Abstract. This paper discusses the ongoing lack of gender equity in architecture - specifically the shortfall of women in design technology - and presents a robotics workshop in the United States as a case study and method to challenge this inequality. The goals of this paper are to 1.) define a research agenda for documenting and understanding gender equity in design technology and 2.) to offer evidence-based strategies from STEM education and this architecture case study for improving the representation of women in this field.

Keywords. Gender; Equality; Women; Feminism; Robotics.

1. Context and Data
It is well documented that women are underrepresented in academic and professional positions that specialize in technology (Corbett and Hill, 2015). As technology becomes increasingly essential to the practice and discipline of architecture, underrepresentation threatens to reduce opportunities for women and the diversity of the workforce. This may have consequences for the quality of design in the built environment. Participation in technology and its reflection of (and possible role in promoting) gender inequality within the profession must be critically examined and countermeasures proposed, tested, and disseminated.

The gender gap in technology is harmful not only to women, but to everyone. According to technology entrepreneur and activist Judith Owigar, women today often see themselves as consumers of technology, rather than its creators. (Newnham, 2016) This has consequences in architecture, when being left behind in technology can limit one’s participation in the design process and access to leadership roles. Within the building profession, design technology is an emerging locus of architectural power: those who control technology have a strong influence upon architectural practice. (Loukissas, 2012)
Acknowledging the scope of the imbalance is difficult because, presently, specific data are not being collected about women’s participation in design technology in architecture, either in practice or in academia. At the moment, the best indications of the gender gap come from other sources of data. For example, in 2014, statistics released by the Association of Collegiate Schools of Architecture found that women comprised slightly more than 40 percent of North American architectural graduates in 2013; 25 percent of designers in the profession; and 18 percent of major design awardees in the 2010s. (ACSA, 2014) However, while the number of women in the profession of architecture has increased, the number of women in the field of design technology appears to be disproportionately small. According to ZweigWhite’s 2013 information technology survey, only 5 percent of technology directors at North American architecture firms are women. (Davis, 2014) An examination by the authors of recent papers from the Association for Computer Aided Design in Architecture (ACADIA) found that, in the years 2010-16, twenty-six percent of all co-authors were women and only eight percent of papers had women as the first or sole author. (Doyle and Senske, 2016) This is well below the representation of women in architecture, but comparable to the gender gap found in other technological fields. (Corbett and Hill, 2015) Unfortunately, there are few other studies focused on this imbalance at the moment. The current understanding of gender in architecture remains limited, as does our understanding of how women access and influence technology.

While there is a lack of data collected about this gender gap in architecture, there is significant STEM (Science, Technology, Engineering, and Math) research on the issue which reveals of the overall state of women in technology as a comparison. STEM data indicates that women are significantly underrepresented in fields similar to technology in architecture, such as computing majors and professions. Women currently earn only 18% of all Computer Science degrees and it is the only STEM major to report a decline in women participation over the last decade. (NCES, 2016) A 2013 report found that just 26% of computing professionals were women – a percentage which is about the same as it was in 1960. (Corbett and Hill, 2015) Collection of this data has been an important step
in helping to highlight and address this issue, though it has not led to gender parity in STEM. To successfully argue for gender equality, detailed and accurate statistics are needed to move beyond anecdotal evidence.

2. Causes

Why does a technology gender gap exist? Research in STEM fields has identified several possible causes which may parallel those in design. These causes may have been inherited by architecture in the transfer of knowledge and technique. In a speech given at the Grace Hopper Celebration of Women in Computing Conference, Susan Wojcicki (CEO of YouTube), proposed two possible reasons women choose not to study computing: they think it is boring and they do not think they would perform well at it. (Wojcicki, 2016) From the outside, working with technology can seem unexciting. Because they lack access to mentoring, clubs, courses, etc. many young women have not had the opportunity to learn firsthand how technology can be creative and empowering. Due to socialization and gender roles, many men begin working with technology from a younger age, which leads to better performance in technology fields in college. Women who are exposed to technology in primary school education are much more likely to participate in STEM majors. (Rogers, 2013) The second reason, concern about performance, manifests as a lack of confidence in one’s abilities and less willingness to attempt new or challenging activities. This may be caused by ‘stereotype threat,’ which is when individuals fear they will confirm a stereotype about a group to which they belong. This has been shown to affect performance and to impact decisions. In this manner, negative stereotypes about women’s performance in math and science are thought to be a factor in the inequality found in computing fields. (Corbett and Hill, 2015)

There is no evidence that women are less capable users or creators of technology. To the contrary, data shows that women have the qualifications and test scores to join STEM-related subjects and perform well when they do. (Fisher and Margolis, 2002) Furthermore, history is filled with great pioneers of computing such as Ada Lovelace, Joan Clark, and Margaret Hamilton who demonstrate women’s capabilities in the field. Ability is not the deciding factor. Many women choose not to study technology because they find its values to be insular and antisocial. They do not feel that a career in technology will allow them to collaborate with other people or make things which create social good. Another aspect of this is the male-centered gamer culture of today that emerged out of early personal computing, which can appear inaccessible to women ‘outsiders.’ As Wojcicki explains, when it comes to technology, many women today feel that they do not belong, and because of this, they do not want to belong. (Wojcicki, 2016) The problems discouraging women from participating in technology are cultural and institutional. Education, which has traditionally held the power to shape culture and produce equality, is part of the solution and redistribution of technology access and authorship.
3. Precedent Workshops

One of the ways that STEM fields address their gender gaps is through the creation of technology workshops. The idea is to create opportunities specifically for women, who may not feel comfortable or encouraged in more traditional settings. For example, Girls Garage is a high school program in Berkley, California where students learn about design and construction through hands-on activities. The founders acknowledged that ‘as female instructors, we recognized that our young girls were not reaching their full potential in the co-ed classroom’. After creating a female-only workshop, 85% of enrolled female participants said they were more interested in STEM fields. (Pilloton, 2017) Girls Who Code is another organization that teaches computer science to 6-12th grade girls. By 2014, 95% of the 3,000 students who completed an intensive Girls Who Code course went on to major in computer science. (Dockterman, 2014) Other STEM workshops, such as the NSF-funded TechBridge camps, led to increased interest in engineering and awareness of green- and electrical-engineering concepts. Compared to control groups, twice as many girls who attended TechBridge camps said they would like to become engineers. (Sammet and Kekelis, 2016) Improving women’s confidence in their abilities and increasing their interest are two ways that workshops can improve the participation of women in technology.

4. Case Study

To begin to address the inequality of women in technology at their institution, the authors developed and taught a workshop in the fall of 2017, entitled *Cyborg Sessions: Women in Robotics*. The term cyborg was used to specifically draw connections between architectural technology scholarship and feminist discourse, specifically the work of scholar Donna Haraway who popularized the term. The cyborg is a hybrid creature, machine and organism, a being of social reality as well as science fiction. As a popular trope of feminist scholarship, the cyborg allows a thing to be “both/and”-a condition that resists the binary nature of computational ones and zeros. Additionally, the cyborg is the integration of human and machine, or a name for what occurs when a robot and human collaborate to produce a creative outcome.

Robots were selected as the primary technology because they represent a form of literal empowerment - allowing women to overcome real and perceived physical limitations that may create, or perpetuate, gender bias. In this context, robots were considered co-authors rather than mere tools or ‘servants’. Through this workshop, the participants identified and pursued methods for investigating the potentials of creative expression via robotics.

The authors looked to a broad range of 21st century feminist discourses about technology to situate the workshop: from techno-feminism to cyber feminism to fourth wave feminism. An important conclusion of the research was an understanding of feminism which does not mean only ‘of and by women’ but looks to a full gradient of potential across a diverse and intersectional set of authors. Additionally, feminist work - that which generates a more just and equal environment - can be produced by authors which do not identify as female. Perhaps
it is a limitation of current language but in the future the term feminism might be used interchangeably with inclusion.

Specifically, the authors drew inspiration from a term they introduced at the 2017 ACADIA conference: Computational Feminism, which is an evolution of feminism and a reaction to the gender biases present in most technologically-focused work found in architecture today. (Doyle et al, 2017) The objectives of Computational Feminism are 1) exploring the full gradient of possibilities technologies offers 2.) enhancing the subjective and intuitive as a counterpoint to methods and devices that have control as a mechanism or goal and 3.) the exploration and production of joy and pleasure as opposed to economies of optimization and bravado expressions of virtuosity. A key provocation of this workshop - which elevated it above merely learning to code for its own sake - was the question of how making with robots can represent a perspective and process that is female. The vehicle for the students’ investigations were the traditions of drawing and painting - with their histories, conventions, and agendas - which served as the interface between the roboticist and robot.

4.1. OVERVIEW

The Cyborg Sessions workshop met once per week over six weeks in the fall of 2017. It was taught by three faculty and three student workers from the Iowa State University Computation and Construction Lab (CCL). There were twenty-one student participants (undergraduates and graduates) from six different majors: Architecture, Graphic Design, Electrical Engineering, Industrial Design, Integrated Studio Arts, and Chemical Engineering. Although, the workshop was advertised for women and women received first priority for attendance, it was not exclusively offered to women. Five men attended the workshop. However, women remained the majority participants (76%).

Figure 2. Left - Turtle robots drawing patterns with loops and variables. Right a Turtle robot and Braccio Arm. Photo by authors.

The workshop consisted of two three-week projects followed by a public lecture and exhibition. Each week, the students met in the CCL to hear lectures about women in technology, computer programming, and robotics. Then they
worked with partners to operate their robots and make their drawings and paintings. At the end of each session, the students met to discuss their work and prepare for the following week. Students did not work on their projects outside of the weekly sessions.

4.2. PROJECT 1: “PLAYING TURTLE”

The authors were concerned that gender stereotypes would continue to play a role in the workshop. Thus, the first project began with a discussion about the challenges of gender inequality as experienced by women in technology. This was important because it framed the workshop as not just learning to make things with robots but doing so as a method for building a culture of engaging with these technologies through design. The students’ concerns were different. While they were excited for the opportunity to learn about programming and robotics, in a pre-class survey 75% of them reported some form of apprehension or anxiety about their potential performance in the workshop. Understanding and addressing student expectations is a critical to helping students get the most from these events.

For their first project, students learned the basic syntax and logic of computer programming while becoming comfortable with the rhythms of making through cycles of writing, compiling, and testing their code. The vehicle for their experimentation is a class of robot called a “Turtle.” These low-cost robots were assembled by the CCL staff from in-house 3D printed parts, electronics purchased online, and open source Arduino code. (Olsen, 2015) The focus of the first project was to gain confidence with the technology while interrogating the potentials of drawing. This blend of the unfamiliar and familiar allowed the designers to reflect upon how drawing with a robot is different from drawing with the hand and how their pre-judgements about code affected their strategies.

Turtles appeared to be an ideal first robot for this group. A classic pedagogical tool created by Seymour Papert at MIT, they were designed to teach children how to think computationally. Turtles have a “head” and “tail” and use simple instructions to move around a surface on two wheels while leaving a trail behind them with a marker. Students learn to program a Turtle by pretending to “be” the Turtle, connecting their sense of their own body in space with that of the robot’s. Thus, “playing turtle” is a profound way to bridge human and machine in the fundamental design act of drawing. (Papert, 1986)

The students quickly engaged with the Turtle robots and their code. One of the first things they discovered was that each Turtle had its own “personality” with its unique mechanical calibration, such as moving faster or turning more accurately. This led to students giving them names and talking with their robots as they worked. Another interesting finding was that the relatively slow speed of the Turtles forced students to be more disciplined and thoughtful in their approaches. The immediate feedback loops found in design software - which students are used to experiencing - were not there. Students would often express surprise at the slowly emerging designs from their code. Oftentimes, if there were bugs in the code, they were more likely to allow the robot to finish and to observe the process rather than immediately starting over. As time went on, they began to incorporate ideas from buggy code into their compositions.
The first code students started with involved letters, shapes, and other forms that students tried to translate into Turtle drawings. Translation was a useful beginning exercise because it allowed the instructors and students to debug initial problems and misunderstandings with hardware and syntax. These misunderstandings proved to be teaching opportunities as well. Once students could reliably create forms, they were free to move on to more complex algorithms with randomness, looping, and recursion. They began to create more sophisticated compositions with code as well as different physical interventions with the Turtles: different markers, taped areas, borders, etc. Each student group created three final drawings for exhibition.

4.3. PROJECT 2: “DANCES WITH ROBOTS”

The objectives of the second project were to further develop confidence with robotics and to move away from the precision of drawing to the indeterminacy and expressiveness of painting. For this project, students used Tinkerkit Braccio robotic arms. These are low-cost kits that feature a 4-axis arm with a gripper attachment. CCL instructors and staff pre-assembled the arms, attached foam brushes to the grippers, and constructed a base for each robot that held a canvas and locations for acrylic paint. The code for the Braccio robots was written in Arduino and allowed for individual movements of each axis.

The experience with the Braccio arms was markedly different from the Turtle robots. First, the arms could be intimidating as they moved quickly and close to the participants’ bodies - sometimes flinging paint in their direction. Second, the arms did not have an inverse kinematics (IK) library, so fine control and initiating loops and other algorithms was more difficult than with the Turtles. A research assistant programmed a macro script that allowed students to record a series of steps, and this helped. However, without the IK library, applying continuous strokes to the flat canvas was difficult because the robot was configured to move in a circle.
Students found that the brushes would not stay on the canvas and sometimes would detach from the gripper. While the cycle of coding, compiling, and running their code remained the same, the number of variables with the equipment increased. The students came to expect a degree of precision with the Turtle robots and this experience challenged their perception.

Fortunately, the students persevered and taught themselves different methods of working with the robots to achieve their ideas. Some of them changed their painting styles, limiting them to smaller areas of the canvas or moving the canvas after each series of strokes. Mixing the paint colors on the canvas and loading the brush with multiple colors were other ways that the students took advantage of the medium to create different, indeterminate effects. Learning to negotiate with the robots was an unexpected challenge, but resulted in work that was spontaneous and expressive; closer to the attributes of Computational Feminism than the Turtle experiments. Rather than merely using the robots to execute instructions, the “play” in the system and differences in their approaches made each students’ work unique.

5. Methodology

In addition to teaching students about computing and robotics, the authors were interested in understanding the impact of the workshop upon the attendees’ self-perception and their overall perceptions of women in technology in architecture. To study this, the authors created two rounds of surveys, which were administered online and anonymously, to measure the changes in student attitudes and beliefs in response to their workshop experience. The pre-class survey recorded data from sixteen students (12 female). Thirteen students completed the post-class survey (9 female).

6. Analysis

The authors found that students’ confidence in their technological abilities grew following the workshop. Of the initial surveyed students, 94% of students initially said they were a little confident, not confident, or unsure about programming. 82% said they were a little confident, not confident, or unsure in their ability to work with robots. Following the workshop, nearly 50% of students surveyed reported they were confident or very confident in their abilities with computer programming and robotics. Only one student reported they were not confident or unsure. The survey instrument did not determine the source of the students’ lack of confidence - whether it was from a perceived stigma about performance (such inherited bias from computing or ‘stereotype threat’ (Corbett and Hill, 2015)) or from other personal anxieties. In future workshops, we hope to study this further.

A majority of the students, regardless of gender, changed some of their attitudes about women’s relationship to technology. Before the workshop, about half of our students (46%) surveyed felt there were no gender differences in people’s ability to learn and use technology; one-third were unsure. Following the workshop, no students were unsure and 82% of those survey felt there were no differences.

All the students attending the workshop reported that they would be more likely
to take advanced technology courses (robotics, programming, digital fabrication, etc.) in the future. 73% of students said they would work again with the robots on their own. All the students who responded to the question “Do you feel that events like our workshop are an effective way of improving gender parity in your field?” agreed workshops were effective.

A potential issue with the survey methodology is that the anonymous format makes it difficult to determine how the gender of the participant affected their answers. In light of the STEM reports from all-women workshops, it would be useful see if a single-gendered demographics would result in different data for an architecture workshop. However, the overall trends for the workshop in the case study - which are statistically significant - are positive. These findings compare favorably with the results of other STEM workshops and suggest that events like Cyborg Sessions can serve as means of facilitating gender equity in technology.

7. Discussion

From the case study, it appears that workshops like Cyborg Sessions are one way to address gender equity in design technology by providing a supportive environment and opportunities for women. This paper proposes a research agenda aimed at describing and correcting the gender gap, but there are many remaining questions to be answered.

One issue is that specific data are not being collected about technology and gender in architectural practice or in academia. Determining the meaning of participation with respect to technology is a challenge which prevents accurate measurement. Participation is a nuanced and ill-defined measure, even in architecture, but must be addressed if we are to understand and convey the true scope of the issue. Data collection efforts from STEM fields could serve as a model.

Another important strategy for addressing the gender gap is to highlight successful women in technology. Many of our students cited their time with Madeline Gannon as their favorite part of the event and the moment when the ideas of the workshop most connected with them. A lack of women role models is a known issue in STEM. Studies have shown that when students are exposed to histories of women in technology, it reduces stereotyping and bias and encourages women to enter the field. (Corbett and Hill, 2015)

8. Conclusion

Within the discipline, digital technology is an emerging site of architectural influence. This topic matters because architecture is imbued with values and ideas that both reflect and exert tremendous influence over the patterns and quality of our lives. This paper described some initial data on gender inequalities and introduced STEM research on the scope and causes of the problem. The authors’ case study of a Women in Robotics workshop applied the model of a STEM women’s workshop to a group of undergraduate and graduate designers. Surveys of the twenty-one multi-disciplinary participants indicated that the workshop improved confidence in their abilities, encouraged them to pursue more technology, and reduced their
stereotypes about women in technology.

STEM workshop models were not directly replicated but rather adapted to the design-specific contexts through the use of creative design outcomes via technology: drawing and painting. By presenting robotic technology as a creative medium, rather than a tool of efficiency its application to design potentials became more legible to the students. What remains to be seen is whether these strategies can be scaled and applied to curricula and practice.

The authors hope that other institutions and individuals will find our examples useful and take up the charge to develop this work further. Improving gender equity in technology access and authorship will improve education and design by embracing the full gradient of possibilities for design technology.

References


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