Society of Women Engineers (SWE) Welding and Machining Day: Women's Confidence with Individual Hands-On Manufacturing

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Introduction

In 2016, the collegiate section of SWE at Kettering University instituted a program to teach female students hands-on manufacturing skills. In this program, the students were taught skills in either MIG welding or various machining techniques. The event took place over one day, and included a speaker at lunch, who provided the women with a female role model who was familiar with manufacturing processes. Participants in this event were asked to fill out a short post-event survey, in order to determine the program's value and effectiveness and guide future improvements.

In this paper, the program is described, and the evaluation data from the survey is presented. This data shows that participants felt that the event was valuable. The description of the event, together with the data on its effectiveness, can be used by other universities that wish to create similar programs. With additional programs, it would be possible to further explore the role of individual hands-on projects in enhancing student confidence.

Background

McIlwee and Robinson[1] discussed how women engineering students excel in theoretical learning, but fall behind in hands-on learning. This difference in male and female learning styles begins at a young age. During adolescence boys are often raised to be tinkerers and encouraged to develop hands-on skills, a fundamental trait of an engineer, whereas girls are socialized differently. Girls are often not given the same access to hands-on activities, and thus they do not think of themselves as tinkerers and do not take part in many hands-on opportunities[1]. This social upbringing is further enforced by a perception that they do not belong in engineering, which is reinforced by the lack of female role models and mentors in their engineering education and early careers[2]. Research has been done on counteracting this perceived lack of belonging. Rosenthal, London, Levy, and Lobel[3] showed that single gender programs created a greater sense of belonging and compatibility in women in their STEM majors and their co-educational universities. Miyake et al.[4] looked at how value affirmation had a strong effect on decreasing the achievement gap in college STEM classes. Additionally, a study from Harvard Kennedy School of Women and Public Policy Program found that female students exposed to female faculty had

increased self-identification with the STEM field and a greater sense of self-efficacy in pursuing a career in STEM with no negative effects to their male counterparts[5]. Women rate themselves lower for tasks, which are identified as male gendered. Furthermore, negative feedback from male counterparts are likely to have a greater effect on women due to this lower self-perception[6]. While these studies address the need to help female students have a sense of belonging and confidence in the classroom, they do not address the disadvantages female students face in a hands-on learning environment.

The importance of adding hands-on education to the engineering curriculum for both genders is known. There exist many studies about the usefulness of hands-on engineering group projects in the classroom. Industries like these because they promote useful soft skills like communication, project management, and team work, in addition to the technical content of the projects. Seeley[7] bemoans the loss of practical hands-on experience in engineering education as engineering science entered the educational domain. Todd, Red, Magleby, and Coe[8] examine traits that industries value from engineering educational institute. The list includes collaboration skills, systems engineering, communication skills, and an understanding of manufacturing processes as areas of high importance. Furthermore, they discussed how hands-on group manufacturing courses could fulfill these missing areas in engineering education[8]. Ssemakula[9] at Wayne State University implemented a program where three to five students worked in a group to create a complete engine. He found this project to be a success allowing students to gain hands-on experiences in manufacturing processes and working as a team. In his project, student self-assigned their roles in the group, learning for themselves where they fit in the group, as opposed to being assigned by the professors, which could allow female students to self-select less of the technical hands-on position in favor of more social roles[9]. Engineering design competitions have also served as an excellent way to allow students to gain hands on experiences outside the classroom. Buchal[10] discussed the importance in solving real world problems, understanding the design process, closing the non-technical gaps, and practicing team work. Many teams gain motivation from getting to choose to take part in these activities rather than being required. These projects often require extensive hands-on experience to complete functioning models versus rough prototypes. The obstacle to implementing these projects are often the high expense, lack of workspaces, and lack of available advisors and technicians. These are, however, very effective in gaining the needed skills for engineering education[10]. Although the importance and effectiveness of these hands-on learning projects are well understood, female students often have a lower rate of participation and take a less active role in these group activities. Niederle and Vesterlund[11] concluded a majority of women are not encouraged by this competitive environment as men are. This often leaves these less competitive women out of competitive jobs and activities where situations for advancement often exist.

There have been several programs implemented to provide hands-on activities in a way that promotes females' sense of belonging, which have been studied by various researchers. Carlson and Sullivan[12] found many females, in addition to other underrepresented populations, have been approached at middle school and high school level to take part in different hands on education experiences with a focus in computer science and coding tasks. The purpose of this was to promote STEM fields for a career path, which many of the female students would otherwise not consider. In some cases, these programs provided them with female role models and female engineering mentors in order to help with self-identification with a future in engineering. These

efforts were shown to help retention across the board[12]. Other programs which have strived to increase female exposure to hands-on education are all-female competitive engineering teams. One such team was the all-female SAE Mini Baja Team at Embry Riddle Aeronautical University. In 2005, the university created an all-women team which designed and manufactured an off-road vehicle for an international collegiate engineering competition. According to the surveys, this experience is one that many would not have taken part in if it were a mix-gendered group. The single-gendered setting was less intimidating, allowed for greater female participation, and had increased their positive feeling of their place in the engineering sphere[13].

Motivation

At Kettering University, several women expressed interest in learning hands-on skills such as welding and machining. Based on research and previous experience, we decided to provide an opportunity for female students to gain these skills through individually completing a hands-on project. Having seen many programs involving co-gendered group work where females often stepped back, allowing others that they felt were more capable take over the hands-on tasks, we wanted to create a program where women could support each other by words and encouragement while completing the program/task on their own. We wanted to create a hands-on experience not focused on teamwork and soft skills, but rather as a method of increasing self-esteem and self-efficacy through individual work. An important aspect of this event would be the equal mechanical experience and social background of the participants; this stands in contrast to the research mentioned above. We focused on activities that are often seen as daunting, scary, or dangerous to females, who have not been socialized to feel comfortable around large and potentially dangerous equipment such as lathes, mills, power tools, and welders.

Elements of the Workshop

The workshop was setup to be a single day event in order to make it more appealing to busy college females; however, the technicians offered to have the students return on their own time if they wanted to work on their proficiency in these areas after the event was done. Due to the single day time frame, the students were given the choice to participate in one of two sets of manufacturing activities. One option was creating a design of their choosing by welding horseshoes cut and shaped with handheld power and air tools. The other option was machining a bolt and nut out of aluminum round stock using a lathe and vertical mill. The schedule for the event started out with a short safety overview section in the morning. As all of the tools are inherently dangerous, it was important to impress upon the participants a healthy understanding of safety precautions needed to operate these tools. The safety overview in both cases included ways to expand their hands on experience after the one day classes ended. It was important that safety ideas were transmitted without creating a fear of the equipment. The small 1:3 ratio of technician to participant allowed the technician to explain the safety details with more nuance, discussing specific applications in mind and allowing for discussion of different safety practices under different condition or usages, rather than making large overarching “never do this” statements.

Although there were several male students offering to help with teaching, we felt it was important to keep the instructors to the technicians at the school. This was due to technicians having a better understanding of the processes and safety best practices, due to years of professional experience. A second consideration was to avoid creating an environment that may be intimidating. There was also a worry that these male students would step in to help too much, taking over for the female students, and undermining the female-focused learning experience. This did not have an adverse effect on the number of participants as the number of machines, welders, and lathes available was the limiting factor.

Figure 1: Student with completed bolt project

Figure 2: Completed horseshoe projects

Each individual in either group completed a project which had an item that they could take home. For the women's sense of self confidence, it was important that they were able to see a project through from beginning to end. For the welding project, the student brainstormed the design and machined the horse-shoes, culminating in the completion of the project by welding the created parts together. The female participants for the welding project were given time to design and draw out their plans. They then were given a class on set up of the MIG welding machines and given time to practice welding on coupons. After they felt sufficiently comfortable with their skills, the

students began to shape the horseshoes under the guidance of a technician. The technicians were allowed to alter the students designs, if they felt welding would be too complicated. The students then welded the pieces together creating a completed design to take home. The bolt and nut machining project was more time intensive and thus design was not part of the process. Due to the large amount of machining needed, no practice pieces were created. The participants were shown easier tasks like using a horizontal bandsaw to cut off the nut, hand tapping threads, and milling the flats on the nuts to do on their own while waiting for the lathe, which was taught one-on-one with a technician and student. The machining was done in aluminum, but maintained lower cutting speeds to allow the participants time to get comfortable with the actions. Threading the bolt was done on a lathe, a process which is no longer used in industry, but gave the women more insight on the versatility of a lathe.

We were fortunate in having amazing technicians who were willing to help out with the planning and implementation of the event, though all of the technicians at our school with a strong base in these manufacturing processes are male. Therefore, we felt it was important to include a female role model in this event, not only in field of general STEM, but rather in a more specific area of hands-on heavy duty manufacturing technologies. Through a mutual contact, we located Anne M. Lucietto, PhD., Assistant Professor of mechanical engineering technology at Purdue University. Dr. Lucietto grew up working in a tool and die shop owned by her family, where she was able to gain extensive and valuable experience with production manufacturing. She discussed the prejudices that she faced as a young technical person from customers of her family shop. She discussed how her father's visible support was a key factor in her success. She further discussed the struggles she had to gain respect from male subordinates in her early career, and how this was overcome by expertise and confidence. It is a key lesson for women to understand how to overcome these prejudices in male dominated fields and have a role model to show us how they have handled these circumstances.

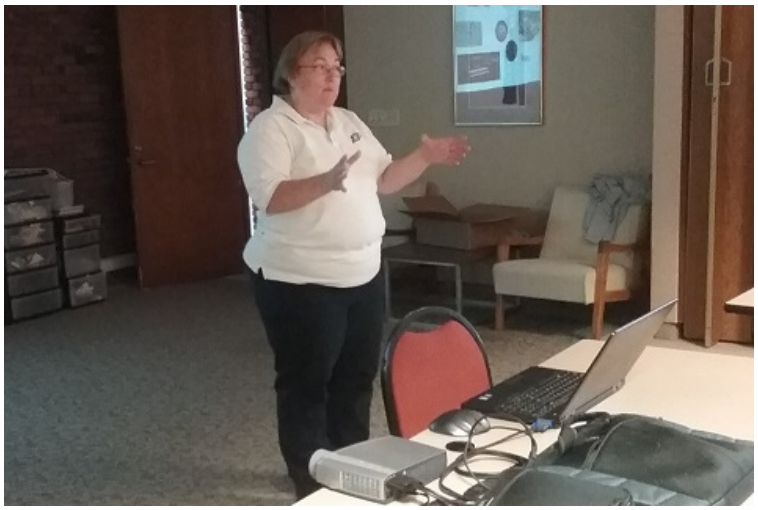

Figure 3: Female fabrication role model presenting a lunch talk

For the participant base, we approached the event through Kettering University's collegiate SWE organization. This gave us a primarily female base from which to recruit, and all participants were female.

We designed the workshop to achieve specific learning objectives: by the end of the workshop, each participant should be able to (1) understand how to use the equipment safely and (2) demonstrate the use of the machines required to complete the selected project. To support the achievement of these learning objectives, specific elements, as described above and summarized in Table 1, were strategically selected.

Table 1: Elements Implemented in the Workshop

Element	**Purpose**	**Implementation**
All female cohort	Encourage women to see themselves in this role Avoid intimidation	Event was organized through SWE
Hands on tasks	Gain experience with real world manufacturing techniques	Machining and welding were the chosen focus
Role model	Allow students to self-identify with a future in this field	Female lunchtime speaker
Supportive technicians	Experts with the equipment, ensure safety, support the participants	Recruited four technicians familiar with the facilities to support the workshop, 1:3 ratio between technician and participant

The unique individual-focused activity in an all-female group was an interesting combination, especially involving machining and welding that are traditionally seen as male tasks. As such, it deserved to have some post event evaluation to understand the effect on the female students' feeling of confidence and belonging in hands-on manufacturing and STEM fields as a whole.

Method for Assessment

In order to understand the results of the event and solicit feedback for future events, a survey was given to each participant at the end of the workshop. The survey contained multiple choice response questions to evaluate the value, engagement, content, benefit, and quality of the event, and a series of short answer questions were used to understand the usefulness and results of the event, as well as room to include any suggestions. This survey was adopted from a format that is used by Kettering University's Center for Excellence in Teaching and Learning, with questions created by Dr. Edwin Imasuen, formerly at the Kettering Office of Institutional Effectiveness and Dr. Cindy Finelli, University of Michigan Center for Research on Learning and Teaching in Engineering. A copy of the survey is included in Appendix A. Due to the small sample size, the multiple choice response questions will not be evaluated in this paper. If in the future we run more events, these questions will become more statistically relevant and may be used. All of the participating students signed a release of their survey results on a paper separate from their surveys acknowledging that this information would be used in an ASEE paper at the request of the IRB.

Assessment Data and Results

Table 2: Multiple Choice Responses

	Agree	**No Opinion**	**Disagree**
Value	10	0	0
Engagement	10	0	0
Content	9	1	0
Benefit	10	0	0
Quality	10	0	0

Free Response Answers

What aspect of this event did you find most useful?

- Freshman and Sophomores
  - I found the hands on activity very useful for learning
  - Learning a new skill
  - The hands-on learning. To see and learn for yourself by doing the actual work helped me understand better.
- Juniors
  - Everything! The instructors were awesome and very helpful!
  - Learning how to weld
  - Hands on. They instructed but didn't do anything for us. I learn best this way
- Seniors
  - Working one on one with the technicians in the shop and learning to use and be comfortable with the tools
  - Small groups, very hands-on, individualized teaching was really helpful
  - One on one time with the machines. In machining classes, most of the assignments are group work.

What might you do differently as a result of attending this event?

- Freshman and Sophomores
  - I might add more information of different types of welds, what is a poor weld etc.
  - Nothing
- Juniors
  - Attend more events like this one
  - Make more stuff
  - Feel more confident in future machining work
- Seniors
  - Use some of these techniques in future course projects and my thesis or senior capstone class
  - Better understand how machining works
  - I am more comfortable with the machines. They are much less intimidating, and I am less afraid to make mistakes.

Do you have any suggestions for how we could make this event more useful?

- Freshman and Sophomores
  - This was a pretty good event, I learned something I didn't know anything about and was good at it and I had a good time
  - Do something about waiting time or decrease slots available if people not willing to wait
  - No, I think everything was fine
- Juniors
  - Advertise it more. I only knew about it because I was asked if I wanted to participate
  - Tastier Lunch
- Seniors
  - Have the participants talk about what they are learning during lunch
  - I would've liked to do welding also, perhaps have another event in the future
  - We had uneven station times, so a few of us had to stand around and wait for the machines to be free. Not sure how to alter this.

What additional comments would you like to share? Please use the back of the sheet if necessary.

- Freshman and Sophomores
  - The lab techs were great at teaching us, and letting us do it ourselves.
  - The food was good
- Juniors
  - Today was a lot of fun and I would definitely do it again!
  - Great event
- Seniors
  - Have a shorter presentation during lunch. I did think the speaker was interesting but wanted to get back to my project.
  - I really appreciated SWE hosting this event and allowing me to attend! Thanks for providing lunch and the speaker and everyone who came in to help!
  - I'm pretty proud of what I made. :)

Discussion of Results

Ten students participated in the event. Of the ten students, there were two freshman, one sophomore, three juniors, and three seniors. To obscure the answers of the single sophomore, all underclassmen results were combined together. The results of the multiple choice questionnaire showed that the participants felt that the event was valuable, engaging, beneficial, high quality, and had good content. The results were generally positive with "agree" responses for all respondents in all categories, except for one "no opinion" response in the events content category. These answers, although positive, are not statistically significant due to the small sample size of only ten participants. However, these survey results may be more useful in the future as more of these events are organized and the sample size grows. The results would provide a better understanding of the benefit that the program provides for different grade levels.

Although the sample size was small, the short answer response proved to be enlightening. In their comments the participants confirmed the effectiveness of the clinic for several of our motivations in running this clinic. This section allowed participants to comment on the usefulness of hands-on learning in an individual hands-on project. There was general agreement from the participants that being able to perform the task by themselves with minimal help from the technicians was beneficial. One student noted that the technician were good at "letting us do it ourselves." Another student referenced the machining class at our university, suggesting this event's experience was superior due to the focus on individual work versus the group work. This points to the importance of individual work to the participants. The hands-off teaching approach of the technicians, as well as the small technician-to-student ratio, were seen to be valued throughout the questionnaire responses. The small ratio allowed the students to do more of the projects on their own. In larger groups more of the projects are often done by an instructor due to safety concerns. The small individual work had the desired result to getting the participants to take a more active role in the manufacturing processes being taught.

Another part of our motivation was to decrease the intimidation factor and increase the confidence of the individuals by operating in a single-gendered environment. Its success can be seen in the participants' comments that the event's environment helped to lessen the intimidation they might otherwise have felt. However, whether this was an effect of the lack of male participants or the one-on-one hand on machine time was not made clear in the comment. Another positive finding from the workshop was that the students talked about the pride and confidence that they gained from this activity; these comments included: "Feel more confident in future machining work" and "I'm pretty proud of what I made. :)". The short-response section showed that the participants gained confidence and many said they would either apply their learning in future occasions or even participate in another event like this one. This confidence will help them to better be able to participate in future events and class in ways they might not have felt as comfortable doing before this clinic.

There were also comments in the questionnaire on possible opportunities for improvement. Students had mixed review on the lunch speaker. This was meant to increase the students' feeling of confidence and belonging; however, some students were so excited and engrossed in their project that they felt the speaker took up machining and welding time. The same student also mentioned that her presentation was interesting. The projects in this event was interesting enough on their own that the participants were displeased about changing their focus. One student thought it would be more useful to talk about their projects during lunch. This might be a case of trying to fit too much into one day. The speech by a role model could be added as a separate event in any future efforts. Another downfall, which was faced was that students felt that there was too much waiting time due to the one-on-one instructional nature for many parts of the program or bottle necks at different machines. Other students thought it would be useful to expand advertising of the event to more individuals. The wait time is partially due to the one-on-one instruction needed for many of the projects. The group was limited to maximum twelve participants for four instructors. The hope was to reach as many students as we felt we could safely manage. This balance between reaching as many females as possible while keeping them safe and engaged is a difficult one to reach. Events may need further work in this area.

Overall, the students had a positive view of the event, commenting on a decrease in intimidation

and increase in confidence, pride, and a greater interest in manufacturing technologies. They for the most part liked that small instructor-to-student ratio for its ability to allow for more individual hands-on machine usage; however, some students thought it caused excess wait time or limited the number of students the event could help. Generally, the students became engaged with the activities and all had a positive outlook of the event overall. The machining specialist speaker was seen as interesting, but it took away time from hands-on learning time. This was frustrating to some participants, suggesting it might be beneficial to have the expert presentation outside of future events.

Limitations

While the survey was adapted from a previous instrument, the primary intent of the survey was to gather feedback to improve future events. However, since there was some unique and useful data provided from the small sample, we decided there was value in sharing the data with the engineering education community. In the future, we will add specific questions about the workshop elements and participant attitudes. Additionally, the number of participants in the workshop was limited to ensure a chance for hands on experience and safety, which also limited the number of responses to the survey. We plan to continue to collect data at future events.

Conclusion

The Machining and Welding day event achieved success in increasing the female participants' feeling of confidence when it came to manufacturing processes. After the event, they felt that they could bring these skills with them into future classes, and even into the workplace. As we have seen in past studies, a single-gendered environment lessened the sense of intimidation even when using large and potentially dangerous machinery. The hands-on learning, although not increasing communication skills due to the lack of team work, had a greater impact on the participants' understanding of manufacturing processes as they were forced to learn each part of the process for themselves rather than being able to step back in classes where these technologies are presented in a group-work format. Further study of the effects of individual hands-on learning is needed to help understand how it can affect students' pride and confidence in engineering. Although the group-work in design and manufacturing projects are important, it is also important to consider that they do not create the same sense of learning, especially for females, due to unequal participation.

Going forward, it would be valuable to obtain more data from future workshops. This would give more data to be able to analyze the multiple choice questions' results. This could also give a better way to separate the effects of the single-gendered environment and the individual hands-on learning. Opening up the event to male participants and studying any differences in the event could help studying their affect in a multi-gendered learning environment. Finally, due to safety concerns, we were unable to push this learning opportunity down to high school students. It would be interesting to study the effects of this event on increasing the sense of belonging in engineering to an age group, who is deciding which field to pursue in college.

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Appendix A

Event Title: SWE Machining & Welding Day

Event Date: April 23, 2016

☐ Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Other

Your feedback on this event is appreciated. Please mark the circle that corresponds to your level of agreement with statements # 1-5 and respond to questions 6-9.

#	Statement	Response
1.	**Value**: This event was valuable.	○ Agree ○ No Opinion ○ Disagree
2.	**Engagement**: I felt engaged with the topic and presentation materials.	○ Agree ○ No Opinion ○ Disagree
3.	**Content**: The material covered is useful for academic/ professional growth.	○Agree ○No Opinion ○Disagree
4.	**Benefit**: I would like to attend this or a similar event again.	○Agree ○No Opinion ○Disagree
5.	**Quality**: I would recommend this event to colleagues.	○Agree ○No Opinion ○Disagree

6. What aspects of the event did you find most **useful**?

7. What might you do differently as a **result** of attending this event?

8. Do you have any **suggestions** for how we could make this event more useful?

9. What additional **comments** would you like to share? Please use the back of this sheet as necessary.