2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38654

Board 88: Work in Progress: Impact of Electronics Design Experience on Non-majors' Self-efficacy and Identity

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Abstract

Before the advent of the internet, electronics hobbyists embarked on lifelong learning journeys with instructional books such as Forrest Mims III's *Getting Started in Electronics*. Prototyping circuits with physical components provided mastery experiences that built a sense of personal self-efficacy and identity as an engineer, launching many engineering careers. We advocate for providing these mastery experiences to non-electrical engineering majors to develop technical literacy. To this end, we developed an electronics course aimed at a broad, interdisciplinary audience which guided students through a series of projects teaching the fundamentals of soldering, circuits, and microcontrollers, then a guided, open-ended circuit design project. We measured self-efficacy and sense of identity before and after participating in the design project. We found a 13% increase in self-efficacy for engineering skills, but no significant change in identity as a "maker" or an engineer. These results are interpreted in light of the strengths and limits of this teaching-as-educational-research project. We propose modifications for an ongoing research study to further contextualize and develop these findings.

Introduction

As technology continues to be embedded in many aspects of daily and professional life, students would benefit by gaining confidence and agency in their ability to interact with it. A background in circuits and electronics is essential for understanding the modern technological landscape. Tinkering and experimentation are a direct way to learn these topics and are central in the traditional university engineering curriculum as embodied by labs and project-based learning. Outside of the university, building projects at home was an experience that minted generations of engineers. This "do-it-yourself" approach to education is exemplified by the classic *Getting Started in Electronics* by Forrest Mims III (1983), which invited readers to learn by building a series of 100 circuits. The modern-day "maker" culture continues this autodidactic tradition, empowering people to create new technological artifacts using the tools available to them in makerspaces and increasingly at home. Maker culture has attracted participants from diverse backgrounds globally, has been embedded in popular culture, and access has increased with the proliferation of low-cost fabrication tools and microcontrollers (Bilkstein, 2018; Halverson & Sheridan, 2014; Irie et al., 2019; Martin, 2015). Engagement with the culture is associated with a "maker mindset" that is coupled with a strong sense of identity (Dougherty, 2016). The present study investigates how non-major students change in their confidence and sense of identity related to making after completing a cornerstone engineering design project.

We have created a semester-long (14-week duration) course about circuits, incorporating hands-on experiences that purposefully serve the educational needs and desires of students across disciplines at Carnegie Mellon University. The goal of this "non-major" course is to train students in basic electrical principles through soldering, building circuits on a breadboard, and taking electrical measurements in a series of integrated laboratory-lecture experiences. The class culminates in an open-ended design project in which the student proposes a system that uses a microcontroller to accomplish a useful task. While open-ended "capstone" design projects are a mainstay of engineering curricula, first-year "cornerstone" projects that introduce the design process to novice engineering students have recently become more prominent (Sheppard et al., 2009, pp. 84, 91; Vest, 2005; Whitfield et al., 2011; Zajdel & Maharbiz, 2016b). We propose that such design experiences would be impactful to non-major students' technical education as well.

Students outside of the engineering disciplines can develop these technical skills without the traditional barriers of calculus and physics that gate the engineering major at the university level. Our course targets students from the arts, humanities, computer sciences, and business disciplines, working to improve their technical literacy and help them develop their technical abilities. Engineering students in non-electrical disciplines have also been attracted to the course to build their electronics skills for lab work. These skills should better prepare students to meaningfully engage with technology in their lives and careers after graduation. The pilot study ran during the Fall 2022 semester with 9 enrolled students and an extension and replication is currently underway. To recruit more students for future studies, we have been building relationships with advising staff and curriculum committees across the university, ensuring this course would meet engineering/science elective requirements for various undergraduate programs.

To understand how students are impacted by the final design project, we defined and measured a number of constructs, including self-efficacy, maker identity, and engineering identity. Self-efficacy refers to the strength of an individual's belief in their capabilities to complete tasks and achieve a planned outcome (Bandura, 1997). We quantified students' self-efficacy in two areas:

1) self-efficacy for tinkering with circuits (Tinkering SE), and
2) self-efficacy for designing new electronic systems (Design SE).

Higher self-efficacy has been found to be associated with positive outcomes in engineering education and career development, such as increased retention in STEM fields and decreased burnout in stressed student populations (Bresó et al., 2018; Marra et al., 2009; Ramey & Ramey, 2018). According to Bandura (1997) there are multiple sources for the development of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and psychological or physiological states. For example, providing mastery experiences refers to a person successfully practicing a particular skill over time, which strengthens their confidence in their ability to use that skill. Our intention with this course is not to persuade students to declare an engineering major, but rather to build self-efficacy through mastery experiences for tinkering with circuits to cultivate an identity that will support students contributing to the ever-advancing technological workplace.

In addition to measuring students' self-efficacy, we also measured their identity both as a "maker" and as an "engineer." Empirically, identity and sense of belonging have been tied to persistence with STEM subjects and long-term career success (Marra, 2009; Stets et al., 2017; Trujillo & Tanner, 2017). If students are to engage meaningfully with technology after this course, a stronger sense of identity as an engineer or maker would be a desirable outcome.

Self-efficacy and identity were measured using a mid-semester survey taken just before students began working on their open-ended design project, and with an end-of-the-semester survey taken after showcasing their prototypes to the campus community. The present study sought to test a range of research questions (RQs) about students' self-efficacy and identity.

RQ 1. Do non-major students' self-efficacy change after completing an engineering project?
Hypothesis: After completing an open-ended design project, non-major students' self-efficacy for engineering skills of tinkering and design will increase. Because this design project requires students to build something they have never created before, it tests the students' ability in a direct way. We predict that practicing these skills for the demanding task of design would increase their self-efficacy.

RQ 2: Do non-major students' sense of identity change after completing an engineering project?
Hypothesis: After completing an open-ended design project, non-major students' sense of identity as a maker or as an engineer will increase. Circuit building, prototyping, and tinkering are one subset of the maker culture, and design is a critical function for an engineer and a maker. By participating in these activities, students may come to identify more strongly with these groups.

RQ 3. Do non-major students' change in sense of identity correlate with the change in their self-efficacy after completing an engineering project?
Hypothesis: There will be a positive correlation between change in strength of identity as "maker" or engineer with degree of change in self-efficacy for engineering skills. An alternative hypothesis would be that sense of identity of the student upon starting on the design project might affect how their self-efficacy changes. Students with a low starting sense of identity might become discouraged by an open-ended project experience, and this may result in a less significant change or a reduction in self-efficacy.

Method

Participants

Participants were nine students enrolled in a Fall 2022 14-week semester-long course called "18095: Getting Started in Electronics." Analysis was performed on the five participants who provided both pretest and posttest data. One of these participants completed the posttest measure twice, but only their first set of responses was used in analyses. Three paired participants self-identified as male and two as female. Participants were from a range of non-electrical engineering majors (e.g., music technology, computer science, economics/statistics, and biomedical engineering). This study was approved by the Carnegie Mellon University Institutional Review Board.

Measures & Materials

Measures

The researchers developed a survey instrument to measure self-efficacy (SE) related to engineering skills of tinkering and design as well as sense of identity. Self-efficacy items were created using the best practices recommendations from the literature including using a 100-point unipolar scale anchored by degree of certainty and beginning each item with "I can" (Bandura, 1997; Pajares, Hartley, and Valiante, 2001; Talsma, 2018). Tinkering SE was measured on a 5-item, 100-point scale (0 = completely uncertain, 100 = completely certain). A sample item is: "I can recognize changes needed for a circuit to work." Design SE was measured on a 4-item, 100-point scale. A sample item is: "I can develop a circuit to achieve a desired outcome."

The sense of identity measure had a 4-item subscale for maker identity and a 4-item subscale for engineering identity. Both of these collected responses on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). Both subscales used the same phrasing apart from referencing makers or engineers. A sample item is: "'Makers' share my personal interests."

Participants' demographic information was collected using two open-ended questions: "What is your major or intended major?" and "What is your gender identity?"

Participants self-reported what they perceived their sources of SE in the course to be by answering the open-ended question: "What experience(s) in this course have contributed to your confidence in building circuits?"

The complete survey instrument can be found in the Appendix.

Materials

Data were collected before and after participants completed an open-ended design project. As part of this course project, participants were presented with a lab kit containing a toolbox of prototyping tools (e.g., digital multimeter, screwdriver, wire strippers, and a solderless breadboard), a robotics kit, and other supplies necessary to carry out the design project (see Appendix for a complete list of lab kit materials).

Instructions informed participants that this would be an open-ended design project called the “Final Hack” in which students were invited to build a new system using the parts in their lab kit. In addition, students were given a budget of $30 each to purchase additional components required for their specific project idea. Students were given the option to complete the project in groups of two or individually, though only two students elected to form a group in the pilot semester. This “Final Hack” project comprised 25% of their course grade.

The project design process was scaffolded throughout the semester with development questions and proposals completed prior to data collection. These assignments gave participants feedback on their ideas before the Final Hack project started. To conclude the Final Hack project, participants submitted a written report and documentation of the hack’s hardware and software and showcased their project during a class presentation in the last week of the course.

Procedure

Participants were introduced to the opportunity to complete the research survey during a class session. This happened midway through the semester, but before students began the Final Hack project. They were told that the survey was an optional part of the educational research taking place in the course that semester. They were emailed a link to the survey and were asked to complete it before beginning their project if they were interested in being a part of the study. The landing screen of the survey was informed consent. There was no deception in this study, but participants were not presented with specific hypotheses for the constructs under investigation. If a participant affirmed that they had read the informed consent and were at least 18 years of age, they could proceed to the survey items. The next screen of the survey contained instructions and the tinkering self-efficacy (SE) items. Subsequent screens contained the design SE items, the maker and engineer identity items, and finally the sources of SE and demographics items.

Participants then engaged with their Final Hack design project and other regular course activities. At the end of the semester, after participants presented their final projects in the course, they were then given the opportunity to take the posttest measure. This was identical to the pretest measure except in two ways: the demographics items were replaced with a question about how successful they thought their final project was on a 100-point scale and they were asked to give their definition for “success.” During the final project presentation, a panel of three expert electrical engineering instructors judged the projects on a 100-point scale in the categories of creativity, build quality, and overall success.

Results

Data related to students' quantitative rating of their project success, their qualitative description of "success", and expert reviewers' quantitative ratings of the project were not analyzed in answering the current project's research questions. To test the hypothesis that students' self-efficacy for engineering skills would improve after completing the open-ended design project, we conducted a dependent-means t-test for each SE construct of tinkering, design, and their combined SE score comparing the difference between students' pre and post measures. There was a marginally significant effect for Tinkering SE ($t(4) = -2.53$, $p = .07$, Cohen's d = .36; see Figure 1). There was a non-significant effect for Design SE ($t(4) = -2.00$, $p = .15$, Cohen's d = .38; see Figure 1). When tinkering and design were combined into an Overall SE score, there was a significant effect ($t(4) = -3.33$, $p = .03$, Cohen's d = .37; see Figure 1).

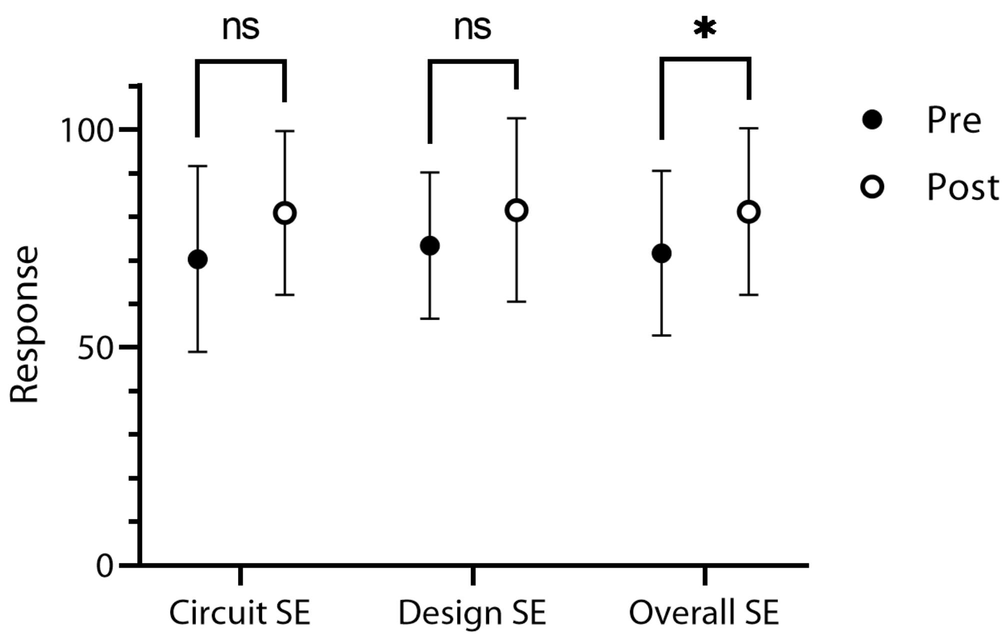

Figure 1: Self-Efficacy Results Summary. The y-axis represents the mean response on the 100-point scale. The x-axis represents the type of self-efficacy. Asterisk * indicates significant difference ($p < .05$) between Pre and Post survey results; n.s. indicates difference is not significant. Error bars represent 95% confidence interval.

To test our hypothesis that students' identity as a maker or as an engineer would increase after completing the open-ended design project, we ran a series of dependent-means t-tests on the pre and post measures of these constructs. There was no significant increase in either sense of identity from the beginning to the end of the design project (Maker: $t(4) = .56$, $p = .61$, Cohen's d = .23; Engineer: $t(4) = .91$, $p = .41$, Cohen's d = .65; see Figure 2).

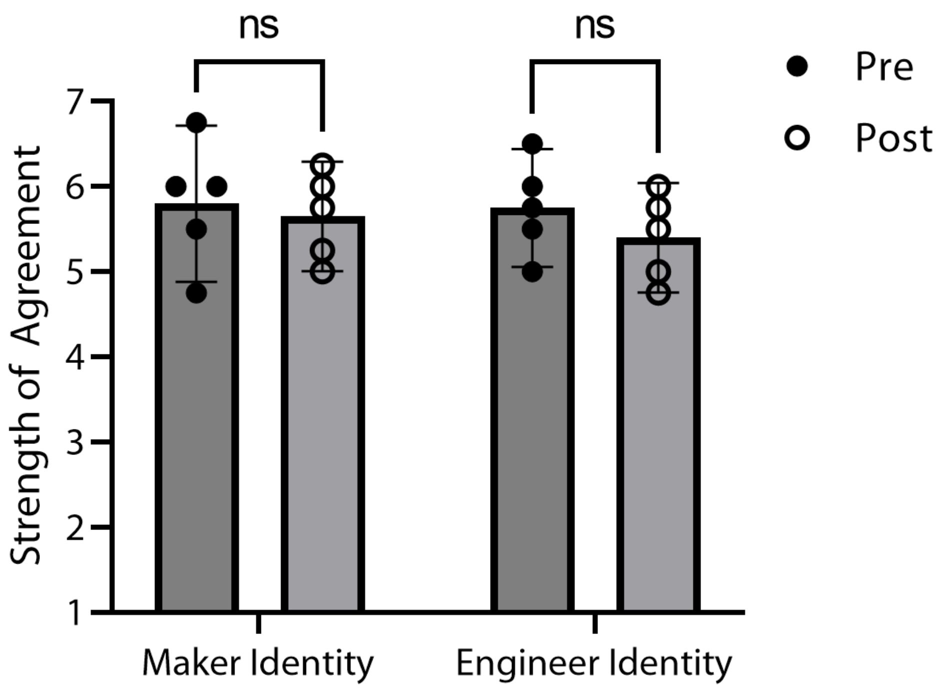

Figure 2: Maker and Engineer Identity Results Summary. The y-axis represents the mean response on the 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). The x-axis represents the type of identity students hold. The notation of n.s. means neither of the pre-to-post differences was statistically significant. Dots represent individual students' responses.

A Pearson's correlation was run to test the hypothesis that there would be a positive correlation between change of identity (ID) as maker or engineer with degree of change in self-efficacy for engineering skills. Change in Maker ID and change in Engineer ID were highly correlated ($r(5) = .96$, $p = .01$; see Table 1). The correlations between change in Design SE and change in ID showed a moderate effect size, but was not significant (correlation with change in Maker ID, $r(5) = -.53$, $p = .36$; correlation with change in Engineer ID, $r(5) = -.42$, $p = .48$; see Table 1).

To better understand sources of SE, students were asked to respond to the open-ended prompt "What experience(s) in this course have contributed to your confidence in building circuits?" for both pre and post surveys (14 responses total from all participants, not restricted to pre-post paired data). Written responses were coded using Bandura's (1997) sources for the development of self-efficacy. Mastery experiences were the most highly represented (n = 10), while vicarious experience was mentioned in one response (n = 1). An additional theme, which was coded as "Instructional Help" emerged in a number of responses (n = 3). See Table 2 for a summary along with sample responses.

Table 1: Bivariate Pearson's correlations between identity (ID) and self-efficacy (SE) constructs. All data are post-minus-pre change measures. Values in the table are the correlation coefficient *r* (*p*-value).

	Δ Maker ID	Δ Engineer ID	Δ Tinkering SE	Δ Design SE	Δ Overall SE
Δ Maker ID	-				
Δ Engineer ID	.96 (.01)	-			
Δ Tinkering SE	-.53 (.36)	-.51 (.38)	-		
Δ Design SE	-.53 (.36)	-.42 (.48)	-.08 (.90)	-	
Δ Overall SE	-.78 (.12)	-.68 (.20)	.65 (.24)	.71 (.18)	-

Table 2: Sources of self-efficacy reported by participants. Students responded to the open-ended prompt "What experience(s) in this course have contributed to your confidence in building circuits?" on both the pre and post measures.

Sources of self-efficacy	**Example responses**
Mastery experiences (n = 10)	"the literal hands on approach. If we started with theory I wouldn't have been able to keep up or feel confident I could."
	"Building circuits during class, example circuits"
Vicarious experiences (n = 1)	"Working on a circuit side by side with other students has been invaluable."
Instructional help (n = 3)	"Also, my TAs have helped me immensely; they validate my approaches and steer me in the right direction."
	"All the help available to us. Easy to ask questions and get them answered. Instructor and TAs had patience."
Notes or no category (n = 2)	"I want to build a product that could revolutionize the music and engineering industry"

Two example project outcomes are mentioned here to establish the scope and the creativity of the Final Hacks. One student prototyped an automated plant watering system consisting of a stepper motor-driven turntable that spun a handheld spray bottle actuated by a motorized arm (Figure 3, left). Potted plants would encircle this device and capacitive soil moisture sensors were used to determine which plants needed watering. Another student created an electronic timer-gated cell phone lockbox (Figure 3, right). Servomotors would lock a phone inside the plastic case and a bright countdown display would indicate when the box would unlock again. Both of these projects were developed to solve real problems in the students' lives: keeping plants alive over the upcoming winter break and reducing distractions when studying.

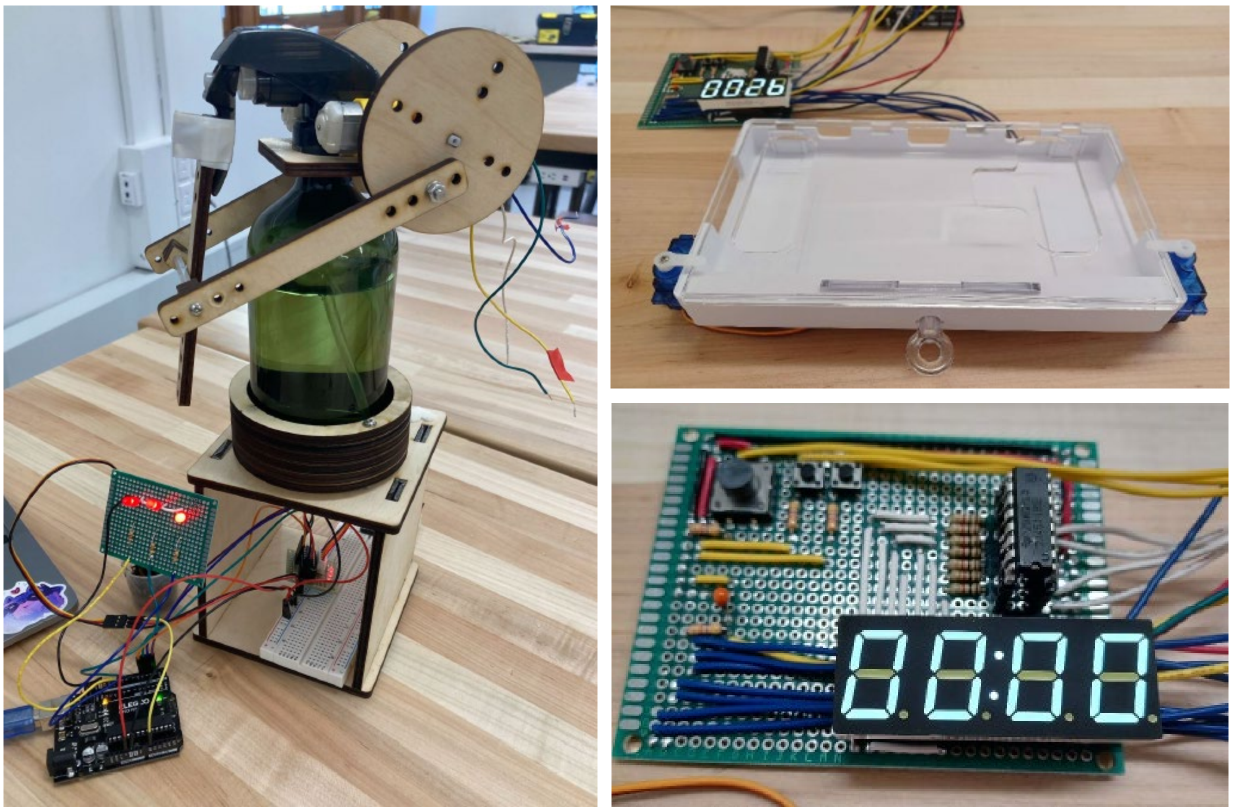

Figure 3: Example Final Hack outcomes. An automated plant watering system (left) and a timed phone lockbox (upper right). Some students elected to use a soldered circuit board to organize their design as with the timed phone lockbox (lower right).

Discussion

Our work joins a growing number of courses, both at the university level and as massive open online courses (MOOCs), introducing electronics to students outside of a traditional engineering university track with a focus on tinkering with hardware and design (Retz & Derickson, 2016; Valvano et al., 2016; Ward, 2022; Zajdel & Maharbiz, 2016a). Our work is most closely aligned with Retz and Derickson (2016) who report teaching a "Microcontrollers for All" course as an engineering elective to liberal arts majors. A final open-ended design project was the key experience of their course, much like in our pilot for "Getting Started in Electronics." Retz and Derickson (2016) reported project performance outcomes, but did not study student attitudes towards engineering as a result of their experience. Our study therefore contributes to a more wholistic understanding of the impact of such a course on students by including our self-efficacy and identity measures. While there have been numerous studies regarding self-efficacy in students pursuing engineering careers (Lu et al., 2016; Marra et al., 2018; Smith et al., 2019; Ramey & Ramey, 2018), studies of technical development in non-engineering students are less common.

Our first objective was to determine how self-efficacy (SE) was affected by the open-ended design project. Self-efficacy is a person's belief in their ability to achieve a certain goal or use a specific skill (Bandura, 1997). Although our students are novices to engineering, a basic knowledge of electronics can empower them to make something of value, as evidenced by Retz and Derickson's (2016) "Microcontrollers for All" course and electronics hardware-oriented MOOCs that have delivered similar hands-on experiences at scale (Valvano et al., 2016; Zajdel & Maharbiz, 2016). Project-based learning presents students with mastery experiences, which have frequently been found to be the most powerful source for developing self-efficacy (see for instance Usher & Pajares, 2009).

Students' SE for both tinkering and design increased from pre-to-post Final Hack project, supporting our hypothesis. However, neither alone reached statistical significance ($p = .07$, $p = .15$, respectively). When these subscales were combined into an overall SE value, the pre-to-post change from a mean of 71.8 to 81.2 (responses were between 0 = completely certain and 100 = completely certain) was significant ($p = .03$). These results should be interpreted within the context of the small sample size. Because this was an educational research project, sample size was limited by the number of students enrolled in the course and who were willing to participate in the research component. This resulted in five pre-post data pairs for analysis. With a larger sample size, this study would have more statistical power to detect an effect where it exists. Given the small-to-medium effect sizes for these results (e.g., Cohen's d = .37 for overall SE), we believe that non-major students do experience growth in self-efficacy from engaging with an open-ended engineering design project.

Our open-ended design project had the pedagogical motivation of providing novice students with a mastery experience in engineering. In alignment with this goal, students overwhelmingly (10 out of 14 responses) reported the class' hands-on approach to building circuits as the largest contributor to their SE (Table 2). While the sample size was limited and more context is necessary to fully understand the impact of this course on students, the initial results show that the design project may have had a sizeable effect on the development of SE. Despite overall SE starting at a relatively high level of 71.8/100, the four-week design project resulted in an increase in reported self-efficacy by 13% over a relatively short period of time. This, coupled with students' open-ended comments about the power of the design project in the development of their SE, suggests the design project had a strong influence on these novice students' beliefs about their ability to do key engineering tasks.

The timing of the pre and post measures within the 14-week semester may have weakened the degree of change we were able to capture. Data collection started after the midpoint of the semester after students had already engaged in various hands-on engineering activities. If we had captured participants' SE and identity at the beginning versus the end of the semester instead, the growth may have been larger. Data capturing students' SE when the class begins would provide a more comprehensive picture of the development of their attitudes over time. Our ongoing replication study uses pre-course survey data to determine the effect of the guided circuit-building labs presented during the first 10 weeks of the course. These pre-survey data will better contextualize the effect of the design project experience on students' development of their engineering SE and identity.

Our hypothesis that students' identity as a maker or an engineer would increase after completing the Final Hack project was not supported. Interestingly, participants self-reported strong identities at the pre measure with means approaching 6 on a 7-point scale. This ceiling effect has the consequence of offering little room for improving their sense of identity. It is possible that our pre measure was so high because it was taken part way through the semester, after students had completed nearly two months of this experiential course. It would be informative to get a pre measure at the very beginning of the semester in addition to a pre measure at the beginning of the final design project to see how students' identity changes across the course of the semester. We also believe that having students periodically reflect on their engineering experiences and progress through written exercises might also help them recognize their personal growth and any changes in their SE or identity. This is what we have implemented in our ongoing replication study, which had 11 students enrolled Spring 2023 and has over 20 students enrolled for Fall 2023.

We thought that non-electrical engineering major students attracted to this elective course might identify more strongly as "makers" than "engineers," given the modern prevalence of maker culture in education (Bilkstein, 2018; Dougherty, 2016; Halverson & Sheridan, 2014; Irie et al., 2019; Martin, 2015) The results show that among this small sample, student identities as makers and engineers are very similar (post measure means: Maker Identity = 5.65, Engineer Identity = 5.40, $p = .19$). While we treated these as separate constructs in our conceptualization of this study, it is possible that these identities may not have been distinct to the participants, or that any distinction between these identities may have diminished by the end of the course when our posttest measure was taken. As with the SE scales, understanding student identities before the majority of the hands-on experiences in the course are completed will be important context for our ongoing replication study.

Our hypothesis that the degree of change in students' self-efficacy would correlate with their change in strength of identity was not statistically supported. The obtained r-values were moderately strong ranging from -.42 to -.53 and in a negative direction. With the small sample size, these correlations failed to reach significance. With such a limited sample size, we do not have a strong interpretation for the relationship between these variables, however, their relationship bears further investigation. A counter hypothesis could be that the relationship between this course and students' identities operates in the opposite direction to what we proposed – that non-electrical engineering students who more strongly identify as makers or engineers were attracted to this elective course. The ongoing replication study takes a pre measure at the beginning of the semester, before many hands-on experiences in the course, and should help to better disentangle these possibilities. Another intervention we plan to incorporate in future semesters is adding shorter, guided design experiences throughout the course, allowing students to build their design skills with smaller, lower-stakes assignments before starting on the open-ended final project. We expect this approach to introduce more mastery experiences to build self-efficacy for design throughout the semester while still teaching the fundamental concepts.

A strength of the present study is that it takes place within the classroom while providing students with authentic semester-long learning experiences versus short-term, artificial lab-based studies. While our work is in progress and the number of data pairs are small ($n = 5$), this course provides a viable way to study the development of technical skills in students who do not intend to start a career in electrical engineering.

We affirm that there is value in everybody learning how technology works, given its outsized impact on our daily lives. We believe that working on an open-ended design project shifts students towards a productive, creative relationship with technology rather than one about consuming technological products without agency. Coming from diverse disciplinary backgrounds, this group of students will be better equipped with tools for interacting with the technologically-advanced modern economy. This technical literacy is critical, regardless of career. Our course represents an effective way to build technical literacy in non-major students in a manner that is personally meaningful to them. While this approach is designed for non-engineering majors, making more space for creativity and design experiences should build self-efficacy for those preparing for engineering careers as well.

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Appendix

Lab Kit Contents

Part	Qty	Mftr	Vendor	Vendor Part No.
Main Toolbox	1	Stanley	N/A	N/A
1660-Pt Breadboard	1	Jameco	Jameco	20774
Elegoo UNO R3 Kit	1	Elegoo	Elegoo	N/A
9V Battery	2	N/A	N/A	N/A
9V Battery Clip w/ DC Barrel Jack	2	Adafruit	Digikey	1528-1117-ND
Banana/Grabber Cable - Red/Black Set	1	E-Z Hook	Digikey	461-1055-ND
DC Barrel Jack to Screw Terminals	2	Sparkfun	Digikey	1568-1510-ND
Adafruit 6-spool Wire Kit (Solid Core)	1	Adafruit	Digikey	1528-1743-ND
Jameco Screwdriver	1	Jameco	Jameco	127271
Wire Stripper 16-26 AWG	1	Jonard Tools	Digikey	K598-ND
Flush Cutters	1	Hakko	Digikey	1691-1037-ND
Extech MN35 Digital Multimeter	1	Extech	Digikey	MN35-ND
10K Potentiometer	2	TT Electronics	Digikey	P160KN-0QD15B10K
50K Potentiometer	1	TT Electronics	Digikey	PDB181-K415K-503B-ND
Thermistor	1	Vishay	Digikey	BC2394-ND
CD4511BE 7-Segment Decoder IC	2	TI	Digikey	296-2072-ND
SE555P Timer IC	2	TI	Digikey	296-9684-5-ND
LM393AP Quad Comparator IC	2	TI	Digikey	296-6609-5-ND
10nF Ceramic Capacitor	4	KEMET	Digikey	399-13907-1-ND
100nF Ceramic Capacitor	4	TDK	Digikey	445-173588-1-ND
1uF Electrolytic Capacitor	4	KEMET	Digikey	399-ESE105M100AC3EACT-ND
10uF Electrolytic Capacitor	4	Wurth Electronik	Digikey	732-8788-1-ND
100R Resistor 1/4W 5%	10	Stackpole	Digikey	CF14JT100RTR-ND
470R Resistor 1/4W 5%	10	Stackpole	Digikey	CF14JT470RTR-ND
1K Resistor 1/4W 5%	10	Stackpole	Digikey	CF14JT1K00TR-ND
4.7K Resistor 1/4W 5%	10	Stackpole	Digikey	CF14JT4K70TR-ND
10K Resistor 1/4W 5%	5	Stackpole	Digikey	CF14JT10K0TR-ND
47K Resistor 1/4W 5%	5	Stackpole	Digikey	CF14JT47K0TR-ND
100K Resistor 1/4W 5%	5	YAGEO	Digikey	100KQTR-ND

Speaker 1W	1	PUI Audio	Digikey	668-1682-ND
PN2222TF NPN Transistor	4	onsemi	Digikey	PN2222TFCT-ND
Tactile Pushbutton Switch SPST-NO	4	APEM Inc.	Digikey	430476085716-ND
CD4081BE AND Gate IC	2	TI	Digikey	296-2066-ND
CD4071BE OR Gate IC	2	TI	Digikey	296-2062-ND
CD4070BE XOR Gate IC	2	TI	Digikey	296-14128-ND
CD4069BE NOT Gate IC	2	TI	Digikey	296-3518-5-ND
Line following Robot PCB Kit	1	MiOYOOW	N/A	N/A
Astable Multivibrator PCB Kit	1	Electronics-Salon	N/A	N/A

Self-Efficacy Instrument

Scale = 0 (completely uncertain) to 100 (completely certain)

Instructions: Please respond to the following statements regarding your level of certainty that you can perform the different activities. If you aren't sure, just go with your first instinct. There are no right or wrong answers!	
Tinkering Self-Efficacy (5 items, Pre and Post)	I can work with circuits.
	I can build circuits.
	I can recognize changes needed for a circuit to work.
	I can modify circuits to adjust their behavior.
	I can use tools to fix circuits.
Design Self-Efficacy (4 items, Pre and Post)	I can identify tasks that circuits can accomplish.
	I can develop a circuit to achieve a desired outcome.
	I can test that my circuit design works.
	I can assess the value of my circuit design.

Identity/Sense of Belonging Instrument

Scale = 7-point Likert (7 = Strongly Agree, 1 = Strongly Disagree, with neutral point (4) of neither disagree or agree)

Instructions: Please respond to the following statements regarding your level of agreement or disagreement with the following statements. If you aren't sure, just go with your first instinct. There are no right or wrong answers!	
Maker ID (4 items, Pre and Post)	I am a "maker."
	I can relate to "makers."
	I have a lot in common with "makers."
	"Makers" share my personal interests.
Engineer ID (4 items, Pre and Post)	I am an engineer.
	I can relate to engineers.
	I have a lot in common with engineers.
	Engineers share my personal interests.

Additional Questions

Demographics (Pre only)	What is your major or intended major? [open-ended response]
	What is your gender identity? [open-ended response]
Sources of SE (Pre and Post)	What experience(s) in this course have contributed to your confidence in building circuits? [open-ended response]
Reflecting on the Design Project (Post only)	In your opinion, how successful was your final hack? [0 = completely unsuccessful, 100 = completely successful]
	How do you define “success” in this project? [open-ended]