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Building Community and Increasing Confidence Among First-Year Female Engineering Students through an Engaging Co-Curricular Workshop

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Abstract

Engineering students often take either primarily general education courses or participate in a first-year engineering program that combines all disciplines into one course consisting of multiple sections. This structure can dilute the female engineering student population, meaning the students are distributed between multiple sections and courses during the first year. Because of this, female engineering students may be less aware of each other and have fewer opportunities to connect, which can result in feelings of isolation, questioning their sense of belonging, and potentially affecting their retention.

At Louisiana Tech University, a first-year program called Living with the Lab offers an immersive, hands-on, project-based course sequence that focuses on problem-solving and building a strong academic foundation for engineering fundamentals. Equipment like milling machines, soldering irons, and drills are all used within the course sequence. The classroom setup is strategically designed to encourage collaboration through a six-person table layout. Feedback was received that female engineering students often felt intimidated when entering the classroom and underconfident while using the equipment. A workshop that provided female students advanced access to the equipment by working through multiple hands-on activities while also making connections with female faculty, engaging with upper-level female students, and building community with their peers was implemented to address these concerns.

At the beginning of the Fall 2023 academic term, the first INSPIRE Workshop experience for first-term, female engineering students was offered. Nineteen female students participated in the two-day workshop. Survey data on confidence in using the equipment and sense of community were collected. This paper will describe the workshop experience and provide results from the survey data. Results indicate positive statistical significance on the overall confidence in using lab equipment and a sense of community.

Introduction

Females remain an underrepresented population within science, technology, engineering, and mathematics (STEM) fields. According to the Report *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2023* produced by the National Science Foundation, 24% of the United States workforce consists of STEM or STEM-related occupations. However, only 18% of the total working females are employed in STEM professions, resulting in 35% of the overall STEM workforce [1]. This number becomes more dire when filtered for science and engineering occupations, reducing the percentage of females to 28%. Furthermore, when looking at the makeup of engineers in the labor force, only 16% are females [1].

More promising is the statistic that over a ten-year period from 2011 to 2021, the female STEM workforce saw a 31% increase. A small contribution to this is the number of bachelor's degrees awarded to females in engineering, which rose from 19% to 24% over the same ten-year period [1]. While this number remains low, it is encouraging to see the needle moving in the positive direction. Over this timeframe, many universities have implemented initiatives to help increase the number of females in their engineering programs and the STEM workforce [2] - [8].

At the college level, researchers have found that males are often more likely to persist in engineering than their female counterparts [2] - [3]. A five-year study assessed the impact of retention initiatives on the female student population. Specifically, the university offered six programs:

1. A mentorship program that paired female first-year and senior engineering students.
2. An extra-curricular female-centered professional engineering society.
3. Intentional hiring of female faculty and staff.
4. Female-supported co-op program.
5. A first-year design course.
6. A dedicated resource center for women at the University.

The engineering programs experienced a 21% increase in female retention from first year to second-year students shifting from 52% in year 1 of the study to 73% in year 5 [2]. Recognizing this notable increase in retention, Universities with goals to increase female students and their retention may consider incorporating these or similar programs to yield similar positive impacts.

Fostering a sense of community and belonging is a component often found in retention programs [4], [9] and is particularly impactful for the retention of first-year students [10]. A report entitled "STEM Students & Their Sense of Belonging: S-STEM Programs' Practices & Empirically Based Recommendations" identifies cohort experiences as an important factor in academic integration and success [9]. Offering retention programs is valuable, but if students do not attend or participate, they will not receive the maximum benefits that these programs can provide.

Students are more likely to participate in retention programs if they feel a sense of community within the institution [9]. Furthermore, female engineering students, who have been found to highly value the sense of connectedness, benefit from the positive impact of a supportive community, enhancing their resilience. Thus, the social community plays a crucial role in retaining women in engineering programs [4]. Tinto asserts that for students to believe they can persist, they must "see themselves as a member of a community of other students, faculty and staff who value their membership -- that they matter and belong [11]." When applied to female engineering students, who are underrepresented in their programs, it is important that retention initiatives address the sense of community in all aspects - connection with their female peers, connection with female upper-level students, and connection with female engineering professors. Building confidence, especially in early courses, has been known for years to have a significant impact on the persistence of female engineering students [5] - [6], [12]. For females in engineering and science programs, self-confidence emerged as a major perceived barrier to persistence. Particularly in the first year, enjoyment of and performance in mathematics and science courses, linked to confidence levels, played a noteworthy role [5]. At Embry Riddle, an extra-curricular all-female activity that applied skills from their sophomore year engineering curriculum resulted in increased levels of confidence. The participants cited that their involvement directly influenced their ability to succeed in their chosen engineering program. Many of the first-year students participating were able to work with upper-level female peers and gain exposure to tools that they will use in future courses [7].

As engineering courses become more hands-on, various fabrication equipment and tools have become more regularly used but are often seen as intimidating by students. Particularly female students often indicate low levels of confidence towards using the equipment. In one such course, the instructors decided to incorporate a small activity that uses different fabrication equipment and tools before diving into the more involved activities found within the course. The addition of the mini project had a significant impact on the confidence of all students when using the equipment. Most notably, the female students reported large positive increases in confidence in using the different equipment for the course [8]. It is evident that providing students with early access or exposure to intimidating aspects of a course, like equipment or tools, can help increase confidence, thus impacting persistence and retention.

At Louisiana Tech University, many retention initiatives have been implemented to provide students with resources for success. Specifically for female students, the University offers multiple female-centered professional societies. These groups offer community, upper-level role models, connections to alumni and industry, and, in some cases, formal peer mentorship programs. A substantial commitment to strengthen support for females within the College of Engineering and Science involved the creation of the Office for Women in Science and Engineering (OWISE) [13]. This office is dedicated to offering resources and organizing engagement events for female STEM students and faculty. Initially, OWISE efforts were primarily focused on faculty support, but over time the office has grown to incorporate community-building activities and essential resources for both graduate and undergraduate female students in the College of Engineering and Science [14].

Project Motivation

Beginning in 2019, OWISE committed to hosting monthly student engagement events. These events range from bringing in guest speakers from industry to providing community-building activities. During a share session event in the spring of 2022, both students and female faculty members engaged in an open dialogue sharing their experiences of attending classes that were predominantly populated by male students. Among the faculty members present was the First-Year Engineering Programs Coordinator, who posed questions about the program and sought suggestions on how OWISE and other faculty members could enhance and support their first-year experience.

The students expressed positive reflections on their first year but highlighted certain aspects of the course that felt intimidating. Many shared their experiences of entering classes predominantly composed of male students, feeling overwhelmed and uncertain about where to sit—a notable departure from their high school environments. Additionally, they conveyed feelings of under-confidence and intimidation, particularly when dealing with fabrication equipment used in the courses. There was a prevalent sense that their male counterparts either had prior experience with the equipment or projected a confidence that the female students found challenging to match.

The focus group also highlighted a sense of disconnection from their female peers. Despite comprising 20% of the students in engineering classes, females in their first year will primarily meet and interact with their peers from their specific sections. The engineering and math course sections are blocked together within the first-year program at Louisiana Tech University. All engineering students, regardless of discipline, must take these first-year courses. While the intention behind blocking the course together is to foster community building, it inadvertently limits the perception of the female community to the composition of their individual class sections. The 20% of female students are randomly distributed across multiple sections, resulting in a skewed perspective of the overall female student population. Consequently, some sections boast as much as 33% female representation, while others have as low as 5%.

Specific engineering disciplines attract more females than others. According to the report Engineering and Engineering Technology by the Number released by the American Society for Engineering Education, disciplines like Environmental, Biomedical, Biological, and Chemical engineering have the highest percentages of degrees awarded to women, 57.8%, 51.5%, 39.1%, and 38.5% respectively [15]. These disciplines are reflected in the Civil, Chemical, and Biomedical Engineering degree programs at Louisiana Tech University. For the Fall 2023 class, which is the focus of this study, these three disciplines, out of the total seven engineering disciplines offered, boasted 57% of the female student population. However, it is unlikely that many of these students would interact in the first year unless they are in the same sections or participate in an extra-curricular or co-curricular experience.

By identifying these gaps in the first-year experience of female engineering students at Louisiana Tech University, targeted initiatives can be developed to bridge the gaps. Recognizing an opportunity to offer more support to this group of students, a co-curricular workshop aimed at fostering a sense of community and building confidence in curricular activities was created. This paper will assess the impact of the workshop on the sense of community and confidence of the participating first-year female students.

Background

At Louisiana Tech University, every first-year engineering student, regardless of their discipline, is required to participate in the Living with the Lab (LWTL) first-year engineering course sequence. Comprised of three courses (ENGR 120, ENGR 121, and ENGR 122), LWTL instills problem-solving skills and engineering fundamentals. In each of these courses, the Arduino microcontroller is the chosen platform for education, enabling immersive and inquiry-driven learning. This project-based course sequence utilizes the Arduino with sensors and devices, offering a hands-on approach that fosters a deep understanding of fundamental engineering concepts and troubleshooting skills. LWTL first-year courses follow a lecture/lab format, spanning ten weeks per quarter with two meetings per week, each lasting one hundred ten minutes.

The classroom setup includes four laboratory classrooms, two accommodating 40 students and two with a capacity for 24 students, Figure 1. Designed for collaboration and community building, the classrooms feature multiple tables at the center, each equipped for six students. Additionally, fabrication stations along the perimeter provide essential project tools such as milling machines, soldering stations, and hand drills, creating an environment conducive to hands-on learning and teamwork. These engineering courses are blocked together with their mathematics courses. Cohorting students in this way is intentional to help build community

Figure 1. Panoramic view of first-year projects laboratory classroom seating (42 students capacity).

among the students in their classes.

ENGR 120

On the first day of the ENGR 120 course, students receive a strategically curated kit containing various tools and supplies. This kit serves a dual purpose—not only facilitating their course project but also contributing to the development of their personal engineering toolkit. Among the included measurement devices and tools are multimeters, dial calipers, screwdrivers, and scales, along with a variety of electrical components such as LEDs, resistors, jumper wires, DC motors, and a breadboard.

Throughout the course, students learn and apply concepts of electricity as they construct circuits and measure components on their breadboards. Soldering procedures, including safety measures and maintenance practices, are taught to students through hands-on activities, such as soldering extensions on a photoresistor. Beyond the Arduino activities, students build a small centrifugal pump, utilizing milling machines, hand drills, vices, and other tools found at the fabrication stations, Figure 2. This project involves the application of concepts like conservation of energy, data collection and analysis, and electricity. To further enrich their experience, students design an impeller for their pumps, which is 3D printed in the college's prototyping lab.

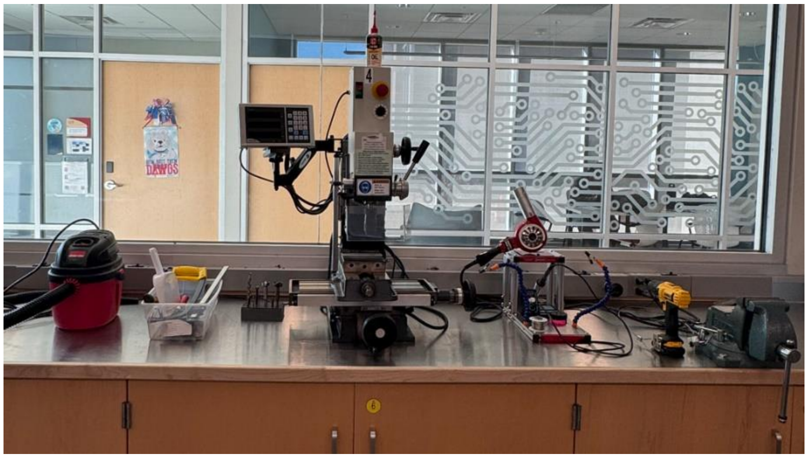

Figure 2. Fabrication stations that are found along the perimeter of the first-year laboratory classroom.

ENGR 121

As the students progress into ENGR 121, they transition from the mobile platform to using the Arduino with a stationary canister oven system that acts as a data collection and control systems device. As they control the temperature of their canister ovens, students learn and apply fundamentals related to thermodynamics and heat transfer. The fabrication of their systems involves using tools included in their LWTL kits and in the fabrication stations found within the classroom. In the latter part of the course, students learn about forces and moments while they construct a linear actuator. This hands-on project necessitates the application of soldering techniques and machining a coupling for the linear actuator assembly.

ENGR 122

Moving into the final first-year course, students work in teams of three to apply the skills they learned in ENGR 120 and ENGR 121 to build a smart product that solves a problem of their choosing. The beginning of the course is focused on learning and demonstrating concepts related to statics while also introducing new sensors and devices. They also complete a fabrication project that uses a laser cutter/engraver to make a nameplate that uses extruded aluminum as the base. The second half of the class is geared towards engineering economics, finalizing their project designs, and building their fully functional prototypes. Students have access to a library of sensors beyond the ones covered in class. They also utilize the fabrication stations and equipment to build their final prototypes.

Fall 2023 Course Demographics

In the Fall of 2023, a total of 433 students were dispersed across fifteen sections of ENGR 120, with class sizes varying from twenty-two to thirty-four students. Twenty percent of the participants in these ENGR 120 courses were female. This demographic distribution reflects a standard composition for a fall ENGR 120 course. Table 1 provides the number of female students in each section.

Table 1. Percentage of female students in each section of the Fall 2023 first-year engineering course.

Section	Class Enrollment	% Female
1	30	33.3
2	32	21.9
3	32	28.1
4	33	9.1
5	32	21.9
6	32	18.8
7	34	20.6
8	32	15.6
9	30	16.7
10	31	19.4
11	31	16.1
12	22	27.3
13	18	27.8
14	22	4.5
15	22	18.2
Total	**433**	**19.9**

INSPIRE Workshop

Recognizing that the concerns shared by the first-year female engineering students at the OWISE share session are not trivial and could significantly impact retention and perseverance in the engineering field, faculty members were motivated to create a co-curricular experience addressing these issues. The goal of the experience was to increase retention of the incoming class of female students by fostering a sense of community, support, and connection to the college as well as building confidence with equipment used in their classes. To support this initiative, a mini-grant was awarded from the Alan Alda Center Women in STEM Leadership to launch a pilot workshop for first-year female engineering students. Named INSPIRE (Introducing New Skills and Proficiencies through Immersive Reassuring Experiences), the workshop took place in the fall of 2023, involving 19 first-year female engineering students. Two female faculty members, supported by three upper-level female engineering students and one graduate student, guided the first-year students through the workshop activities.

Acknowledging the impact that getting acquainted early has on fostering a sense of community and connection [12] and desiring to offer the hands-on experience with the lab equipment before its use in their classes, the workshop was held during the second weekend of the Fall quarter, beginning on a Friday night, and concluding on a Saturday afternoon. All 86 female students in the ENGR 120 courses were delivered a handwritten invitation to attend the workshop along with a personalized email providing details of the event. Due to space and funding limitations, only twenty seats were available for the workshop. Registration opened after each student had received their invitation. At the last minute, one student fell ill, dropping the attendance to nineteen students. This resulted in 22% of the female students enrolled in the first-year engineering course participating in the workshop.

Workshop Activities

The INSPIRE workshop consisted of two primary projects aimed at building their confidence with classroom equipment. The first project, designed to instill confidence in utilizing milling machines, challenged students to craft dice from blocks of ultra-high molecular weight polyethylene—the same material used in the centrifugal pumps in ENGR 120. Students used tools from their LWTL toolkit to measure and mark their die. After training on the milling machines, the participants drilled the pips on each side of their die, adding a personal touch by coloring and customizing their creations with paint markers, as illustrated in Figure 3.

Figure 3. Finished die from workshop activity that gave students experience using the milling machines.

The second project (Figure 4) incorporated soldering and circuitry, both skills found within the LWTL course, to produce a working desk lamp. The desk lamp included a customized plate with the INSPIRE logo and each student's name. This plate was cut and engraved on the prototyping lab's laser cutter/engraver, giving the participants exclusive experience with the equipment. Following a thorough review of soldering procedures, students soldered a USB-C power jack onto an LED strip and then assembled their lamps.

Figure 4. Desk lamp soldered, wired, and assembled during the INSPIRE workshop.

Throughout the workshop experience, engaging activities from the Alan Alda Center for Communicating Science Women in STEM Leadership Program were interwoven as icebreakers and discussion prompts. The presence of upper-level female students was instrumental as they offered valuable assistance to participants, providing guidance on projects and equipment usage. These students not only played a hands-on role in the activities but also led discussions and conducted a Q&A session, generously sharing their personal experiences as females in engineering, offering advice, and reflecting on lessons learned.

Adding a unique perspective, a graduate student who returned to the university for graduate school after five years of industry experience shared insights into both industry and college life.

Sprinkled throughout the weekend, faculty members imparted small anecdotes and words of wisdom to workshop participants, acting as guides through the various activities and providing a supportive environment for learning and community building. At the start of the workshop, participants were given OWISE branded tote bags and coffee mugs as a welcome gift and to set a positive, inviting tone. These items were used as an opportunity to tell the students who were new to campus about the initiatives and resources available through OWISE. On the second day of the workshop, everyone was given an INSPIRE sweatshirt, which helped solidify that the participants were part of a community.

Surveys

At the beginning of the workshop, participants were asked to complete a pre-survey. The same survey was administered at the end of the workshop to collect post-experience data. The survey included three questions assessing participants' confidence in utilizing fabrication equipment, along with five questions addressing community engagement and a sense of belonging. Table 2 lists the questions asked in the pre- and post-survey. Each survey question utilized a 5-point Likert scale. The initial three questions required participants to rate their confidence on a scale from 1 (not confident at all) to 5 (very confident). The subsequent five questions prompted respondents to assess their agreement level with each statement, using a scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 2. Pre- and post-workshop survey questions.

Please rate your confidence level on using the following equipment: *Response Options: 1 – not confident at all, 2 – mostly unconfident, 3 – somewhat confident, 4 – mostly confident, 5 – very confident*
Q1. Using the milling machines.
Q2. Using the soldering irons.
Q3. Using the hand drills.
Please rate the level to which you agree with the following statements: *Response Options: 1 – strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 4 – strongly agree*
Q4. I am comfortable walking into the engineering classroom.
Q5. I feel a sense of belonging in my engineering classes.
Q6. I am comfortable sitting wherever I would like in the engineering classroom.
Q7. I feel a sense of community with all of my peers in engineering.
Q8. I feel a sense of community with other females in engineering.

Two new additional variables were created during the analysis of the pre- and post-questionnaires. These variables reflected the overall confidence and the overall sense of community participants felt. For both questionnaires, the Overall Confidence (O1) variable was created by combining items Q1-Q4 and Q6. The Overall Sense of Community (O2) variable was created by combining items Q5, Q7, and Q8. For these variables, higher scores indicated higher levels of confidence and greater feelings of community, respectively.

Survey Results
Respondents' pre-workshop and post-workshop questionnaire responses were yoked together using a personalized identification code. Two participants' data were not included in the analyses because they did not complete either the pre- or the post-survey. Seventeen out of the nineteen participants' data were included in the analyses.

One-tailed, paired t-tests examining pre- and post-workshop opinions were conducted for each item and the two "overall" variables. Table 3 provides the results of the statistical analysis. All results were significant to at least $p<0.05$.

Table 3. Results of one-tailed, paired t-tests for pre and post-workshop surveys.

Pre-Post Pair	***Mean Change (SE)****	
Q1. Milling Machines	-2.88(0.26)	$t(16)=-11.28$, $p<0.001$, $d=-2.74$
Q2. Soldering Irons	-2.18(0.30)	$t(16)=-7.26$, $p<0.001$, $d=-1.76$
Q3. Hand Drills	-1.06(0.30)	$t(16)=-3.50$, $p<0.001$, $d=-0.85$
Q4. Comfort walking into engr classroom	-0.71(0.19)	$t(16)=-3.77$, $p<0.001$, $d=-0.92$
Q5. Sense of belonging in engineering classes	-0.77(0.18)	$t(16)=-4.19$, $p<0.001$, $d=-1.02$
Q6. Comfortable sitting wherever I would like	-0.59(0.24)	$t(16)=-2.42$, $p<0.014$, $d=-0.56$
Q7. Sense of community with my peers	-1.00(0.20)	$t(16)=-4.76$, $p<0.001$, $d=-1.16$
Q8. Sense of community with female engrs	-0.59(0.17)	$t(16)=-3.41$, $p<0.002$, $d=-0.83$
O1. Overall Confidence	-7.41(0.77)	$t(16)=-9.60$, $p<0.001$, $d=-2.33$
O2. Overall Community	-2.35(0.49)	$t(16)=-4.78$, $p<0.001$, $d=-1.16$

** Change values are negative because scores increased from pre to post.*

Figure 5 graphically represents the workshop participants' responses to the pre- and post-workshop surveys. Figure 6 provides a visualization for the new variables that provide insight on the overall confidence and overall sense of community. Both figures include the average response value for each pre- and post-question, along with their respective error bars.

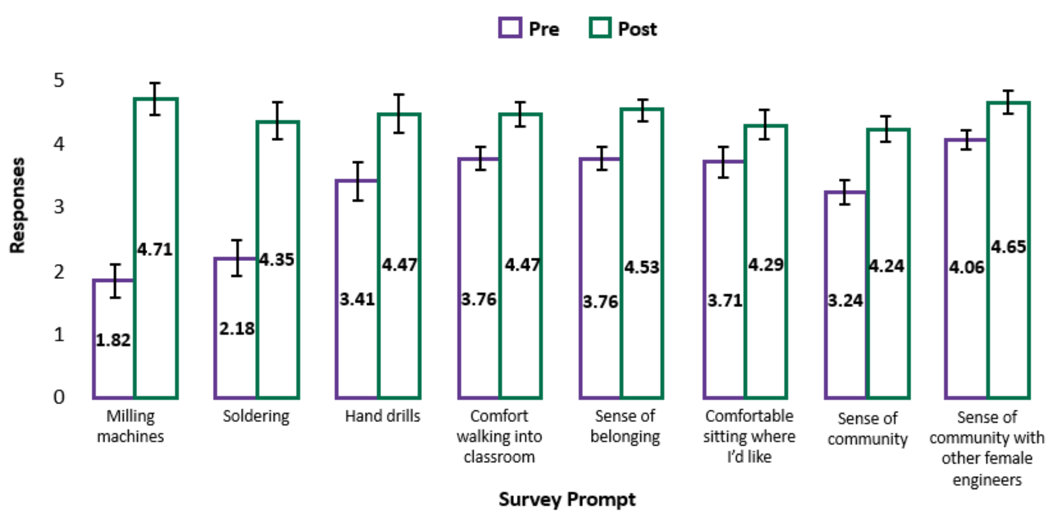

Figure 5. Graphical representation of pre- and post-survey responses.

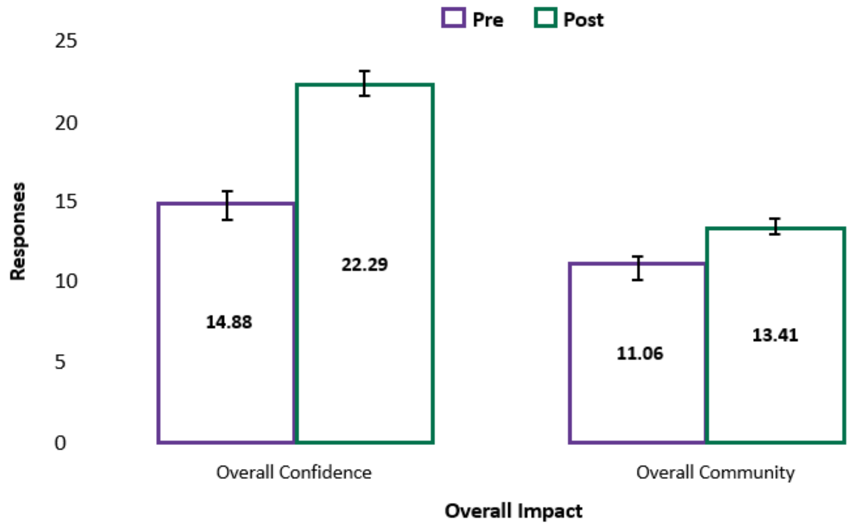

Figure 6. New variables "Overall Confidence" and "Overall Community" were created by combining questions from the pre- and post-workshop survey.

Discussion of Results

Examining the pre-survey responses regarding confidence in using the milling machines, soldering irons, and hand drills, students, on average, indicated they were mostly unconfident for the first two and only somewhat confident in using the latter. After participating in the workshop, their confidence increased significantly to levels of mostly confident and very confident. Knowing that the students would have limited experience with the milling machine and soldering stations, the activities focused on those two pieces of equipment. The large increase in confidence for those is a testament to the effectiveness of the activities chosen for the workshop. Interestingly, while the hand drills were not explicitly used in the workshop, they were located at the fabrication stations with the milling machines and soldering irons. Many of the students already felt somewhat confident in using hand drills, but the experience of using the other, maybe more intimidating, equipment near the hand drills helped increase their confidence in using that tool as well.

The last five questions in the survey asked students to rate the level to which they agreed with each statement. The statements were generally about their comfort level in their engineering class and their feeling of connection with their peers. While these questions did not see as large increases in responses as the equipment confidence questions, they did yield statistically significant positive shifts.

In addition to each individual question showing positive impacts of the workshop, the overall confidence and overall sense of community variables which were developed through combining like questions, showed positive statistical significance. This implies that the overall goals of the workshop - fostering a sense of community, support, and connection to the college as well as building confidence with equipment used in their classes – were met.

Conclusions and Future Work

Students who participated in the workshop gained increased confidence and a sense of community with their female peers, upper-level female mentors, and female engineering professors. Given each survey question resulted in strong positive statistical significance, the researchers are encouraged to continue and expand this effort.

It should be noted that the researchers recognize the sample size is small, and thus, it is not possible to draw definitive conclusions based on these results. Further analysis is planned to measure the impact of this activity on academic performance and retention. Additionally, self-efficacy surveys were given in the engineering course and during the INSPIRE workshop. This data will provide more depth to the analysis of the impact of the workshop experience.

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