2018 ASEE Annual Conference & Exposition
June 24-27, 2018
Salt Palace Convention Center
Salt Lake City, UT

Paper ID #21519

How Free Choice Affects Student Interest in a Junior-level Embedded Systems Lab Course

Mr. Michael Trent Bolt, Auburn University

Michael Bolt is a graduate student at Auburn University pursuing a Ph.D. in Electrical Engineering. He is currently working as a research assistant to Dr. Mark L. Adams in the STORM Lab. His current projects include embedded system programming for environmental sensing projects, X-band RF design work, and the reorganization of lab course content to increase student interest in subject material.

Mr. Andrew Cookston, Auburn University

Andrew Cookston is a graduate student in the Electrical and Computer Engineering department at Auburn University. He is currently working as a research assistant to Mark L. Adams in the STORM Lab. His current research focus is in quantum engineering and introducing quantum systems to high school and undergraduate students.

Prof. John Y. Hung, Auburn University

John Y. Hung is a professor of electrical and computer engineering at Auburn University, where he has been on the faculty since 1989. Prior to his academic career, he worked for Johnson Controls, Inc., in the field of digital controllers for commercial building automation systems, and also worked as a consultant in control systems design. Hung is a Fellow of IEEE, and serves on the IEEE Board of Directors. He is the local coordinator for the 2019 ASEE-SE conference, which is being hosted by Auburn University. John's teaching and research interests are in control systems applications.

Dr. Victor P. Nelson, Auburn University

Victor P. Nelson is a professor and Assistant Chair of Electrical and Computer Engineering at Auburn University. His primary research interests include embedded systems and computer-aided design and testing of digital systems and application-specific integrated circuits (ASICs). He is co-author of the textbook Digital Logic Circuit Analysis and Design and a tutorial book on fault-tolerant computing. He has been Chair of the ECE Curriculum Committee, Coordinator of the ECE Graduate Program, and served one year as Associate Dean for Assessment in the College of Engineering. He is a member of IEEE, ACM, and ASEE, and is an ABET Program Evaluator. He has served as Chair of the ECE Division of ASEE, an at-large AdCom member of the IEEE Education Society, a member of the IEEE Committee on Engineering Accreditation Activities (CEAA), and previously served as an Associate Editor of the IEEE Transactions on Education and on the IEEE Computer Society/ACM Task Force that developed the Computer Engineering 2004 report on model computer engineering curricula. He was a co-winner of the 2005 Wireless Educator of the Year award from the Global Wireless Education Consortium for his role as one of the developers of the bachelor's of wireless engineering program at Auburn University, which is the first of its kind in the U.S.

How Free Choice Affects Student Interest in a Junior Level Embedded Systems Lab Course

Abstract

Graduate students at Auburn University (AU) have developed a new course structure for a long-standing embedded systems lab in an effort to increase student interest in the subject matter. Students are now given a choice between two different lab exercises each week that focus on the same skills and course material. In order to quantify the success of this change in course structure, an anonymous survey measuring the Engineering Identity of each student was administered at the beginning and end of the semester for two groups in two semesters: a control group given no choice of lab exercise and an experimental group given a free choice between two lab exercises. This paper examines the results of these surveys to determine the effect that student agency can have on student interest levels and their perception of themselves as engineers.

Introduction

The United States Bureau of Labor Statistics predicts that jobs related to Science, Technology, Engineering, and Mathematics (STEM) will grow by approximately 13 percent from 2014 to 2024; this area's predicted job growth is second only to the medical field [1]. A large number of these new jobs are expected to be in Embedded Systems, as this field pervades almost every area where electronics are used [2]. For example, the automotive industry is increasingly looking for engineers with skills in Embedded Systems, as the average car can have between 25 and 50 CPUs, while high end vehicles can have as many as 150 CPUs and ten million lines of code [3, 4]. Additionally, jobs creating Internet of Things (IoT) devices and many other common electronic devices are increasingly requiring skills in Embedded Systems [5].

At Auburn University (AU), a lab course focusing on Embedded Systems and the full hardware/software design process is required for graduation. This course is the only course in AU's undergraduate curriculum that explicitly focuses on Embedded Systems and their application, but it is commonly referred to by members of the student population as one of the hardest and most work-intensive courses in the curriculum for the number of credit hours they receive. In an effort to increase student interest in the field of Embedded Systems and to encourage them to take more pride in their expertise in this area with high job prospects, the almost 20 year old course has been reworked to allow students more freedom in their lab assignments. A study has been performed over two semesters of this course to determine the effect that student agency has on interest levels in the course's subject matter as well as on the Engineering Identity of the students.

In this paper, we present the results of this small-scale study. First, we explain the choice of Engineering Identity as the metric of interest and the process used to undertake this study. We then give a detailed outline of the Traditional and Alternate lab exercises that students are allowed to choose between in the updated version of this course. Following this outline of our methods and materials, we present our data and findings both quantitatively and qualitatively before making closing remarks on this study and its results.

Methods

For this study, an existing lab course at AU was reworked to allow students a choice between two lab assignments each week. For the control group, students were only allowed to perform the Traditional lab exercises each week and were not given any freedom in their weekly assignments or final project; this has been the course structure in the past. For the experimental group, students were allowed to pick between two options for each week lab's assignment: the Traditional lab exercise or a new Alternate lab exercise, both of which focused on the same concepts and imparted a similar knowledge. Both the Traditional and Alternate lab exercises are outlined in the following section and Table 1.

To collect data on the success of this course restructuring, an anonymous survey measuring the Engineering Identity of each student was given at both the beginning and end of each semester. Engineering Identity is a measure of an individual's perception of their recognition as an engineer by others, competence as an engineer, and interest in engineering, which combine to create an accurate assessment of how strongly a student sees themself as an engineer [6, 7, 8]. Engineering Identity was chosen as it has been shown to be a strong indicator of educational and professional persistence in numerous studies [6, 9, 10, 11, 12, 13, 14, 15, 16] Furthermore, it has been shown that students develop a strong sense of their Engineering Identity as early as their second year in school, making this a strong metric by which to gauge student growth [17]. For this study, the facet of interest has been broken into interest in engineering and interest in Embedded Systems in order to more accurately measure the effect that this modified course structure had on its primary focus.

The survey prompted students to select how strongly they agreed or disagreed with various statements on an anchored Likert scale ranging from 0 (strongly disagree) to 6 (strongly agree). An anchored Likert scale was chosen to allow for a more accurate interpretation of distance between each numeric choice, removing much of the ambiguity from student responses [6]. Each of the statements pertained to a specific aspect of Engineering Identity: Recognition as an engineer, Performance/Competence as an engineer, Interest in engineering, and Interest in Embedded Systems. The exact statements used on the pre- and post- surveys for both the control and experimental groups, as well as the facet of Engineering Identity to which each statement pertains, are presented in the appendix.

Alternate Labs vs. Traditional Labs

Traditional Lab (Control Group)

The traditional course plan for the Embedded Systems lab is a structured approach to designing and constructing a motor controller with a speed feedback control system. Each week, the students complete a lab assignment that involves implementing and familiarizing themselves with a new module within the microcontroller or constructing and interfacing a new circuit with the microcontroller. As the semester progresses, these individual assignments are combined to create a full system. The final project consists of a DC motor, motor driver circuit, motor feedback circuit, push-button keypad, and STM32L100RC microcontroller. The full system allows a user to select a speed for the DC motor through a keypad while using feedback and control system concepts to compensate for different loading conditions applied to the motor.

Alternate Lab (Experimental Group)

The alternate course plan for the Embedded Systems lab consists of the traditional lab assignments alongside a second lab schedule, which is a structured approach to designing and constructing a simple video game. Each week, the students choose a lab assignment to complete that will familiarize them with the same microcontroller module regardless of which assignment they choose: both lab assignments will have them use the same microcontroller module in slightly different ways. As the semester progresses, these individual assignments are combined to create a full system. The final project consists of either the traditional lab final project or a simple video game consisting of a time-multiplexed LED display matrix, a push-button video game controller, a speaker driver circuit and speaker, and the STM32L100RC microcontroller. The full system allows a user to play a simple video game with auditory feedback and victory and failure states.

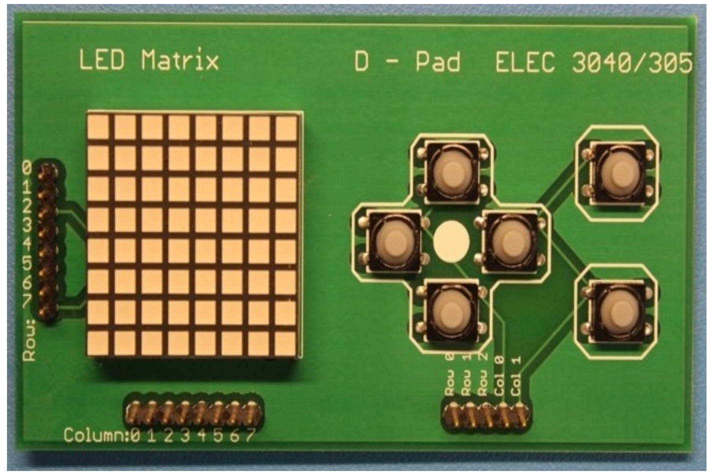
Freedom to Switch

The alternate labs for this course were carefully constructed to be interchangeable with the traditional labs with respect to the knowledge gained. This means that each week a student is free to pick whichever of the two labs is more appealing to them without fear of “missing out” on an important component of the full system for either final project. This was achieved by structuring the alternate lab assignment for each session around the same microcontroller module while utilizing it in a different way. In this manner, the students end the course with the same understanding of the inner workings of the microcontroller regardless of which lab assignment they perform each week. Table 1 shows the traditional lab assignment and alternate lab assignment for each lab session. It is important to note that there are no alternate lab assignments available for the first four lab sessions, as these sessions cover the basics of programming and testing embedded systems and are not specific to either final project. Furthermore, the traditional and alternate labs begin to diverge in the concepts covered around two thirds of the way through the semester. This is done so that the final three labs in either path give the students the main system level components that they will need to complete their selected final project.

Lab #	Traditional Assignment	Alternate Assignment
1	Familiarize oneself with the process of building a project and downloading it to the microcontroller	N/A
2	Develop software to interface digital inputs and outputs (DIOs)	N/A
3	Expand software interfacing DIO modules and familiarize oneself with the oscilloscope and logic analyzer software	N/A
4	Develop software using interrupt service routines and interrupt driven inputs	N/A
5	Interface a Velleman 16-key keypad	Interface a simple push-button video game controller
6	Use timer interrupts to construct and test an accurate stopwatch	Use timer interrupts to create a time-multiplexed display method for an 8x8 LED matrix
7	Use timer hardware modules to generate a pulse-width modulation (PWM) signal and vary its period and duty cycle	Use timer hardware modules to generate a 50% PWM signal and vary its period to play musical notes
8	Construct a circuit to safely drive a DC motor using a PWM signal	Construct a circuit to drive a small speaker using a PWM signal
9	Construct a comparator circuit and interface timer hardware to measure a motor tachometer signal's frequency	Use timer hardware to create animations on an 8x8 LED matrix and change musical notes to play a song
10	Construct a rectifier circuit and interface analog-to-digital converter hardware to measure a motor tachometer signal's amplitude	Implement a user controlled character on an 8x8 LED matrix and provide auditory feedback for different states of operation
11	Characterize the step response of a DC motor using previously designed hardware and software	Implement randomly generated aspects and animations alongside your user-controlled character
12 & 13	Work on your final project (motor controller with feedback)	Work on your final project (simple video game)

Table 1: Traditional and alternate lab assignments by week

(a)



(b)

Figure 1: (a) Velleman 16-key keypad used in the traditional lab assignments (b) LED display matrix and push-button game-pad developed for alternate lab assignments

As an example of this approach, we will discuss in detail the traditional and alternate lab assignments that deal with external interrupts and keypad scanning algorithms. In the traditional lab, students are required to interface a 16-key push-button keypad, shown in Figure 1(a), to their microcontroller and determine which key is pressed and when. In the alternate lab assignment, students are required to interface a push-button video game controller, shown in Figure 1(b), to their microcontroller and determine which button is pressed and when. The circuits for each of these physical interfaces is nearly identical as shown in Figure 2, with the only difference being the number of rows and columns of buttons in each. Due to this similarity, a student that writes software to detect a key press and return the value from the 16-key keypad can very easily adapt their code to apply to the video game controller and vice versa. All alternate lab assignments were created using this approach, allowing students the freedom to choose whichever lab they are more interested each week.

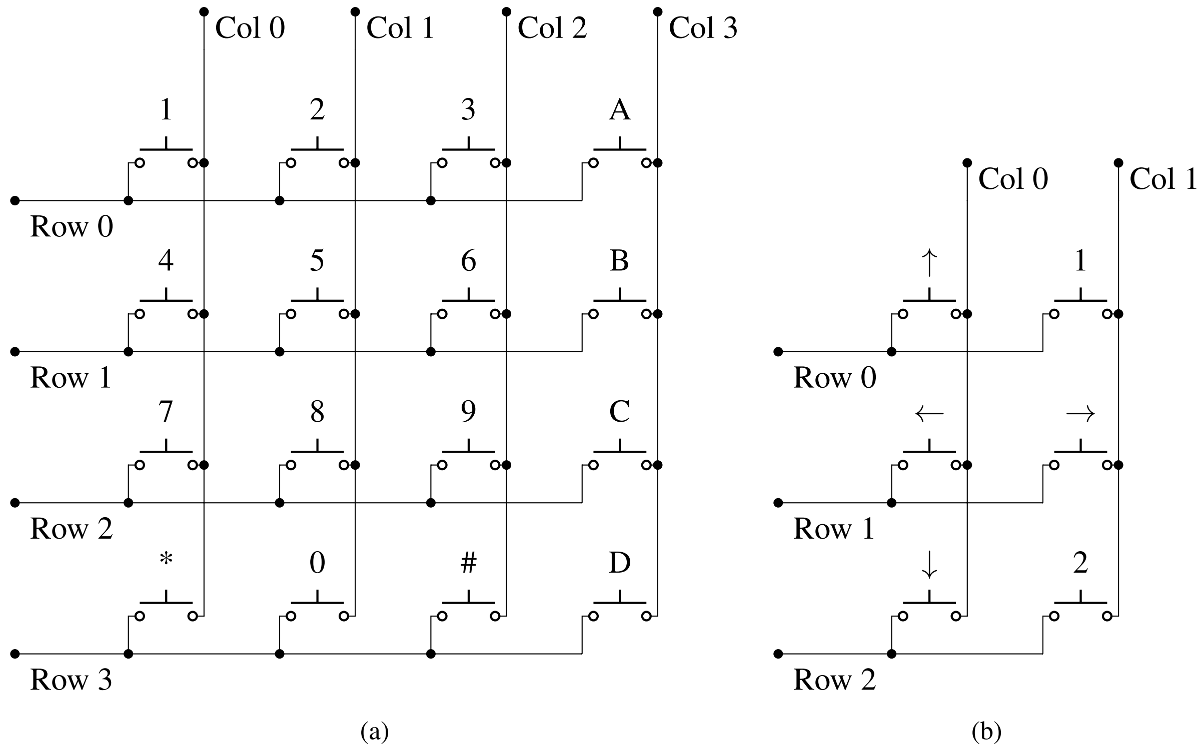


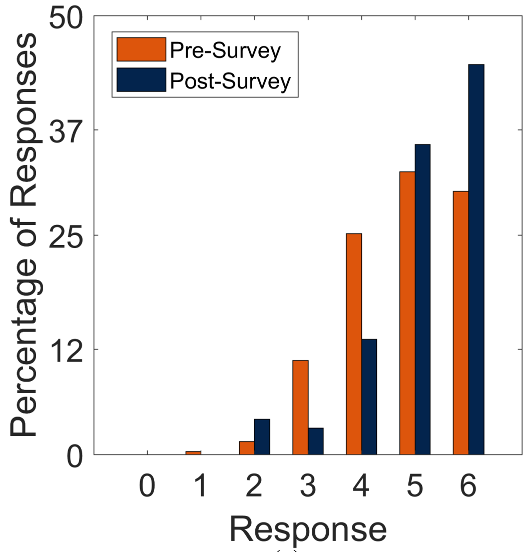
Figure 2: Circuit schematic of (a) Velleman 16-key keypad used in the traditional lab assignments (b) push-button game-pad developed for alternate lab assignments

Data Analysis

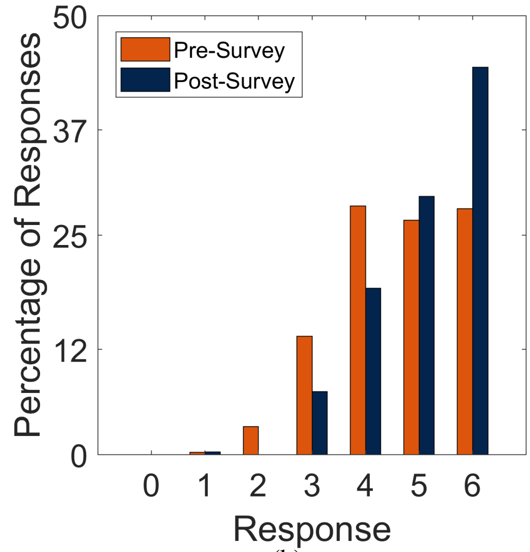
The data gathered for this effort spans two semesters and contains two groups: a control group and an experimental group. Each group consisted of roughly 75% Electrical Engineering students and 25% Computer Engineering students. The student responses to the statements that pertained to each facet of Engineering Identity were combined on a survey-wide basis, allowing us to view the responses as four individual categories (Competence, Recognition, Interest in Engineering, and Interest in Embedded Systems) rather than as 23 separate questions. Table 2 shows the number of responses recorded for each survey. It is important to bear in mind that the small sample size achieved by this effort forbids us from making any hard conclusions on student agency or Engineering Identity. However, the calculated standard deviation values for each category indicate a reasonable response for a valid interest spectrum [18], and the recorded data still shows enough differences between groups to make this effort worthwhile.

Group	Pre-Survey Responses	Post-Survey Responses
Control	30	11
Experimental	42	34

Table 2: Number of survey responses by group



(a)



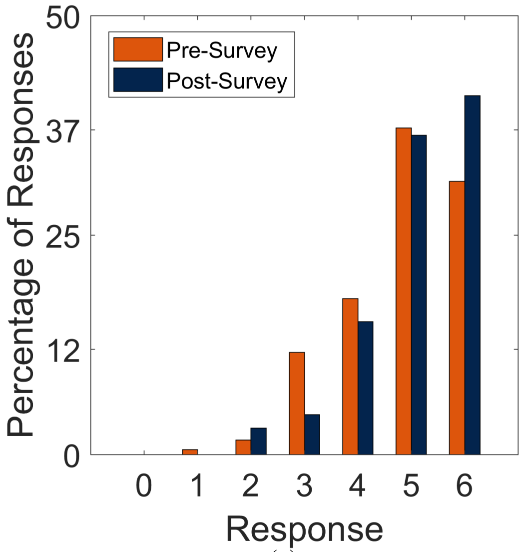
(b)

	Control			Experimental		
	Pre-Survey	Post-Survey	Change	Pre-Survey	Post-Survey	Change
Average	4.77	5.13	+0.36	4.62	5.09	+0.47
Std. Dev.	1.01	0.98	-0.03	1.13	0.97	-0.16

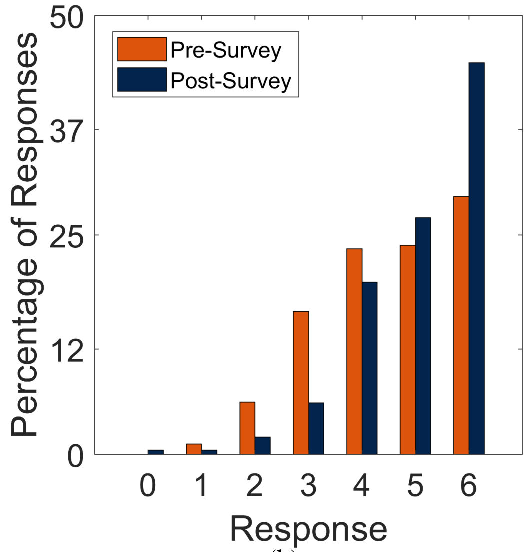
(c)

Figure 3: *Competence.* (a) student responses on pre- and post- surveys in the control group (b) student responses on pre- and post- surveys in the experimental group (c) calculated values for survey responses

Nine of the questions on the pre- and post- surveys pertained to a student's perception of their competence as an engineer. Figure 3 shows the responses of the students on both the pre- and post-surveys for both the control and experimental groups along with a table of calculated values from these data sets. These data show that students in the experimental group had a slightly stronger increase in their perceived competence than those in the control group. Furthermore, a decrease in the standard deviation of the post-survey data accompanied by an increase in the average can be interpreted as the lab causing the students to feel more competent as a whole. This increase in perceived competence indicates that offering students a choice in their coursework can help a student identify more strongly as a competent engineer, possibly due to the pride that comes from completing a project that was chosen rather than a project that was assigned.



(a)



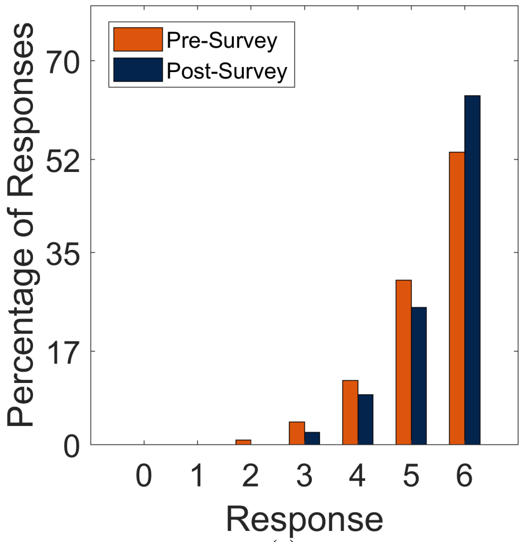
(b)

	Control			Experimental		
	Pre-Survey	Post-Survey	Change	Pre-Survey	Post-Survey	Change
Average	4.83	5.08	+0.25	4.51	5.03	+0.52
Std. Dev.	1.07	0.92	-0.15	1.25	1.08	-0.17

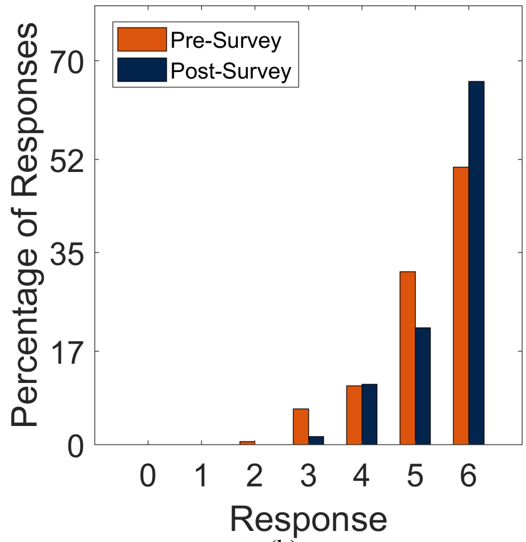
(c)

Figure 4: *Recognition.* (a) student responses on pre- and post- surveys in the control group (b) student responses on pre- and post- surveys in the experimental group (c) calculated values for survey responses

Six of the questions on the pre- and post- surveys pertained to a student's perception of their recognition as an engineer by others. Figure 4 shows the responses of the students on both the pre- and post- surveys for the control and experimental groups along with a table of calculated values from these data sets. These data show that students in the experimental group experienced more than twice the increase of their perception of recognition as an engineer by others than those in the control group. This increase in perceived recognition can also be attributed to the choice made by students, as this additional student agency may result in increased respect from peers and instructors.



(a)



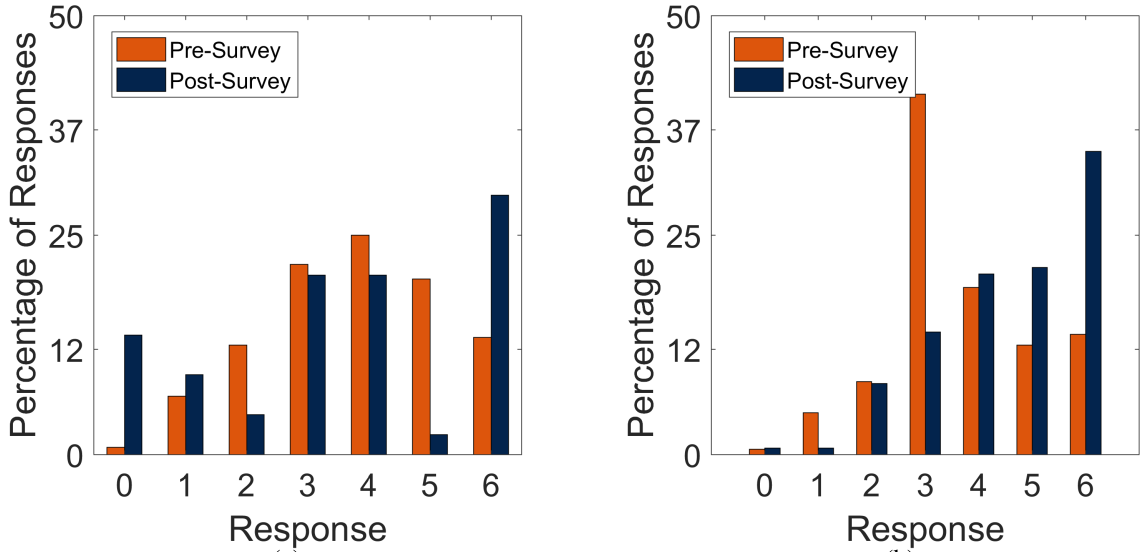
(b)

	Control			Experimental		
	Pre-Survey	Post-Survey	Change	Pre-Survey	Post-Survey	Change
Average	5.31	5.50	+0.19	5.25	5.52	+0.27
Std. Dev.	0.90	0.78	-0.12	0.92	0.72	-0.20

(c)

Figure 5: *Interest in Engineering.* (a) student responses on pre- and post- surveys in the control group (b) student responses on pre- and post- surveys in the experimental group (c) calculated values for survey responses

Of the eight questions on the pre- and post- surveys pertaining to a student's interest level in engineering, four of them pertained to interest in engineering in general. Figure 5 shows the student responses to these questions on both the pre- and post- surveys for the control and experimental groups along with a table of calculated values from these data sets. These data show that the students in the experimental group experienced a slightly stronger increase in their interest in engineering than those in the control group, but not by a large margin. These similar increases in engineering interest levels are likely due to the fact that the general engineering concepts explored in both versions of the lab are the same and the addition of student agency does not change this aspect of the course.



(a) (b)

	Control			Experimental		
	Pre-Survey	Post-Survey	Change	Pre-Survey	Post-Survey	Change
Average	3.7667	3.5000	-0.2667	3.6548	4.5515	+0.8967
Std. Dev.	1.4225	2.1627	+0.7402	1.3046	1.3306	+0.0260

(c)

Figure 6: *Interest in Embedded Systems.* (a) student responses on pre- and post- surveys in the control group (b) student responses on pre- and post- surveys in the experimental group (c) calculated values for survey responses

Of the eight questions on the pre- and post- surveys pertaining to a student's interest level in engineering, four of them pertained to interest in the field of Embedded Systems, the focus of the course. Figure 6 shows the student responses to these questions on both the pre- and post- surveys for the control and experimental groups along with a table of calculated values from these data sets. These graphs have a few noticeable differences from standard Likert scale responses. Firstly, the control group's post-semester responses show a wide spread that does not fit the typical bell-curve response shape that one would expect: this is most likely due to the small sample size, but can also be attributed to the polarization of student interest over the semester, with students coming away from the course with either a strong interest or strong disinterest in Embedded Systems. Secondly, the very large spike in the pre-semester data for the experimental group was not surprising to us, as this response indicates a lack of interest or disinterest in Embedded Systems and this course is the first course in the curriculum that addresses this field. In addition to these points, the data show a very strong difference in student interest levels in Embedded Systems. For students in the control group that were assigned one project for the course, their interest in this area decreased on average. Contrarily, students in the experimental group that were given a choice of lab assignment each week experienced the strongest average increase of any facet of Engineering Identity seen in this study. This difference in student responses between the two groups makes a strong case for the positive effect of student agency on interest levels.

Qualitative Observations

During the course of this study, many observations were made by the lab instructors that could not be captured by the surveys. We noticed that when given the choice between the alternate and traditional lab assignments most students would pick one or the other at the first opportunity and stick with it for the remainder of the semester: no students in the experimental group swapped between the alternate and traditional labs between weeks. The students that chose to pursue the alternate lab project tended to be more creative or motivated than those that chose the traditional project. We believe this is due to the fact that the alternate lab took student agency further by encouraging students to create original ideas, songs, and images for their simple video games, with no two final projects ending with the same game or theme.

Many student groups settled on the long-standing traditional project as a default, rather than actively choosing the alternative. Students that chose the traditional lab cited a professional interest as the reason for picking that project, such as the availability of resources on motor controller design or the design of a feedback system being a more useful career experience, while students that chose the alternate lab tended to cite a personal interest as their motivation, such as a desire to develop their own video game system or that the project simply sounded more "fun". We noted that the students who chose the alternate lab became much more invested in the coursework than students that chose the traditional lab. We believe this is due to the unquantifiable "coolness" factor that comes with building a simple video game over building a motor controller. A few students even expressed regret: students that chose the traditional lab began to express jealousy towards the end of the semester as the alternate final project came together, saying that they would swap projects if they had the opportunity to do it again. This observation indicates the possibility of the alternate project simply being a more interesting project and improving the statistics of the class overall, but only 13% of the students in the experimental group chose this project. This small minority of the class cannot account for the large difference between measured changes in Interest in Embedded Systems between the two groups, and points to student agency as the reason for this change.

Conclusions

A study to determine the effect of student agency on subject matter interest was conducted and its results presented. A traditional Embedded Systems lab course was reworked on a meeting-by-meeting basis to provide two separate experiences: a traditional format with a single lab assignment each week and an alternate format with two choices of lab assignment each week that cover the same subject material. Students in the control group went through the class in its traditional format, while students in the experimental group went through the class in its alternate format; both groups of students took anonymous surveys to assess their Engineering Identity at the beginning and end of the semester.

Upon examination of the data from these surveys, there is clear indication that allowing students a choice in their assignments improves the likelihood that their interest level in the subject matter will increase. It is our belief that this significant increase in interest comes from a sense of personal investment and increased pride and ownership in a completed project when it was chosen freely rather than assigned. Furthermore, the data also support stronger increases in all measured facets of the students' Engineering Identity when students are given a choice. These facts indicate that student agency, when implemented in a manner that does not compromise course content, can greatly increase the efficacy of a course.

References

[1] "Employment Projections – 2014-24 ," tech. rep., United States Bureau of Labor Statistics, December 2014.

[2] Aerotek, "Embedded systems: Emerging trends and the career outlook," March 2016.

[3] S. Mertle, "How cars have become rolling computers," March 2017.

[4] B. O'Donnell, "Your average car is a lot more code-driven than you think," June 2016.

[5] Z. Supalla, "The future of the IoT job market," June 2016.

[6] A. Godwin, "The development of a measure of engineering identity," in *2016 ASEE Annual Conference & Exposition*, no. 10.18260/p.26122, (New Orleans, Louisiana), ASEE Conferences, June 2016. https://peer.asee.org/26122.

[7] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *Journal of Research in Science Teaching*, vol. 44, no. 8, pp. 1187–1218, 2007.

[8] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," *Journal of Research in Science Teaching*, vol. 47, no. 8, pp. 978–1003, 2010.

[9] K. L. Tonso, "Teams that work: Campus culture, engineer identity, and social interactions," *Journal of Engineering Education*, vol. 95, no. 1, pp. 25–37, 2006.

[10] B. M. Capobianco, B. F. French, and H. A. Diefes-Du, "Engineering identity development among pre-adolescent learners," *Journal of Engineering Education*, vol. 101, no. 4, pp. 698–716, 2012.

[11] H. M. Matusovich, B. E. Barry, K. Meyers, and R. Louis, "A multi-institution comparison of students' development of an identity as an engineer," in *2011 ASEE Annual Conference & Exposition*, (Vancouver, BC), ASEE Conferences, June 2011. https://peer.asee.org/17351.

[12] K. L. Tonso, *On the outskirts of engineering: learning identity, gender, and power via engineering practice*. Rotterdam : Sense, 2007. Includes bibliography: p. 273-276 and index.

[13] J. Jorgenson, "Engineering selves: Negotiating gender and identity in technical work," *Management Communication Quarterly*, vol. 15, no. 3, pp. 350–380, 2002.

[14] X.-Y. Du, "Gendered practices of constructing an engineering identity in a problem-based learning environment," *European Journal of Engineering Education*, vol. 31, no. 1, pp. 35–42, 2006.

[15] K. L. Meyers, M. W. Ohland, A. L. Pawley, S. E. Silliman, and K. A. Smith, "Factors relating to engineering identity," *Global Journal of Engineering Education*, vol. 14, no. 1, pp. 119–131, 2012.

[16] D. Chachra, D. Kilgore, H. Loshbaugh, J. McCain, and H. Chen, "Being and becoming: Gender and identity formation of engineering students," in *2008 Annual Conference & Exposition*, (Pittsburgh, Pennsylvania), ASEE Conferences, June 2008. https://peer.asee.org/3597.

[17] L. N. Fleming, K. C. Smith, D. G. Williams, and L. B. Bliss, "Engineering identity of black and hispanic undergraduates: The impact of minority serving institutions," in *2013 ASEE Annual Conference & Exposition*, (Atlanta, Georgia), ASEE Conferences, June 2013. https://peer.asee.org/19524.

[18] N. Salzman, M. W. Ohland, and M. E. Cardella, "Measuring the effects of pre-college engineering, year 3," in *2016 ASEE Annual Conference & Exposition*, (New Orleans, Louisiana), ASEE Conferences, June 2016. https://peer.asee.org/25703.

Appendix - Survey

#	Statement	Category
1	I would consider pursuing a career in Embedded System.	4
2	My parents see me as an engineer.	1
3	I am confident I can understand engineering in class.	2
4	I can do well on exams in engineering.	2
5	My friends see me as an engineer.	1
6	I would consider pursuing a career in engineering.	3
7	Others ask me for help in engineering.	2
8	I enjoy learning and applying engineering.	3
9	I am interested in learning more about engineering.	3
10	I can generate work that is worth presenting.	2
11	I can overcome setbacks in engineering.	2
12	My instructors see me as an engineer.	1
13	My classmates see me as an engineer.	1
14	I enjoy learning and applying Embedded Systems knowledge.	4
15	I am interested in learning more about Embedded Systems.	4
16	I am an engineer.	1
17	I find fulfillment in completing projects involving Embedded Systems.	4
18	I have had experiences in which I was recognized as an engineer.	1
19	I understand tools studied and used in engineering.	2
20	I am confident I can contribute to group work.	2
21	I understand concepts studied in engineering.	2
22	I am confident I can understand engineering outside of class.	2
23	I find fulfillment in doing engineering.	3

Category	Facet of Engineering Identity	# of Statements
1	Recognition	6
2	Performance/Competence	9
3	Interest (Engineering)	4
4	Interest (Embedded Systems)	4