the module to learn skills for the semester project, as approximately half of the module participants ended up employing a microcontroller board in their final design. It may be that at the beginning of the module they weren't familiar enough with Arduino to know whether or not it would be useful for the design project. Alternatively the semester project could have been a contributing factor in their decision but not the primary reason for their choice.

Although a full comparison of students' scores in the Arduino module compared to the other software options has not yet been completed, the average comprehensive quiz score was 85.5%, which falls in the middle of the average comprehensive quiz scores for the other four software options. The full comparison may provide additional insight and suggest specific areas of improvement; however, this overall performance suggests that the students' comprehension of the module's technical content was fairly good, a "B" average, and on par with the other software modules. Students' assessment of their own learning from the fourth week survey is summarized in Figure 1.

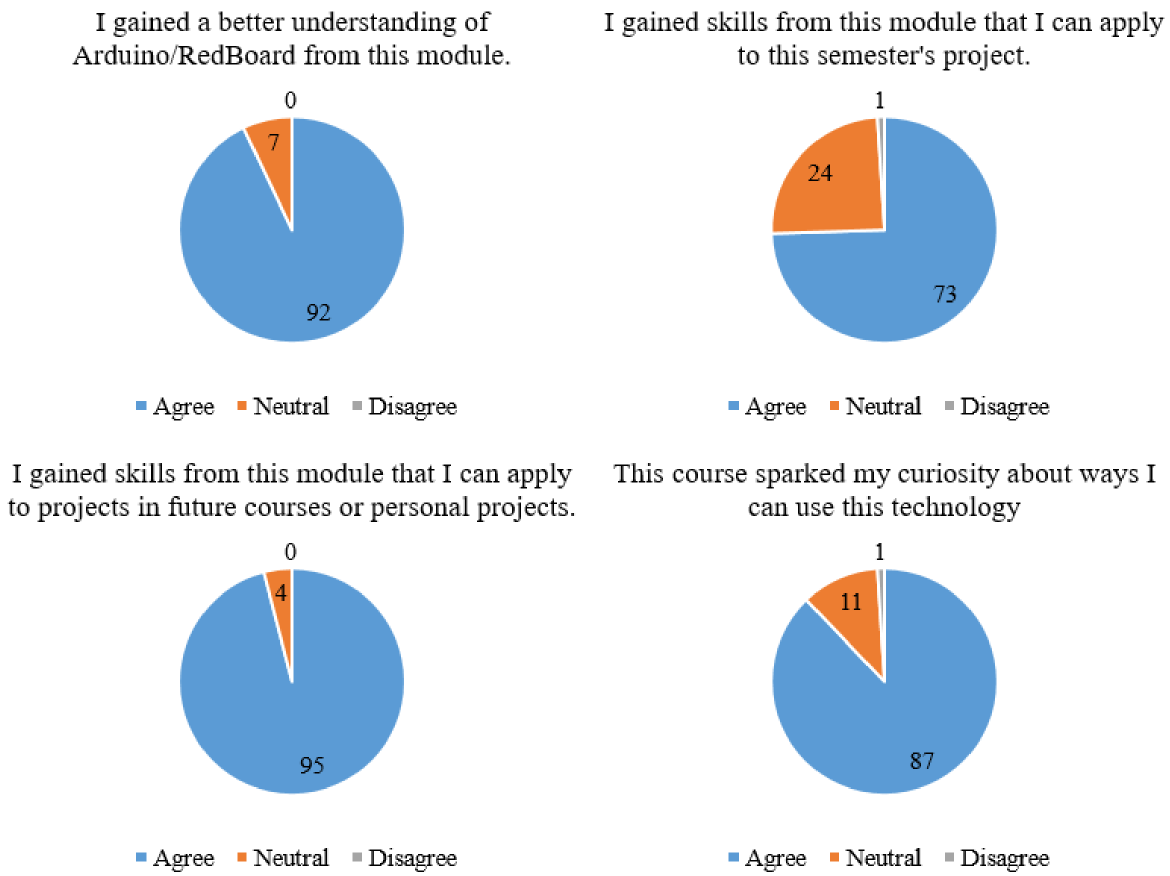

Figure 1: Summary of student responses to fourth week survey questions

While these responses only include one semester worth of data, the majority of students completing the module indicated that they gained a better understanding of the material, gained skills that could be used for projects, both current and future, and finished the module with a sense of curiosity about ways they can utilize the technology. The instructors stressed to students that comments would be appreciated as this was the first deployment of the Arduino module, and most survey respondents included some comments in the free response box at the end of the survey. The majority of these comments fell into one of three areas. First, many students included comments about how the module had piqued their interest in the area of microcontrollers:

"I thought this was really interesting and you made it simple enough to understand, yet stem curiosity of what else could be done with this. I started imagining all these home projects that could be done with this. I enjoyed this activity."

Combined with the fact that 87% of participants agreed that the module sparked their curiosity about this technology, these comments imply that this module did a good job meeting the learning objective of students gaining sense of curiosity about what types of challenges and problems they may be able to solve with their newfound skills. It is anticipated that student reflections after module completion in future semesters will provide additional information about how students are connecting with online resources and whether they are engaging with the active community of makers working with microcontroller technologies.

Second, a number of students, particularly those who indicated that they had little or no prior experience, commented on the module being enjoyable and fun:

"I did not know what I signed up for when I wanted to do the Arduino, I just saw a circuit board and thought it looked cool. I have had no experience coding so this was fun to do and learn."

Anecdotally, it seemed that students were enthusiastic about the hands-on nature of the module. Whether this perceived excitement was accompanied by increased student engagement with the module is currently being examined. Comparisons of module completion percentage (how many of the assignments and quizzes each student completed) as well as numbers of students coming to office hours and participating in the online discussions for each software option are ongoing.

Finally, a handful of students found the assignments to be too easy, and wanted more of a challenge:

"I think that the assignments should ask a little more out of us. Possibly require the use of external sources to figure out what code we need to use (e.g., use google to figure out how to use a function of code)."

While the assignments will remain the same through at least the end of Spring 2018 to collect more feedback, these comments suggest that it may be possible to increase the difficulty of the assignments or provide an additional "bonus challenge" on each assignment for students who want to go deeper into the material. The fact that students are actively asking to be pushed to conduct independent searches and utilize their critical thinking is an encouraging sign of their interest and curiosity.

In addition to students' feedback on their experience with the module, the incorporation of microcontroller technology into students' final projects was recorded and final project grades were compared for students who chose the Arduino module versus their classmates who chose different software options. For this study, project grades were only compared within the Fall 2017 semester and were not compared to historical data from previous semesters because each semester's challenge is different, and although all design challenges are intended to be equal in difficulty, there is a fair amount of variation in the average from one semester to the next. Of the 132 teams completing the design project in the Fall 2017 semester, 79 teams included one or more students who completed the Arduino module. Of the 79 teams with module participants, 40 teams employed a microcontroller board in their projects in some capacity. The vast majority used an Arduino UNO or similar board such as an Elgeoo UNO or SparkFun® RedBoard, although a few groups used other microcontroller boards such as Arduino MEGA, Raspberry Pi, and BASIC Stamp. Only ten teams without any members completing the Arduino module chose to utilize a microcontroller board in their projects. Instructors estimate only 15-20 teams per semester utilized a microcontroller board on previous projects, and the jump to 40 teams after the deployment of the Arduino module was a noticeable change.

These numbers suggest that completion of the Arduino module motivated participants to utilize the technology in their projects, or perhaps groups that were already interested in employing this technology from the beginning of the semester chose to take advantage of the resource offered to them to gain skills in this area. Because respondents were anonymous in the fourth week surveys, the prior experience of the students who chose to utilize the technology in their final projects is unknown. To evaluate the effectiveness of the module, especially for the beginner level students, it would be useful to know what percentage of the students using a microcontroller board in their projects were students with some prior experience versus students with no prior microcontroller experience. This question will be an area of follow-up research during future deployments of the module.

Preliminary investigations into the characteristics of teams that chose to incorporate microcontroller technology included looking at the number of module participants on each team. Of the 79 teams with one or more Arduino module participant, 56 teams had just one member completing the module, 18 teams had two members completing the module, and 5 teams had three members completing the module. With an increased number of module participants on the team, there was a trend of increasing microcontroller incorporation as shown in Figure 2.

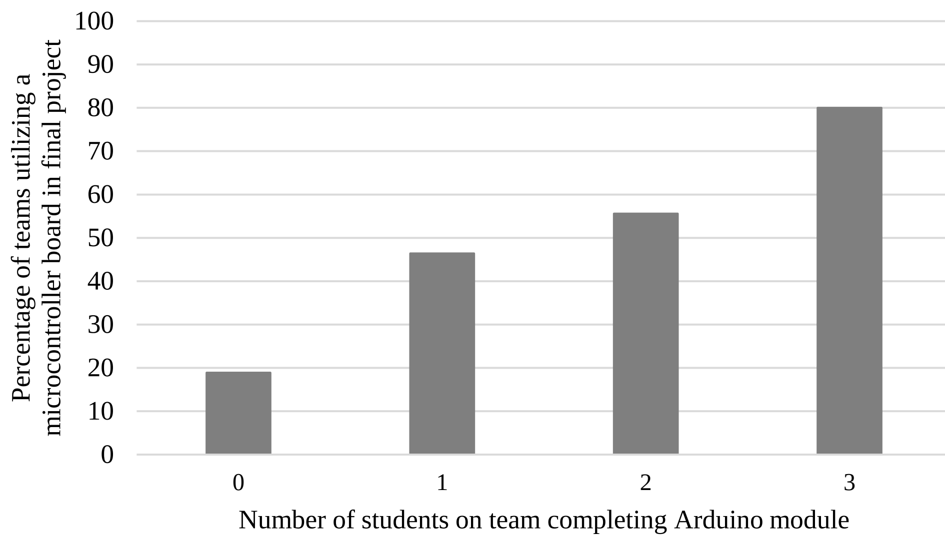

Figure 2: Percentage of teams utilizing a microcontroller boards in the final project when zero, one, two, or three students on the team had completed the Arduino module.

It is possible that “isolated” module participants, those who were the only member of the team completing the module, were more reluctant to use a microcontroller board for a variety of reasons including concerns about shouldering too much of the work or dominating the team’s design decisions, resistance from teammates, or a lack of confidence in their individual skills. Teams with more students having completed the module may have been more inclined to utilize the technology as more of the members had sufficient technical knowledge to be involved in the decision making and troubleshooting process.

The quality of the final projects was quantified with a final project grade (maximum score 105), which was comprised of scores for project performance, complexity, and professionalism as discussed previously. Figure 3 shows the average final project scores for the following four groups: (i) teams without Arduino module participants, not using a microcontroller, (ii) teams with Arduino module participants, not using a microcontroller, (iii) teams without Arduino module participants, using a microcontroller, and (iv) teams with Arduino module participants, using a microcontroller. Statistical significance was determined using one-way ANOVA with the Tukey *post hoc* test with $p < 0.05$ reported as a significant difference between groups.

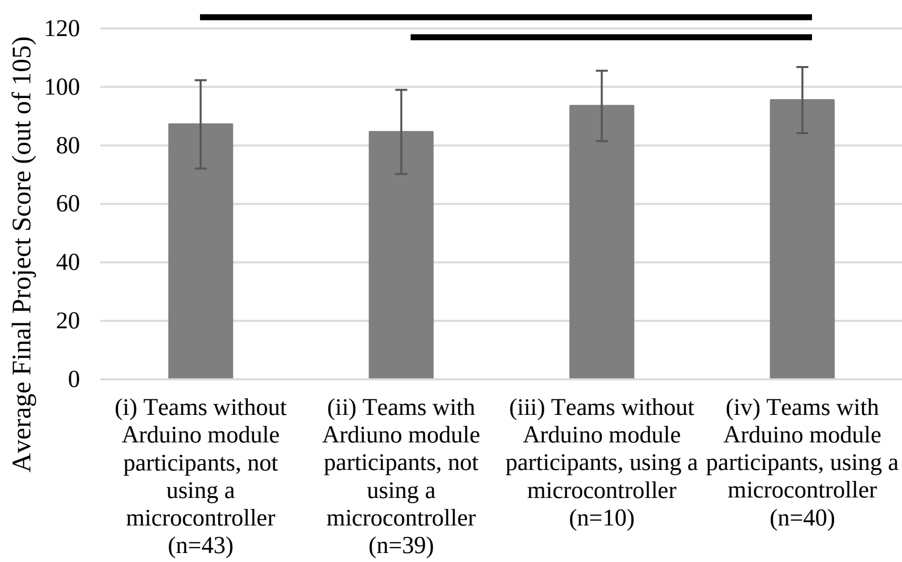

Figure 3: Average final project scores (+/- standard deviation). Horizontal bars indicate significant differences ($p<0.05$) between groups.

Overall, the class average was 89.4 out of 105. With the fairly high average score and substantial variability within each group it is difficult to draw definitive conclusions, particularly considering that these results only represent student performance for the specific design challenge for Fall 2017. However, the final project scores suggest that the students who completed the Arduino module and chose to incorporate a microcontroller board into their final projects (group iv) were able to do so effectively, earning the highest average final project score of 95.5 which was significantly higher than the average for teams not utilizing the technology (both with and without module participants). Incorporation of the skills learned in the Arduino module in the final project resulted in these students outperforming their peers who completed the module but did not choose to utilize the technology. Students were not asked about why they did or did not choose to employ a microcontroller board in their design, so it is unclear whether these students did not feel that the Arduino module prepared them well enough to utilize the technology, or if they chose not to use a microcontroller for other reasons. It is anticipated that student reflections collected during subsequent semesters may help answer this question.

The group with the second highest project average (93.5) was the set of teams that utilized a microcontroller board even though they did not have any team members completing the module (group iii). Statistically, the average final project grade for this group was not different from any of the other three groups, but there does appear to be a trend of improved performance for these students even though they did not complete the module. This represents a relatively small number of teams (ten), and the past experience of the students on these ten teams with regards to microcontroller technology is unknown. In future semesters it may be informative to survey all students, not just module participants, about their experience with microcontrollers and other technologies to investigate whether students are relying on technical skills from past experiences and courses or seeking to acquire new skills as they complete the design challenge.

Although it was not the instructors' intent, it may have been that the use of a microcontroller board was advantageous for this design challenge compared to other approaches teams may have chosen to take. Results from design projects in future semesters are necessary to determine whether the high final project scores for module participants utilizing a microcontroller board were simply due to the nature of this specific challenge or if participants will be able to apply their skills to a wider variety of design challenges.

Looking only at the teams that used a microcontroller board in the final project, the final project grades were compared for teams with zero, one, two, and three Arduino module participants (Figure 4). While there were no statistically significant differences between any of these groups, there does appear to be a slightly upward trend in the scores with teams with zero module participants having the lowest average (93.5) and teams with three module participants having the highest average (101.3). Again, with the scores being high to start with, the room for improvement is slight. Additionally, the number of teams being compared in some of these groups is small; for example, only four teams employing a microcontroller in their project had three module participants, so it is essential to collect additional data in the upcoming semesters to see if this trend is significant.

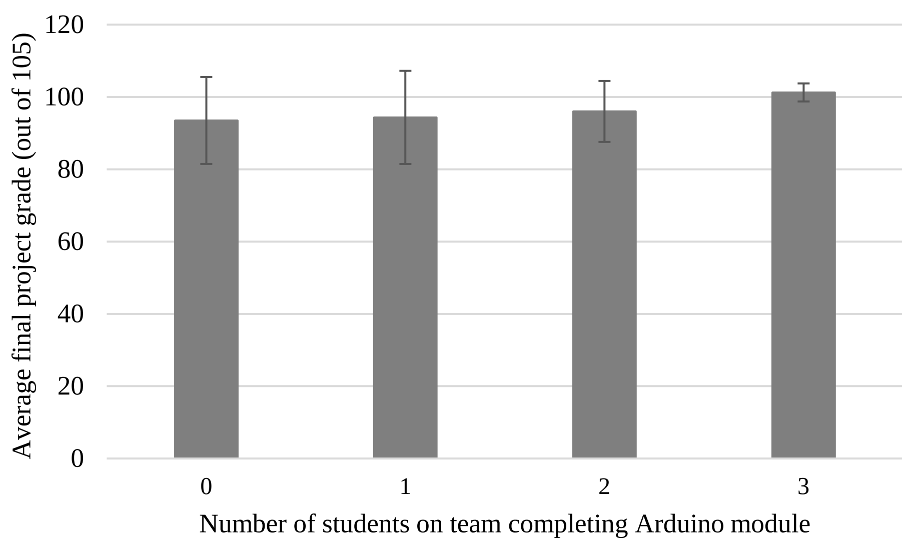

Figure 4: Average final project grades (+/- standard deviation) for teams utilizing a microcontroller when zero, one, two, or three students on the team had completed the Arduino module.

However, this result, combined with the fact that having multiple team members complete the module increased the likelihood that students would incorporate the technology into their projects suggests to instructors that it may be advisable to encourage more students within the same team to complete the Arduino module if they are interested in employing the technology in their final project. Based on past software selections, students often take the "divide and conquer" approach, with team members choosing to learn different programs to broaden their team's knowledge. As the results for the Arduino module suggest that students may be more inclined to apply what they are learning in the online modules to their projects and perhaps do so more effectively when other team members are also learning the program prompts follow-up investigation, not only for the Arduino module in future semesters, but for the other software module options (MATLAB, AutoCAD, Microsoft Excel, and Siemens NX) as well.

Conclusions and Future Work

The results from the initial deployment of the Arduino module were encouraging to instructors and highlighted numerous areas for additional investigation related to the module and the introductory engineering course as a whole. Student feedback was overwhelmingly positive, and there was a trend of increased incorporation of microcontroller technology into the final project by module participants. Improved project grades for module participants who elected to employ a microcontroller board in their final projects suggest that the students were able to effectively expand on what they learned in the introductory online module to approach a design challenge. Analysis of existing data is ongoing, comparing assignment scores, completion percentage, and discussion forum participation between the Arduino modules and the other software options. The Arduino module is currently being deployed a second time as an option for students in the Spring 2018 semester with only minor content changes in order to collect additional student feedback and observe final project results for a different set of design constraints.

The second phase of this study will begin in Fall 2018 when instructors plan to administer both pre and post surveys (weeks 1 and 4) and ask students to submit a short reflection about their engagement with the online Arduino community and why they chose or did not choose to incorporate the technology into their project. The results of the pilot implementation of this module suggest that it may be useful to survey and request a reflection from all students about their experiences with the online software modules, not just those completing the Arduino module. All online software modules are intended to teach students technical skills that can be used for the design project, so understanding more about students' prior experience with the software and why they did or did not choose to employ the skills from the online modules in their project may be insightful. It is anticipated that the pre/post survey format as well as this reflection will help answer many of the follow-up questions prompted by the pilot implementation of this module including to what extent students are becoming curious and seeking out additional resources, the prior experience of students who ultimately choose to utilize a technology or software program for their final project, and whether teams with more students learning a certain software program are more inclined (and perhaps better equipped) to use it for their project.

Additionally, although the online software module format for this class is not new, this was the first time that students were offered an option that involved hardware as well as software. A recent study [16] has suggested that including hands-on robotic experiences in an introductory programming course improved student motivation and performance. With this in mind, it would be interesting to see if exposure to this Arduino module, which many students considered to be a "fun" introduction to programming techniques, during freshman year translates into increased motivation or success in future programming courses. In future semesters it may be possible to track students who have participated in the module as they complete introductory programming coursework. Students' positive reception of this hands-on module may also pave the way for development and implementation of online modules on other topics of interest such as rapid prototyping within the online software portion of the course. An early introduction to these techniques during freshman year may encourage students to engage with the campus (and broader) maker community throughout their university education.

Finally, the successful pilot implementation of this module suggests that by making the module mandatory for everyone in the course, it may be possible to provide all students with the basic microcontroller programming skills that would be necessary to take on a semester design project that required the use of a microcontroller board. The ability to instruct all students in this large enrollment course in microcontroller basics without cutting into the limited lecture and lab time could enable instructors to assign new, and possibly more challenging varieties of design challenges for students to address with their semester projects. Numerous universities have published on successful implementations of design projects with a coding or microcontroller related aspect [1]- [3], [6]- [8], and students in this introductory course may benefit from the additional challenge such a design project poses.

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