# Examining How Skill-building Workshops Affect Women's Confidence over Time

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Megan Keogh is an undergraduate student studying environmental engineering and environmental policy at the University of Colorado Boulder. Megan has been involved in education outreach and mentorship for much of her college career. She completed a STEM education class in which she shadowed a local 5th grade teacher and taught three of her own STEM lessons. Megan has also been a new-student mentor through her department's peer mentoring program. Now, Megan is interested in researching how team dynamics affect undergraduate women's confidence levels in engineering.

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# Skill-building workshops: The gateway for increased self-efficacy for women in engineering design courses?

*Key words:* Workshops, Women in STEM, Self-Efficacy, Active Learning, Technical Skills, Skill-Building

## Introduction

Universities across the country are implementing hands-on activities in the classroom because there is evidence that they improve long-term material retention and critical thinking skills [1][2]. A study at Oregon State University found that working in teams gives students opportunities to communicate with others, set group expectations, and practice conflict-resolution, all of which are skills that are highly desired in industry [3]. A major goal of implementing groupwork into the classroom is to prepare students for teamwork in the engineering workforce, yet students are not learning technical and non-technical skills equally in these types of classroom settings. Many studies have shown that women frequently take on stereotypically feminine roles, such as being in charge of documentation or organization, while men work on more stereotypically masculine aspects like programming or building [4][5].

The role self-efficacy plays in the ways students take on technical and non-technical roles in project teams requires further study. Self-efficacy is defined as "an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments" and is directly tied to self-confidence in a particular domain, such as a specific academic course or technical skill [6][7]. One way of addressing the different incoming levels of technical self-efficacy among students is to provide out-of-class, skill-building workshop opportunities that students can elect to enroll in to increase their comfort and exposure to specific technical domains. In 2003, the University of Colorado piloted a women's-only skill-building workshop to help women build the fundamentals they need to feel comfortable working on technical roles in group projects. A similar pilot course was taught more recently at the University of Florida with women-only and co-ed sections. Both studies found similar results: Women enjoyed learning in the low-stress, grade-free environment of a workshop and they felt empowered after learning how to use tools [8][9].

The Engineering Plus (e+) program at The University of Colorado is focused on teaching students engineering material in a hands-on, collaborative setting. One of the degree requirements is that students must take three Engineering Design Projects classes in which student teams design and prototype various products. Students in the e+ program take several technical skill-building workshops as part of their project and personal development. In light of previous research, the e+ faculty is interested in determining how effective these skill-building workshops are at helping women feel more comfortable in technical roles. Our primary research question is: "How do skill-building workshops affect a woman's self-efficacy in engineering?" We take a mixed methods approach to answer this question. All students in the projects classes are asked to take a survey at the end of each semester that they complete a projects course. These surveys ask students to evaluate how confident they feel with a particular skill after taking the workshop and to provide feedback about the workshops, the workshop instructors, and their skill development in their engineering projects course. The data in the surveys is analyzed alongside qualitative data from individual student reflections and focus groups to determine the

effectiveness of the workshops and how students report subsequently using those skills. The goals of this study are to 1) identify if and how students are using the skills developed during skill-building workshops, 2) determine if and how those skill-building workshops affect students self-efficacy levels in engineering, and 3) generate suggestions for improvement to the workshops to make them more equitable experiences for all students.

**Background**

The role self-efficacy plays in the ways students take on technical and non-technical roles in project teams requires further study. Self-efficacy is defined as "an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments" and is directly tied to self-confidence in a particular domain, such as a specific academic course or technical skill [6][7]. In this study, self-confidence is a term used by students that indicates how comfortable they are with a specific skill, i.e. using a 3D printer or programming an Arduino. Self-efficacy is defined as the student's belief that they are capable of achieving the desired broader outcome, such as technical aspects of engineering projects.

Low self-efficacy for engineering concepts and technical abilities is a major factor in explaining the current attrition rates for undergraduate engineering degrees [10][11]. Women who are originally in STEM undergraduate programs are less likely to complete their degrees than men due to lowered self-efficacy [12][13]. Furthermore, even when women do graduate with an engineering degree, they are more likely than men to pursue degrees outside of engineering[13][14]. A study published by the American Sociological Review suggests that women feel less professional role confidence than men in engineering[14]. Lowered professional role confidence, combined with an extra pressure for women to prove themselves to their male coworkers is a contributing factor in the gender gap in STEM fields [15][16]. A 2017 U.S. Department of Commerce report indicates in the last decade, women have consistently held less than 25% of the STEM jobs in the United States even though they make up almost 50% of the workforce[17].

Many schools and universities are now implementing various activities into their curriculum to help students become more comfortable with technical skill-building content, such as materials testing, computer aided design (CAD), manufacturing processes, and the latest electronics or programming platforms. Several of these curricular models try to help build skills through visualization, including simulations and field trips to factories to help envision concepts discussed in lecture [18][ 19].

A more common way to help students build their technical self-efficacy is through hands-on workshops. In 2003, the University of Colorado piloted a women's-only skill-building workshop to help women build the fundamentals they need to feel comfortable working on technical roles in group projects. Students worked in small teams to assemble a project requiring the use of several tools like lathes, saws, and drill presses. The pre-workshop survey revealed that 80% of respondents had no prior experience working with power tools. The post-workshop survey indicated that there was an average skill gain of 137% across all of the machines covered [8].

A similar pilot course was taught more recently at the University of Florida with women-only and co-ed sections. For two hours a week for 7 weeks, students convened in a makerspace to design and build individual projects using various power tools. The post-workshop surveys indicated that 26 of the 40 students were "very likely" to try soldering again on their own and 33 out of 40 students "strongly agreed" with the statement "I believe the build group helped to increase my tool knowledge, basic making skills, and confidence to participate in the design and building portion of team based engineering projects" [9].

The Carpentries is a nonprofit organization that teaches data science skills to researchers. Their paper for the 2018 ASEE Annual Conference reports that short (1-2 hour) workshops are an efficient way to help people who have little to no prior experience explore different platforms within data science. Participants in the workshops individually work on mini projects and are guided by helpers in a "friendly" and "interactive" environment. The pre and post workshop surveys indicate that there is a significant increase in using programming software in respondents' respective fields after taking the workshop. Additionally, 66.7% of the undergraduate students and 78.4% of the graduate students who took the workshop indicated that they are more confident in programming now that they have taken the workshop [19].

*Background: Local Context*

In the 2017-2018 academic year, the University of Colorado conducted a study on how team dynamics affect women's confidence levels in engineering. In this study, we examined peer evaluations to determine how women perceive themselves as teammates as compared to how their teammates view them. In the peer evaluations, each student is given a prompt stating that they are in charge of distributing an imaginary $1000 bonus to their team. We analyzed these bonus money allocations to determine how many times women rated themselves above, equal, or below what their peers rated them. The data showed that women most often rated themselves higher than their peers based on individual contribution to the team project. See Table 1 for results. Preliminary research in the 2018-19 academic year yields similar trends. See Table 2 for results. We hypothesize that many women over-inflated their bonus allocations because they are concerned that their teammates would not score them well.

**Table 1.** Comparison of women's peer evaluation scores of self versus other team members, by gender in 2017-2018 academic year.

| | ***First Year Engineering Projects*** (n= 21 male and 9 female ratings) | ***Engineering for the Community*** (n= 36 male and 11 female ratings) | ***Invention and Innovation*** (n= 20 male and 12 female ratings) |
|---|---|---|---|
| %Women allocated themselves a higher bonus than male peers | 57% | 64% | 5% |
| %Women allocated themselves a higher bonus than female peers | 44% | 82% | 25% |
| %Women allocated themselves the same bonus as male peers | 3% | 19% | 60% |
| %Women allocated themselves the same bonus as female peers | 0% | 0% | 92% |
| %Women allocated themselves a lower bonus than male peers | 10% | 8% | 35% |
| %Women allocated themselves a lower bonus than female peers | 22% | 9% | 50% |

**Table 2.** Comparison of women's peer evaluation scores of self versus other team members, by gender in 2018-2019

| | ***First Year Engineering Projects*** *(n=26 male ratings and n=13 female ratings)* | ***Engineering for the Community*** (n=14 male and 8 female ratings) |
|---|---|---|
| %Women allocated themselves a higher bonus than male peers | 46% | 79% |
| %Women allocated themselves a higher bonus than female peers | 61% | 75% |
| %Women allocated themselves the same bonus as male peers | 35% | 7% |
| %Women allocated themselves the same bonus as female peers | 15% | 0% |
| %Women allocated themselves a lower bonus than male peers | 19% | 14% |
| %Women allocated themselves a lower bonus than female peers | 23% | 25% |

In the previous research, several women participated in focus groups to discuss their experiences in hands-on engineering design classes. A common theme among the women was that they initially did not feel confident taking on technical roles in their group project, but became more comfortable doing technical tasks after taking skill-building workshops. This feedback, combined with the research from other universities, prompted our research team to study the effectiveness of the workshop offerings.

The skill-building workshops offered at the University of Colorado can be completed outside of class. They are generally interactive lessons taught by qualified students or full-time instructors. Most workshops are 1 hour sessions that give students a step-by-step walkthrough of a skill or process like soldering or designing a part in a CAD software. Depending on the workshop, there can be up to 30 students at one time, with most workshops having around 15 students each. The workshops are generally taught by a single instructor with supporting assistants in larger workshops. If applicable, each student receives access to the machinery required for the type of skill, such as access to the manufacturing room or the 3D printers. See Appendix A for individual workshop descriptions.

The goals of this study are to 1) identify if and how students are using the skills developed during skill-building workshops, 2) determine if and how those skill-building workshops affect students' self-efficacy levels in engineering, and 3) generate suggestions for improvement to the workshops to make them more equitable experiences for all students.

**Methods**

The data collected in this study were taken from students enrolled in e+ courses. The e+ program is a department with a focus on teaching students engineering design with a breadth of technical and non-technical skills. Students in the e+ program are required to take three semester-long engineering design projects courses. *First Year Engineering Projects* introduces students to the engineering design process and to problem-solving while working in teams. Second Year Engineering Projects, *Engineering for the Community*, is a sophomore-level course in which student teams are assigned a client and must prototype a product that solves that client's problem. Third Year Engineering Projects, *Invention and Innovation,* is a junior/senior level

class in which student teams design a product and a business in parallel. Team size for projects classes typically ranges from four to six students. See Appendix B for course descriptions.

*Research Questions*

The primary research question addressed in this study is "How do skill-building workshops affect women's self-efficacy levels in engineering?" To support this research, additional questions include:

- What workshops are students taking?
- How/are students using the skills they learned in the workshops?
- What improvements can be made to the workshops to make them more equitable for all students?

This research requires a mixed methods approach. We used quantitative Likert scale survey data, as well as qualitative survey data, individual student reflections, and focus groups. Each of the methods of data collection and analysis are discussed in more detail below. Surveys, individual reflections, and focus groups from students were conducted with approval from the University of Colorado Institutional Review Board (IRB). Student names have been removed or given pseudonyms to conceal their identities.

*Surveys*

Attitudinal surveys for students enrolled in engineering projects courses were distributed at the end of the Fall 2018 semester and in the middle of the Spring 2019 semester with the following rates of response: *First Year Engineering Projects* (n=12), *Engineering for the Community* (n=11) , *Invention and Innovation* (n=17) and unspecified class (n=2). This survey intended to gauge which workshops students took within the semester, how confident they feel in those skills after having completed the workshop, and how they used those skills in their team projects and other courses. Students were first asked to indicate all of the skill-building workshops they took within the semester of their projects course. The complete list of workshops that students took during the Fall 2018 and Spring 2019 semesters is shown in Table 3. Descriptions for these workshops can be found in Appendix A.

Table 3. Workshop Series

| **Arduino** | **CAD** | **Electronics** | **Manufacturing** | **Prototyping** |
|---|---|---|---|---|
| Introduction | 3D Scanning | Eagle & Printed Circuit Board (PCB) | Saws & Drills | Laser Cutting |
| Motion 1 | ---- | Soldering | ---- | 3D Printing |
| Communication | ---- | ---- | ---- | Sewing |

For each workshop completed, students were asked three questions:
Likert Scale:

- To what extent do you agree with the following statement: I feel more confident in my ability to use skill X now that I have taken Workshop X.

Yes/No:

- Have you used the skills you learned in workshop X?

Open-Ended Response:

- Please provide any feedback about your experience with the Workshop X (i.e. What did you find helpful? Did you follow up with the workshop instructor at all?, etc.)

*Individual Student Reflections*

Throughout the semester, students enrolled in *Engineering for the Community* are required to complete individual reflections for homework about different aspects of the course, such as personal growth and team dynamics. For this research, we examined Fall 2018 late-semester reflections (*n=4 women, n=6 men*) that asked students to respond to a prompt asking:

> An underlying theme of the Engineering Projects classes is the opportunity to broaden and develop your skillset in engineering design and communication. During your first reflections, you described a design skill that you would like to work on during this class, how you would develop that skill, and your experiences/plan to incorporate this skill in your product development. For this last reflection, please go back to your original reflections and write about your progress this semester. Think about your personal skill development in manufacturing, electronics, programming and/or communication, your team's dynamics, and the overall experience in developing a local client-based product over the course of the semester. Do you feel more confident in your abilities in any skills?

In particular, we searched for what skills students intended to work on at the beginning of the semester, what workshops they took, and what skills they developed by the end of the semester.

*Focus Groups*

Students enrolled in any e+ engineering projects course during the 2018-19 academic year were solicited to participate in 45-60 minute focus groups with 3-5 students total. Within these focus groups, we asked the students about their thoughts on active learning courses and skill-building workshops. A list of focus group questions is provided below:

- Introductory questions:
    - What is your major?
    - What engineering projects class are you enrolled in?
- Team dynamics
    - What was the gender makeup of your team?
    - What role(s) did you take on in your project?
    - Are you happy with those role(s)?
    - Did you experience or witness any sexism in your group?
- Workshops
    - What skill-building workshops did you take this semester?
    - Did you use these skills in your project?
    - What did you like/dislike about the workshops?
    - Do you have any suggestions for improving the workshops?

One focus group was convened during the last month of the Fall 2018 semester. There were three women and one man participating and one researcher. An interview with one man was conducted in the Spring 2019 semester.

## Findings

*Surveys*

The first question in the survey asked students to check all of the workshops they had taken in the last semester. For each workshop, students were asked the same set of questions. One of the questions asked students to respond on a Likert scale to the prompt: "To what extent do you agree with the following statement: 'I feel more confident in my ability to use skill X now that I have taken Workshop X.'"

The results are shown below in Table 4 below. For simplicity in reporting, the "strongly agree" and "somewhat agree" categories were combined, as were the "strongly disagree" and "somewhat disagree" categories.

**Table 4**: Student responses to "To what extent do you agree with the following statement: 'I feel more confident in my ability to use skill X now that I have taken Workshop X.'"

| | | | ***n*** | **Agree** | **Neutral** | **Disagree** |
|---|---|---|---|---|---|---|
| **CAD Series** | 3D Scanning | Women | 3 | **100%** | 0% | 0% |
| | | Men | 2 | 50% | 50% | 0% |
| **Arduino Series** | Introduction | Women | 10 | **90%** | 0% | 10% |
| | | Men | 12 | **67%** | 8% | 25% |
| | Motion I | Women | 8 | **100%** | 0% | 0% |
| | | Men | 3 | **67%** | 33% | 0% |
| | Communication | Women | 5 | **80%** | 0% | 20% |
| | | Men | 5 | **100%** | 0% | 0% |
| **Electronics Series** | Soldering | Women | 6 | **100%** | 0% | 0% |
| | | Men | 14 | **64%** | 14% | 21% |
| | PCB & Eagle | Women | 2 | **100%** | 0% | 0% |
| | | Men | 6 | **83%** | 0% | 17% |
| **Manufacturing Series** | Saws and Drills | Women | 7 | **100%** | 0% | 0% |
| | | Men | 9 | 56% | 33% | 11% |
| **Prototyping Series** | 3D Printing | Women | 2 | 0% | 0% | **100%** |
| | | Men | 5 | 60% | 0% | 40% |
| | Laser Cutting | Women | 3 | **100%** | 0% | 0% |
| | | Men | 10 | **90%** | 10% | 0% |
| | Sewing | Women | 2 | **100%** | 0% | 0% |
| | | Men | 2 | **100%** | 0% | 0% |

In 9 of the 10 workshops, at least 50% of women agreed that they feel more confident in their skills after taking a workshop. The only exception to this trend was in the 3D printing workshop. In all 10 of the workshops, at least 50% of the men agreed that they felt more confident after taking a workshop. This is positive, as the students generally felt that the workshops taught them something.

Another question in the survey question asked students to report how they used the skills after the workshop. In the Fall 2018 survey, many students interpreted the question as "*Have* you used skill X since the workshop?", rather than *how* they have used the skill, resulting in "yes/no" responses rather than detailed answers. This question was changed to only ask "Have you used skill X since the workshop?" in the Spring 2019 survey. The results of this question are shown below in Table 5.

**Table 5:** Student responses to "Have you used skill X since the workshop?"

| | | | ***n*** | **Yes** | **No** |
|---|---|---|---|---|---|
| **CAD Series** | 3D Scanning | Women | 3 | 0% | **100%** |
| | | Men | 2 | 0% | **100%** |
| **Arduino Series** | Introduction | Women | 10 | **60%** | 40% |
| | | Men | 12 | **83%** | 17% |
| | Motion I | Women | 7 | **71%** | 29% |
| | | Men | 3 | **67%** | 33% |
| | Communication | Women | 5 | 20% | 80% |
| | | Men | 5 | 40% | 60% |
| **Electronics Series** | Soldering | Women | 6 | **83%** | 17% |
| | | Men | 14 | 57% | 36% |
| | PCB & Eagle | Women | 2 | **100%** | 0% |
| | | Men | 6 | 50% | 50% |
| **Manufacturing Series** | Saws and Drills | Women | 6 | 50% | 50% |
| | | Men | 10 | **70%** | 30% |
| **Prototyping Series** | 3D Printing | Women | 2 | 0% | **100%** |
| | | Men | 5 | 20% | **80%** |
| | Laser Cutting | Women | 3 | **100%** | 0% |
| | | Men | 10 | **100%** | 0% |
| | Sewing | Women | 2 | 50% | 50% |
| | | Men | 2 | 50% | 50% |

Women and men reported using different skills after the workshops. Interestingly, for this group of students, a higher frequency of women using a skill again often correlated to a lower frequency of men using that same skill. Women reported more use of electronics skills, whereas men reported more use of manufacturing skills. All of the women who took the Eagle & PCB workshop reported that they used those electronics skills again and 83% of women said they used the soldering skills again. In the manufacturing series, 70% of men reported using their saws and drills skills again, as compared to 50% of women. All of the men and women who took the laser cutting workshop reported that they used that skill again. The two least used workshops

were 3D Printing and 3D Scanning: 100% of women said that they did not use either of these skills after the workshop, 100% of men said they did not use the 3D scanning skills again, and 80% of men said they did not use their 3D printing skills again.

The final question of the survey asked students: "Please provide any feedback about your experience with the Workshop X (i.e. What did you find helpful? Did you follow up with the workshop instructor at all?, etc.)."

Student responses (women *n=15* , men *n=34)* varied from general remarks about the workshops to detailed suggestions for workshop improvement. For a complete list of the student responses, see Appendix C. Overall, students felt that the workshops were beneficial. Most of the responses from women said the workshops were "helpful" and that the instructors were "great." One woman reported her approval of the Saws and Drills workshop, saying "Saws and drills are so useful. I am very glad that I learned this workshop. I cannot wait to actually use these skills." Both men and women noted that the hands-on portion workshops were beneficial. In the Introduction to Arduino workshop, one woman said "I liked that it was hands on. Most important part. We learn by doing."

The 3D Printing workshop received the most negative feedback from both women and men. These responses explain why the majority of women and men did not feel more confident after that workshop and subsequently did not use these skills in their engineering projects (See Table 4 and Table 5). One man responded "I thought the 3D Printing workshop was awful...I did not get to print anything or see something be printed." A woman commented "This was not a good workshop. They read from the PowerPoint and we all had to huddle around a tiny 3D printer. No hands on and it cost money to do nothing."

Another theme in the responses was that students thought the workshops were useful, but they have not used those skills since. For the Sewing workshop, one man said "I would feel more confident if I practiced using the sewing machine more. This was not a fault of the workshop, but rather the lack of need afterwards." Another man had a similar response to the soldering workshop: "Amazing workshop. I just haven't used the experience yet." These responses align with the results in Table 5, where many students reported not using their skills again after the workshops.

*Individual Reflections*

The individual reflections (*n=4 women, n=6 men)* were analyzed through multiple iterations to identify common themes in student responses. All responses are from the Fall 2019 section of the second year engineering projects course, *Engineering for the Community.* For the first pass, the research team read through the responses and extracted passages that mentioned a workshop or a technical skill. In the second pass, we reread the responses and noted passages that supported and/or countered each other. Two main themes emerged from the individual reflections: 1) some students feel more confident in their skills after taking a workshop and 2) some students did not use their skills again after taking the workshop.

From the responses, we determined that students feel more confident in their skills after they take a workshop and then apply those skills in their project. One man reported that he mostly used the manufacturing skills he learned in the Saws and Drills workshop, and says he is "very confident in [his] skills in manufacturing and could apply them to any project." Another woman commented on her manufacturing skills saying, "I still feel some of the same apprehension with needing help in engineering, but have gained significant experience and confidence in most areas, including manufacturing" since taking the workshop.

Many students reported that they went from having no experience in a certain skill to feeling confident in their abilities after the workshops. Students often noted that they understood that learning skills would take extra time, but felt that learning a particular skill was important. One man wrote:

> Prior to this semester, I had very little experience with CAD other than an introductory workshop from last semester. Yet it was something that I knew would be very valuable to our project and valuable for future knowledge. With a little bit practice and some trial and error, I was able to become very competent with this software, allowing our team to 3D print customized designs for our project.

Another theme that arose in the individual reflections was that students did not use the skills they learned in the workshops. One woman reported that she did not feel confident enough in her electronics abilities, saying:

> Although I did take the Eagle/ PCB Printing workshop, I decided to labor through the creation of a soldered Arduino shield- and this I regret. My thought process was that I wasn't proficient enough at PCB printing after one workshop to print my group's board, but it really would have saved me so much time and frustration.

Another explanation for why students do not use their skills after a workshop is because that skill is not applicable to their project or their role. One student said that their client's request of a simple design meant not being able to use Arduino. Another student said there was simply no need to use 3D scanning for his project. Despite not using the skill, some students recognized the importance of understanding the basic concepts. One man said:

> Although, I was not responsible for the electronics side of our project, I went through the 'Intro to Eagle' workshops and had a few conversations with [Teammate 1 (Man)] and [Teammate 2 (Man)] about the requirements and the work that went into this, both of whom are very familiar with the concepts behind this component. This familiarization will better prepare me for future projects.

*Focus Groups*

Lastly, the research team held focus groups to gain more insight into the effects of the skill-building workshops on students' self-efficacy in their technical skills. The first focus group, held in the last week of the Fall 2018 semester, was comprised of three women and one man. Due to complications with the audio recording device, there are no direct quotes from the focus group. In the Spring 2019 Semester, we held one interview with one man. All of the students' names have been replaced with pseudonyms.

*Fall 2018 Focus Group*
Tanya, Nicole, and Richard were all enrolled in the second year projects course, *Engineering for the Community*. Ally was enrolled in the third year projects course, *Invention and Innovation*. Each student provided feedback about different workshops, their experience on their teams, and suggested improvements for future workshops and engineering projects classes.

Tanya said that she took a CAD workshop, but found it to be difficult due to the lack of individual help and the fast pace of the course. She also said that she believes the 3D printers break so often because students are not adequately taught how to input the filament during the workshop.

Nicole agreed with Tanya about the 3D printers, and would have liked to practice putting in the filament during her 3D Printing workshop. During her project, Nicole sought advice from the electronics and Arduino workshop instructors. She said that both were incredibly helpful in developing new skills.

Ally said that she took the Eagle & PCB workshop, which she used for a class other than engineering projects, so she still found it to be helpful. She said she was hesitant to take on an electrical role in projects at first, but after this semester, she feels that she could take on any electrical role from now on. In contrast, Ally did not like the 3D Printing and Laser Cutting workshops. She described them as a waste of time and money. In terms of team dynamics, Ally took on a leadership role as CEO of her company, and noticed that her team quickly separated into groups of men and groups of women, with men doing most of the manufacturing and women doing most of the design and nontechnical work. Ally also mentioned that she was the only woman CEO in her class, and wished that she had seen more women in leadership positions.

Richard took a CAD: Assemblies workshop and found it to be a helpful addition to his CAD confidence. He has used OnShape before, but not SolidWorks. Richard noted that he feels confident in his manufacturing skills, so it is possible that he overpowered the other man on his team who was working on building his manufacturing skills.

*Spring 2019 Interview*
John is a sophomore e+ student studying Aerospace Engineering and Computer Science. In Spring 2019, he took *Engineering for the Community.* His role in his project was electronics, circuitry, and coding. He has taken every workshop in the Arduino series because the workshops were taught during his projects class lecture period, which he thought was helpful. When asked about what he thought about working in groups for the workshops, John replied:

> Working individually definitely feels like it's a little bit more daunting in the case that you're not comfortable with wiring or you're not comfortable with coding, one or the other or even both. That would be a nightmare. It can be a little bit pressured but you learn definitely a lot more because it gets you out of your comfort zone. When you're in the groups of 2-3 you can say 'oh well I'm really good at wiring so I'll do that.'

Working to his strengths goes beyond just the workshops. John said that in his project, he took on the circuitry role because those were the skills he was most familiar with, saying "I feel like it plays to my strengths which only benefits the team. Spring semester is very fast. We're more than halfway through and if our prototype doesn't work, we're in hot water."

Throughout the interview, John noted how he had opportunities in high school to become familiar with many of the skills offered in the workshops, and noticed that not everyone in his group had those previous experiences. In his *First Year Engineering Projects* course, John said

> I was the only one with machining experience on my entire team which was surprising. A bunch of engineering students want to come in and be engineers but they've never touched a drill in their life, so I was a little surprised. I was also the only one with manufacturing experience so I was the one building the prototypes… Since a lot of this was trivial manufacturing, I kind of stepped back and let [teammate 1(woman)] and [teammate 2 (man)] take on the majority of it.

Overall, John saw the workshops he took as valuable experiences as refresher courses for skills he already knew. He noted that how useful the workshops are is dependent on what project a student works on. Many of the projects are mechanically inclined more so than electronics, or vice versa. John also noted that some of the workshops, particularly Laser Cutting, is invaluable for courses outside of the engineering projects series.

**Discussion**

Our research was driven by three main questions. Each is discussed below.

*What workshops are students taking?*

Based on the data in Table 4 and Table 5, students took workshops in all 5 of the categories of workshop series: CAD, Arduino, Electronics, Manufacturing and Prototyping. Men took more electronics, manufacturing and prototyping series workshops than women. Women took more Arduino and CAD workshops than men. The greatest gender gap is in the electronics series, with 20 men taking electronics workshops as compared to only 8 women. Introduction to Arduino was the most attended workshop by both women and men. This is likely due to the workshop being offered during class time.

*How/are students using the skills they learned in the workshops?*

The data show that only some students are using their skills after the workshop. There is a trend that shows a higher frequency in women using a skill correlates with a lower frequency of men using that same skill. Exceptions to this trend are the Sewing workshop which both 50% of women and 50% of men reported using that skill again, Laser Cutting which 100% of women and men reported using that skill again, and 3D Scanning which 100% of women and men

reported not using that skill again. Survey responses, individual reflections, and focus groups all indicate that the most common reason for why students did not use a skill after a workshop was a lack of need for that particular skill in their engineering projects class, either because someone else on their team already fulfilled that role or because the skill simply was not applicable to the project. Of the students who did use the skills after the workshop, many indicated that they felt more confident in their technical abilities by the end of the semester.

The individual reflections and focus groups indicate that some women are hesitant to use technical skills even after taking a workshop. Both women and men indicated that they did not feel proficient right after the workshop, but rather needed to practice their skills throughout the semester in their projects to feel confident. Using the skills in their engineering projects classes and in other engineering courses is the most frequently cited way of students using the skill after the workshop. Most students noted the importance of learning these skills and expressed their interest in improving in technical areas. The desire to learn new skills and a need for that skill in their project was enough of a drive for some students to persist in learning that skill, but other students may need more encouragement from their peers or instructors.

The two least used skills were 3D Printing and 3D Scanning. There were many comments in the surveys and focus groups about how discontent students are with these two workshops. Both workshops are taught using a presentation about the technology and a demonstration of the equipment by a qualified student. Students mentioned, particularly for 3D Printing, that this style of workshop did not help them feel confident in their abilities. It may also be pertinent to note that the 3D workshop costs $17.50 to attend, as compared to the $5 attendance fee for most of the other workshops. The 3D Printing workshop is more expensive than the others to offset the cost of replacement filament heads and machine beds of the 3D printers.

*What improvements can be made to the workshops to make them more equitable for all students?* In the surveys, reflections, and focus groups, students offered many suggestions for improving the workshops and engineering projects classes.

The most contentious workshop was the 3D Printing workshop. Students agreed that its current setup is ineffective. Students would prefer to have a hands-on workshop with guided practice in using the machine rather than an informational PowerPoint lecture and instructor demonstration.

Many students noted that they felt confident in their technical abilities after taking a workshop, but did not get a chance to use those skills in their projects. Because of the size of teams (4-6 students) and short duration of semester-long projects, students feel it is difficult to work on all of the skills they want to improve on in one semester. Some women mentioned that the engineering projects classes are very grade-driven so they are more reluctant to learn a new skill because they do not want to damage the project or put the team behind schedule by learning a new skill. This phenomenon is corroborated by one man in the focus group who said the short timeframe of the semester project does not allow teams to make the mistakes that may happen when someone is learning a skill, so he took on a role that he had previous experience in to benefit the team. Some suggestions for improving the engineering projects classes include

awarding extra credit to groups with the most skill growth and using lecture periods for reinforcing skills and hosting quick 'refresher' workshops.

Both women and men mentioned the need for encouragement when trying to learn a new skill. This encouragement can come from teammates, course instructors, workshop instructors, or TAs. One woman said she was encouraged by her team to learn about electronics because there was a need for those skills in her project. One man noted that encouragement from TAs is beneficial because they are typically the same age cohort as the students. Professors and TAs can encourage students throughout the semester by scheduling check-ins with students to revisit their goals throughout the semester.

**Conclusions**

The results of this study show that skill-building workshops are a viable way to help women build their technical repertoire. In the majority of the workshops, both women and men said they felt more confident in their technical abilities after taking a workshop. The exception to this trend was the 3D Printing workshop. Students disliked the lecture style presentation and prefer a hands-on approach to learning how to use the 3D printers.

A key factor in women's technical self-efficacy levels is reinforcing their skills by using them in subsequent engineering projects. The most prevalent reason for a student to not use a skill after a workshop is a lack of need for a particular skill in a current project. There appears to be a trend in which a higher frequency of a woman using a skill correlates to a lower frequency of a man using that skill, and vice versa.

Hands-on project-based learning is a rapidly growing engineering pedagogy because of its potential to help engineering students problem solve and think critically in teams. These types of learning environments show promise not only for increasing women's retention in engineering, but for helping all students feel prepared for the exciting and complex world of professional engineering practice.

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**Appendix**

A. *Workshop Descriptions*

- **Arduino- Introduction:** "Learn the basics of the Arduino UNO microcontroller board and development environment. The fundamentals of Arduino Input and Output are discussed through connection to sensors and lights. NOTE: this workshop is the same material that is covered in the First-Year projects classes" [20]
- **Arduino- Motion 1:** "Building on the Introduction to Arduino Workshop, the Intermediate Workshop focuses on two devices that produce movement – Motors and Servos. Common coding and troubleshooting techniques are also discussed. Students taking the Intermediate Workshop should be able to understand the fundamentals of Arduino Input/Output and have at least 6 hours of experience with the Arduino microcontroller" [21].
- **Arduino- Communication:** "Participants will learn about Arduino communication through hands-on exercises. Common issues regarding Serial communication will be addressed. Students taking the Arduino Communication workshop should be familiar with Servos, use of the Serial monitor, and have at least 12 hours of Arduino experience" [21].
- **3D Scanning:** "Discover and learn about the benefits and boundaries of 3D scanning. Take reverse engineering to the next level with the NextEngine desktop or the Artec EVA Lite handheld 3D Scanner" [21].
- **Soldering:** "After working on the popular Simon Game from SparkFun, you will have a greater knowledge of through-hole soldering and the tools, techniques, and terminology required to populate your own PCB prototype" [21].
- **PCB & Eagle:** "This introductory workshop will help you use Eagle Open-Source software to create a schematic of your circuit design. layout and fabricate a Printed circuit board for your project" [21].
- **Saws and Drills: "**Completion of this 90-minute workshop is required prior to use of the Manufacturing Center's saws and drills. Topics will include using the drill press, table saw, and others" [20].
- **3D Printing:** "In this workshop, students will become familiar with the three levels of 3D prototyping available at the University of Colorado. At the end of the workshop, students will go through the process of setting up and printing a part" [21].
- **Laser Cutting:** "Completion of this workshop is required before students can use the two laser cutters located in the ITLL. This workshop is offered throughout the semester to groups of 10 students" [21].
- **Sewing:** "This workshop that covers the basics of sewing using the Janome DC2015 machines. The intro includes machine setup, terminology and common troubleshooting tips. All users welcome!"[21].

*B. Engineering Project Course Descriptions*

- ***First Year Engineering Projects*:** "First-year students solve real engineering design problems in interdisciplinary teams. Design projects vary by section. Curriculum focuses on iterative design process, teamwork and team dynamics, supporting design with testing and analysis, and technical writing. Completed projects are exhibited at an end-of-semester design expo" [22].
- ***Engineering for the Community*:** "Design engineering products for local community clients, with emphasis on humanitarian engineering and integrated systems with electrical, mechanical, and software components. Students are challenged to take design projects to a higher level by requiring an additional iteration through the design cycle and more engaged user-testing, in order to infuse student projects with the robustness necessary for public-use products" [22].
- ***Invention and Innovation*:** "Introduction to business development and product innovation with a hands-on approach. Students explore the invention process, hone their engineering design skills, and explore the initial stages of entrepreneurship (patenting, intellectual property, marketing research, and raising capital). Student teams design, create, and test a potentially commercial product, and exhibit at an end-of-semester design expo" [22].

C. *Qualitative Survey Data*

| | **Women's comments** | **Men's comments** |
|---|---|---|
| Introduction to Arduino | "I felt working in groups took away from individual learning. All individuals should have to do the circuit and write the code but can consult one another." | "It was a simple-but-solid workshop that didn't teach me too many things but was still helpful." |
| | "It was very helpful. The instructor was great." | "Really well taught and was very helpful." |
| | "I liked that it was hands on. Most important part. We learn by doing." | "Hands on" |
| | "I enjoyed the presentation and the activities because it was informative yet practical." | "This workshop was taught very well." |
| | "The instructor was great! He taught all the Arduino workshops I took and he is very patient and explains things sufficiently." | "Good it's just hard to expand on" |
| | --- | "It was good and got me interested" |
| | --- | "My team got help from the workshop instructor for our first project" |
| | --- | "Helped me understand the usage of arduino better." |
| Arduino: Motion I | "It was very helpful. The instructor was great" | "The workshop was well done and I was happy with what I learned" |
| | "It was helpful to learn about motors, but to have a real-life application as we're going through (knowing how what we learn applies to a real-life product). I did not follow up with the instructor." | "Again, was taught well and helpful" |
| | "Great instructor" | --- |
| Arduino: Communication | "It was very helpful. The instructor was great" | "More time to complete tasks" |
| | "This will be helpful in working on a project in a project's class this semester (the instructor) gave us several different communication options, so I feel confident in working with Arduino communication in different formats. | "It was helpful" |
| | "Super applicable to concepts I am learning in my circuits class for (mechanical engineers)" | "[The instructor] did a great job in the workshop. He helped us push the limits of what we knew and learn" |
| Soldering | --- | "Amazing work shop I just haven't used the experience yet" |
| | --- | "Slow paced" |
| | --- | "Used soldering for first project." |
| | --- | "Nice skill, I don't know when I will use it next." |

| | | |
|---|---|---|
| | --- | “Used it to solder a circuit.” |
| | --- | “It was very basic level.” |
| | --- | “I had prior soldering experience” |
| | --- | “Intro to something totally new.” |
| 3D Printing | “This was not a good workshop. They read from the PowerPoint and we all had to huddle around a tiny 3D printer. No hands on and it cost money to do nothing.” | “I thought the 3D printing workshop was awful - the machine they tried to demo on was broken and she also couldn't get a machine upstairs to work. I did not get to print anything or see something be printed - a waste of $17.50 or whatever the cost was.” |
| | --- | “It was just a PowerPoint presentation that was not very helpful and it was expensive for what I got out of it” |
| | --- | “Would like hands on experience changing filament.” |
| | --- | “The printers break a lot more trouble shooting” |
| Sewing | --- | “I would feel more confident if I practiced using the sewing machine more. This was not a fault of the workshop, but rather the lack of need afterwards.” |
| | --- | “Not long enough, really brief, had to reteach myself when I had to use it for a project” |
| 3D Scanning | “The most helpful part was the information provided but in general the workshop was poorly run and not very useful” | “3D scanners are expensive and only able to do a limited number of tasks” |
| ‘<br>Saws and Drills | “Saws and drills are so useful I am very glad that I learned this workshop. I cannot wait to actually use these skills” | “More available time slots open” |
| | --- | “They were good at giving instruction and helping if we got stuck” |
| | --- | “I think that the staff were very knowledgeable about saws and drills.” |
| | --- | “Good focus on safety.” |
| | --- | “Sometimes the guys in the workshop are not very open to questions, they can be pretty condescending” |
| | --- | “I already had a lot of experience with the machines before I took the workshop” |
| Eagle and PCB | “It was one of the most helpful workshops that I have taken. It was incredibly well taught.” | --- |