Playful Computer Science for Girl Scout Juniors

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***Abstract*—It is widely recognized that play is an important part of the learning process for children. There is also a nation-wide gender gap in the fields of computer science and engineering. One identified reason for this gap is a lack of positive exposure to STEM activities for young girls. This paper explores workshops aimed at addressing the gender gap by leveraging playfulness. Specifically, two computer science workshops were deployed for young girls in fourth and fifth grade as part of a larger Girl Scouts of America initiative. These workshops embrace playfulness as a fundamental design constraint to ensure an early positive association with STEM concepts. Students are exposed to basic coding skills through simple robots that are programmed to play games. Survey results show that these workshops lead to a stronger interest in CS for the participants.**

Keywords—Playfulness, CS in Early Age Group, Gender Gap

I. Introduction

"CS for All" is an initiative to present computer science (CS) theories and practices to all K-12 students in order to give them computational thinking skills that will strengthen their digital literacy. However, computing courses for K-12 students are still under development with many high schools continuing to teach standard office software suites in their "computer science" courses [1]. Extensive research shows that most underrepresented student groups do not have access to learning environments that promote future science, technology, engineering, and mathematics (STEM) careers through scientific experimentation or other hands-on activities [2-5]. Furthermore, there is a significant and well-studied gender gap in CS and engineering fields [6,7]. It is crucial that all students are exposed to high quality and impactful STEM experiences to overcome these ongoing inequities. Educators, education administrators, individuals, and decision-makers in the United States and around the world are searching for the best methods to do exactly that.

Women obtain 37% of undergraduate STEM degrees in the United States. The distribution is uneven among STEM disciplines. Women receive more than 50% of undergraduate degrees in biology, chemistry, and mathematics. On the other hand, they obtain less than 20% of undergraduate degrees in CS, engineering, and physics [8]. Much of this difference can be attributed to a lesser overall interest in CS, engineering, and physics that occurs well before young women enter college. It is imperative that this issue be addressed by educators and practitioners alike. Career opportunities in STEM fields are projected to continue growing over the next couple of decades. Unless the situation changes, these fields will continue to be male-dominated to the detriment of all. This work is focused specifically on decreasing the gender gap in CS and engineering by building targeted programs for young girls that coincide with their other interests.

Engagement at an early age is vital to future motivation and learning. The introduction of and exposure to domain-specific environments will help learners to broaden their recognition of various disciplines, following the constructionist approach [9]. The current flood of information demands that every individual learner's own construction of knowledge occurs within a context where he or she is already engaged. Previous experience and a sense of being within a community are related to participation decisions in general. This certainly extends to interest in computing and/or engineering subjects. As such, this effort is focused on the design of playful and engaging CS workshops for K-12 female students.

The use of robotics for educational purposes has increased remarkably in recent years. Eguchi [10] reported that educational robotics as learning tools has promoted college students' 21st century skills – collaboration, communication, creative thinking, and critical thinking skills. Research has shown that educational robotics is an effective learning tool for various contents areas such as physics, geography, and mathematics [10-13], as well as other crucial skills including reading, writing, critical thinking, and problem solving. The positive effects of educational robotics are due, in large part, to the development of learning environments that are fun and engaging [10-12].

In conjunction with the Girl Scouts of Eastern Massachusetts, we have developed and offered two playful CS workshops in coding and robotics for girl scout juniors. These programs are designed to give the students a chance to explore broader computational thinking through a playful coding and robotics experience, with no prior knowledge of the field required. The rest of this paper is organized as follows. In Section II, we introduce playfulness related research and the four main factors for playfulness: peer-work, personalization, construction, and play. In Section III, we present our playful CS workshops in detail. By integrating robot-playing games with simple block coding, we developed a beginner-friendly and playful learning environment. In Section IV, we share our findings from anonymous survey results. Finally, Section V presents our conclusions and final thoughts.

II. Playfulness

Many public K-12 schools, which are often evaluated by the results of high-stakes testing, have adopted a drill-and-practice approach to education in the hopes of better academic performance in their classroom. It is difficult for educators to prepare young people to develop creative and innovative ideas in this era of standardized curriculum. Unfortunately, this has also made it more difficult for most young people to associate fun with the process of learning. Creativity and innovation are critical skills in any STEM field, and they are also highly correlated with fun and enjoyment. Playfulness is at once both an obvious part of learning and something that is often overlooked or dismissed in formal education settings. Playfulness in education is about aligning natural positive emotions with our intrinsic motivation to learn. This includes designing learning activities that embrace playfulness as a fundamental component of the process. Young children begin to learn their culture through play from the beginning of their lives. Formal education should be no different.

Playfulness as an intrinsic personal character: Scholars have long studied playfulness as one of the characteristics of a well-rounded person. Moreover, play is commonly found to be a successful learning medium, particularly in science, mathematics, and engineering [14,15]. Liberman [14] conceptualized playfulness through observations of the play activities of young children. He identified the five central traits of playfulness as physical spontaneity, social spontaneity, cognitive spontaneity, sense of humor, and manifest joy. Liberman emphasized the importance of playfulness not only as an individual psychological concept for young people but also in its influence on everyday living. Barnett [16] adopted Liberman's five traits of playfulness and extended the associated measurement instruments into 23 items to measure the frequency with which a child expressed a certain characteristic during play. He defined playfulness as an intrinsic desire to play and a positive attitude driving a child to participate in playful activities. Holmes and Geiger [17] characterized playfulness as the student's internal predisposition to be playful.

Creativity and playfulness: Early research into playfulness and childhood education found that creative and highly intelligent adolescents demonstrated more playfulness in many activities. Wallach and Kogan [18] found that fifth graders who were identified as highly creative and intelligent presented more creativity in certain interpretation activities with stick figures. Chang [19] asserted that playfulness has a positive correlation with creativity when studying a sample of 321 junior high school students, who were high achievers in mathematics and science. Students are more engaged when having fun than when presented with easy and boring activities. Playfulness has a stronger positive correlation with engagement and sustained student interest, as compared to the difficulty of the task [17,19].

Our approach to playfulness: Playfulness in CS activities for beginners is a crucial element to promote positive initial interest in STEM areas and careers. We approach playfulness not only as an individual's inherent merry feeling but also as an element of activities which are amusing and/or enjoyable. Playfulness in any activity is one important element contributing to the ongoing motivation and interest in that activity. Workshops should therefore be designed with an emphasis on elements that allow children to have fun. In other words, fun should be a first-class concern during the design of the workshop rather than a secondary item to be considered after the material itself has been developed. The factors for playfulness and a feeling of fun are: peer-work, personalization, construction, and play.

A. Peer-work

People of all ages are generally interested in what others are doing, as well as in interacting with them. Indeed, society requires collaborative effort and collective action. Resnick [20] reflected on how the Computer Clubhouse got shifted from think-it-yourself to make-it-together. His team began in 1993 with a local version of collaboration. Young people worked together side by side at their Computer Clubhouse within the same physical location. He reported in [20] that by 2017 the Clubhouse Village, an online community, included more than 100 Clubhouses in 20 countries. New technologies affected the types of possible collaboration. Scratch [21] is a programming language and online environment which Resnick and his colleagues developed as space to create, share, work, and learn with others. Peer interactions, especially in computer supported collaborative learning (CSCL) may better serve future generations who are digital-native.

B. Personalization

Many students initially find STEM subjects to be impersonal and irrelevant to their daily lives. The Board on Science Education (BOSE) has developed core ideas to guide and inform a new framework that established essential scientific practices and concepts for students to master. One of those criteria states that concepts must "relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge" [22]. Sadler [23] asserted the importance of humanistic approaches and situated learning in science education. He indicated that situated learning is essential to the learning process in the science realm.

Learners are most engaged with activities when they are interested in and passionate about the topic and context. Professionals in STEM fields reported that their experiences playing games were consistently enjoyable and ultimately benefited their constructive and creative skills [15]. Each individual has different needs and preferences. Each would prefer to do their own projects based on their interest. A goal of this work is for the students to leave with enjoyable memories of the robot activities. For example, students can name and decorate their robots to personalize the experience and make a stronger positive connection to the learning that happens during the workshop.

C. Construction

Students like to build, make, and do hands-on activities far more than traditional instructional teaching. Papert [24] believed that children would build a more robust understanding through personal construction of knowledge linked to their own previous knowledge. Papert perceived education as promoting bricolage, or constructing new things out of something available, i.e., children's prior experience or knowledge. People experience the most valuable and impactful learning when they are "actively engaged in designing, building, or creating something – learning through making" [20, p. 36]. Young people can design and program their own stories with Scratch. This can be done either as an individual and novel project or by remixing work from another. Ness and Farenga [25] highlighted how unstructured play with blocks contributed to developing young people's spatial and geometric thinking. They further investigated the relation between spatial and geometric thinking and architectural principles. They provided spatial, geometric, and architectural coding systems as guidelines to observe and examine how children's behaviors are mathematical and scientific during block building play.

D. Play

Ancient Greek texts interpret "play" as the opposite of "work". Play has often been intrinsically regarded for children from ancient times through modern days. Plato considered how play can affect the way young people grow into adults. He proposed to regulate young people's play emphasizing its importance for social stability. Plato's utilitarian approach to harness play was intended to prevent social disorder by restricting children's play with rules and conditions. However, Plato also recognized the educational aspects of play. Play is primarily irrational. The rules, objects, and rituals of play are typically less intentional and purposeful [26]. Gee [27] argues that play is powerful in early learning because play frees people from the worry of failure, allows people to take risks, and encourages people to try new ways. Failure is also a critical part of learning, but failures are far less demotivating when students are having fun during those failures. Children have fun when they play and "mess around".

TABLE I. GSEM Program

	2018 Workshop Descriptions	2019 Workshop Descriptions
Computer Science	***Robot Soccer Game:*** We will build a robot with the Scratch programming language. After learning how to move the robot, we will play a robot soccer game.	***Treasure Hunting Game:*** A line follower robot is an automated guided vehicle, which follows a visual line embedded on the floor. After learning how to make your robot move along the black line on the floor, we will play a treasure hunting game.
Mechanical Engineering	***Engineering Machine Products:*** Learn how to use a Computer Numerically Controlled engine lathe. Assist in the operation of the equipment to shape a small aluminum bowling pin.	***Manufacturing Center Experience:*** The lab will finish with a hands-on demonstration of a Computer Numerically Controlled lathe. Each attendee will get to keep the part that they make while assisting the lathe operators during the demonstrations.
Science	***Liver Enzyme Action:*** We will be investigating the impact of artificial sweeteners on the rate of fermentation by measuring the change in carbon dioxide production as compared to that produced using a simple sugar in Saccharomyces cerevisiae (baker's yeast).	***Cabbage chemistry:*** We will make predictions about the acid/base characteristics of common household foods and items based on their properties. Using our cabbage indicator we will test our predictions.
Electrical Engineering	***Hand-to-Eye:*** Tests one's ability of hand -to-eye steadiness and accuracy. The challenger that transverses the greatest length or wire without electrical contact is the winner.	***LED Dexterity Challenge:*** Girl Scouts will learn how to use a 555 timer in an alternate switching mode of operation while driving two LED flashers. They will learn how to vary the "blink rate" of the flasher and simulate its operation in Multisim.
Biomedical Engineering	***Measuring Body Signals:*** The activity will record and graph EMG signals from a volunteer. The students will build the circuit, modify the computer program, and test the function of the system.	***EMG and Force signals:*** This lab activity will record both the EMG and force signals of muscles. These signals will be used to control actuators (motor or light). Such a system could be used to help a disabled person control devices in their vicinity.

III. Playful CS workshops

The Girl Scouts of Eastern Massachusetts operate the Girl Scouts Engineering Magic (GSEM) program annually for girl scout juniors (grades 4-5 or ages 9-11) [28]. Wentworth Institute of Technology (WIT) and the Society of Women Engineers (SWE) have hosted five science and engineering workshops for GSEM program since 2014. The GSEM program is part of the Girl Scouts' *"fun with purpose"* K-12 curriculum. This initiative introduces girl scouts of all ages to STEM with a goal of inspiring them to embrace and celebrate scientific discovery and, according to the Girl Scouts of America website, "help them see how they can actually improve the world." Between 60 and 80 girl scouts have participated annually in these five WIT/SWE STEM-related workshops, which are offered by CS, Mechanical Engineering, Science, Electrical Engineering, and Biomedical Engineering professors. Each workshop runs five times for five different girl scout groups (12-16 girl scouts per session). Table 1 shows the five different workshop descriptions from 2018 and 2019. In this paper, we introduce our two playful CS workshops (Robot Soccer Game and Treasure Hunting Game) that represent ongoing efforts to interest young women in STEM broadly and CS in particular.

A. Workshop 1: Robot Soccer Game

The first workshop has the students programming robots to play soccer. mBot robots are used along with the Scratch programming language. The mBot robot is an educational Arduino robot developed for K-12 students [29]. Novice programmers can use a block-style, drag and drop graphical programming environment called mBlock to control the mBot in a user-friendly and simple way [30]. Each block represents a single mBot action such as moving, sensing, making a sound, or displaying a graphic. It is possible to create programs with decision-making statements, loops, and subroutines.

Peer-work: Students completed this workshop in pairs (with one potential group of three if the number of participants was odd). Each team was provided one laptop and one mBot robot of participants. Students were actively engaged with various discussions and programming attempts by working as a team. This also promoted a more sustained interest in the programming activity, particularly when one of the students was struggling with the concepts or programming interface.

Personalization: Each student team was asked to give a name to their robot before they began working with it. They were also provided with a few craft items to decorate their mBot. The girls talked animatedly with each other to decide on their robot's name. This helped to start the entire activity with a strong sense of fun before diving into the programming. In many cases, the pair of girls did not know each other well before the activity started. An unexpected outcome of the naming decision was that these pairs were given a chance to get to know each other quickly, sharing some of their own personality with each other and building a positive relationship from the start. Then they decorated their robot with the provided craft materials. This led the students to be more engaged all around. Each team started the programming portion of the workshop by naming their mBot in their programs, tying the established fun to the next step of the activity.

Construction: In this workshop, the students can easily build a soccer-playing robot by using only simple drag and drop blocks in mBlock. Figure 1 shows sample mBot soccer robot code. The easiest soccer robot design can be accomplished with only 11 Scratch blocks. The design is as simple as possible. That simplicity motivates these beginners to be engaged in developing their own programming code

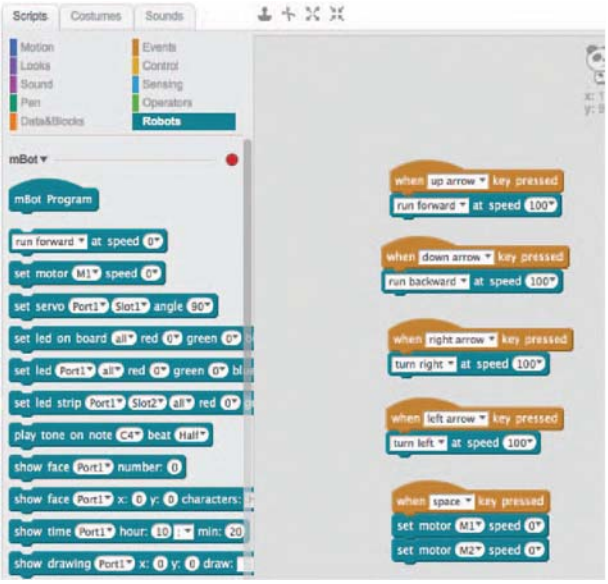

Fig. 1. mBlock code of mBot Soccer Robot

with a minimum of background and in a short time frame. It also ensures that a high level of playfulness is maintained throughout the workshop.

Bluetooth was used to link the laptop to the mBot robot. By sending keyboard signals from the laptop to robot, the girls can control the robot by moving it in different directions. The robots are therefore not fully automated. The girls actively control the robots themselves when playing soccer.

Play: Figure 2 shows how the robot soccer game looks in action. There were two separate soccer fields to allow two simultaneous games. Depending on the number of student teams, either two or three teams were asked to play on each side of the soccer match. The teams were given five minutes to test their initial programming blocks, then were asked to modify their programming blocks and/or parameters used in those blocks. After another five minutes of testing, the teams played two or three ten-minute soccer matches. The girl scouts were very excited initially to make their robots move at their instruction. The excitement level increased further when the soccer games began. They actively discussed and modified their programming blocks and values to make their robots faster and more competitive. Even though only one team member at a time could control their robot via the Bluetooth connection, all other team members were engaged with the game play. Loud cheers accompanied team successes throughout every match, reinforcing both good programming and the fun atmosphere throughout the workshop.

B. *Workshop 2: Treasure Hunting Game*

The first workshop was built for girls who had no prior exposure to CS and programming ideas. As the GSEM program continued to be successful, some fifth grade girl scouts came back for a second year after attending during fourth grade. This necessitated a second and more complex workshop for those with more experience. The first workshop was made with simplicity and real-time robot control in mind. The second was therefore developed to introduce sensors, algorithmic thinking, and autonomous robotics. Playfulness and fun were still core design principles and so the workshop

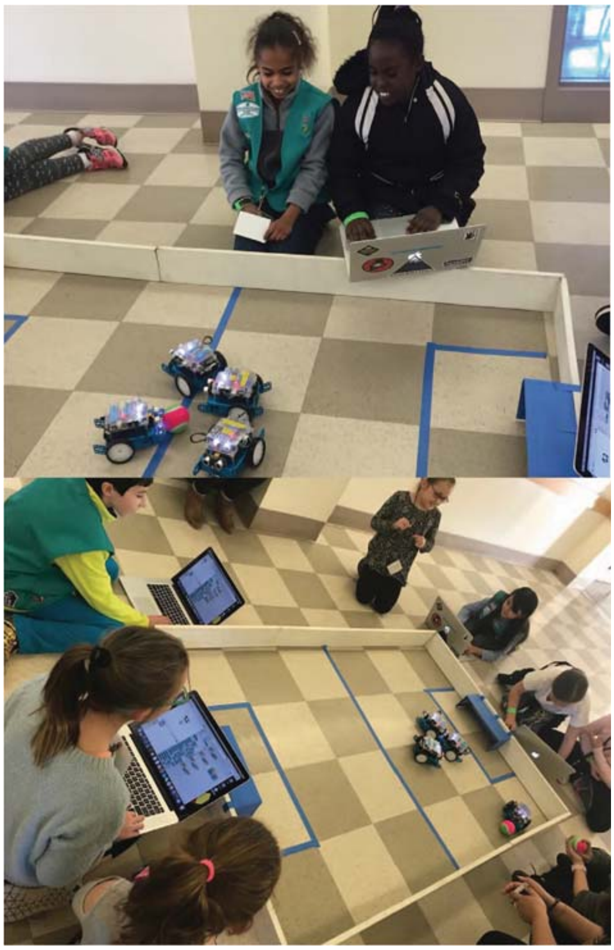

Fig. 2. mBot Robot Soccer Game in Action

was built around a treasure hunting game with a line follower sensor on the robot. The students were first shown how the sensor works. Then, the group works together to develop a set of rules (that is, an algorithm) to make a line follower robot.

This workshop also provided one laptop and one mBot robot to each team. Each team similarly gave a name to their robot and decorated it as part of personalization. The comments for peer-work and personalization for the first workshop above apply here as well.

Construction: The students first spent some time to learn the basics of the line follower sensor including what values are sent to the robot for different sensor states. All of the students then worked together to build the rules to make a line follower robot. As shown in Figure 3, the rules are simple enough to

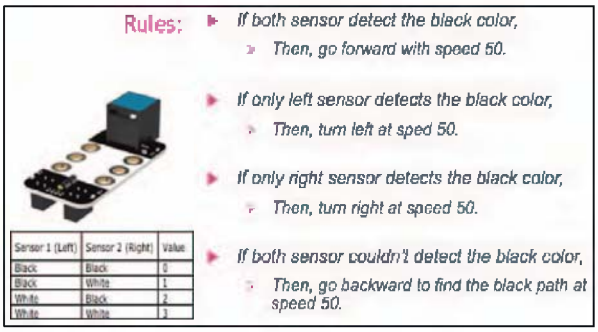

Fig. 3. Rules for a Line Follower Robot

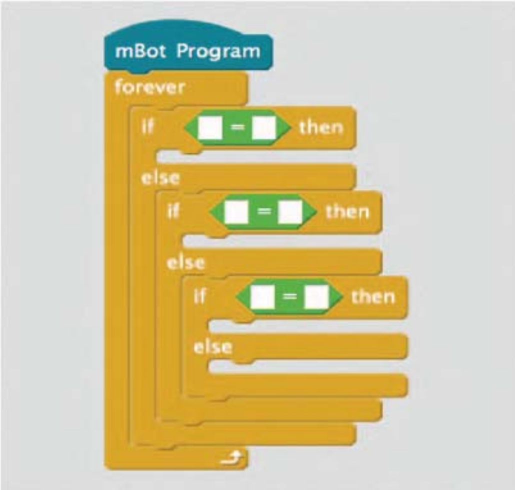

Fig. 4. Skeleton for a Line Follower Robot

allow every student to follow along but complicated enough to require careful thought. The students were then provided with the skeleton Scratch blocks shown in Figure 4 so that they could be introduced quickly and simply to selection and repetition structures. Finally, the students were ready to implement their rules by simply dragging and dropping the programming blocks and filling in a few values. Figure 5 shows how to upload mBlock code to the mBot/Arduino robot. After simple testing with a small individual map as shown in Figure 6, students applied different speeds to find the best solution to find treasure on a larger map as shown in Figure 7.

Play: A black line map (8x8 feet) was drawn on the floor. At most eight robots played together on the large shared map. The same general timing structure was used as in the first workshop. Each team had five minutes to test their initial programming choices and were then asked to make any modifications based on their observations. They were then given a second five minute testing round before moving on to the large shared map to play the treasure hunting game two or three times. Various treasures were placed on the map such as small snacks/candy, game cards, etc. This motivated the girls to make their robot navigation programs as strong as they could. The excitement level was high throughout with happy exclamations when the robot made a correct turn and laughter

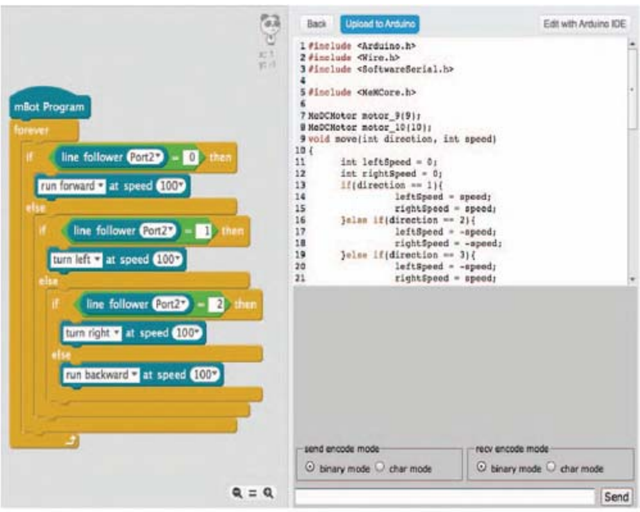

Fig. 5. Uploading mBlock Code to an mBot Robot

Fig. 6. Individual Testing Map for a Line Follower Robot

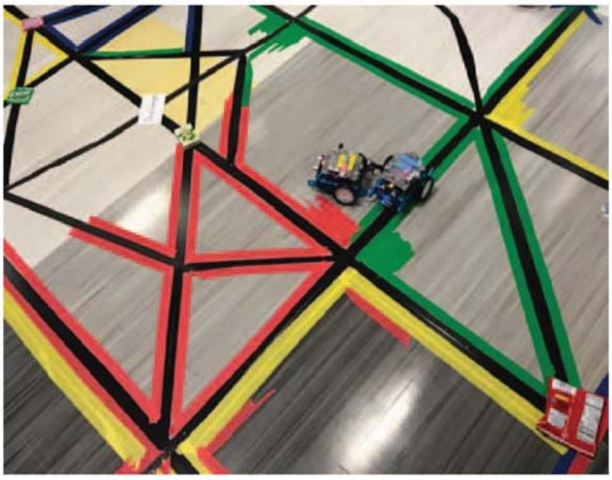

Fig. 7. Hunting Treasure in Action

when the robot went entirely the wrong way. The rapid feedback led to lots of team discussions, quick solution generation, and testing. The difficultly level is higher than in workshop one, but the playfulness helped ensure that failures were met with laughter rather than frustration.

IV. Results

Anonymous surveys were conducted for students who participated in the CS workshops in 2018 and 2019. 78 students participated in the survey in 2018, and 65 students participated in 2019.

39.74% of participants (31 out of 78) in 2018 and 41.54% of participants (27 out of 65) in 2019 did not have any previous coding experience whereas 43.59% of participants (34 out of 78) in 2018 and 47.69% of participants (31 out of 65) in 2019 had previous coding experience. Other answers included that they did not know or couldn't remember if they had any previous coding experience. The critical question was to determine whether or not the workshops made an impact on the participants' interest level in CS. Each participant was asked to self-report their level of interest in CS and technology and if they wanted to study CS and technology in the future, compared to how they felt before the workshop. Figures 8 and 9 show the results for 2018 and 2019 respectively. In 2018, 84.61% of participants responded that they felt more

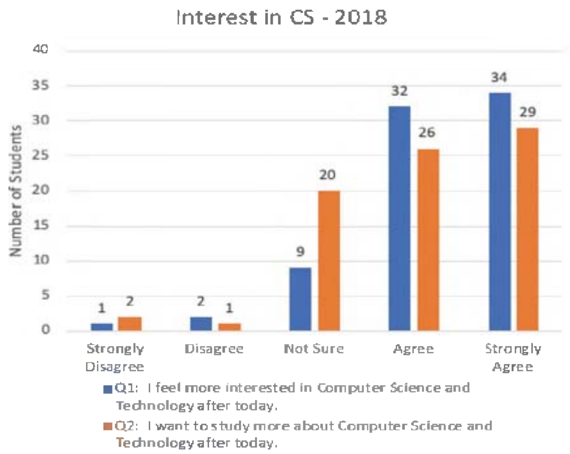

Fig. 8. Interest in CS after 2018 Workshop

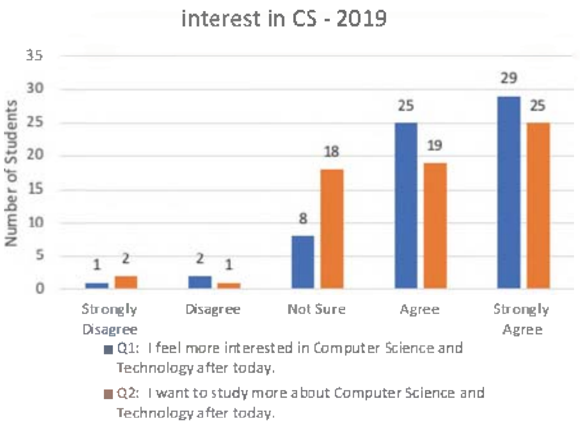

Fig. 9. Interest in CS after 2019 Workshop

interested in Computer Science and technology after the workshop experience, with 34 strongly agreeing and 32 agreeing. In 2019, 83.08% responded similarly, with 29 strongly agreeing and 25 agreeing. 11.54% of participants (9 students) in 2018 and 12.31% of participants (8 students) in 2019 were not sure whether they felt more interested in CS and technology. Interestingly, more than one quarter of participants responded that they were not sure whether they wanted to study more about CS and technology in the future. It is unclear why there is a significant discrepancy between the results for these two questions.

Almost three quarters of participants in both years (Agree: 30.76% in 2018 and 36.92% in 2019, Strongly Agree: 43.59% in 2018 and 36.92% in 2019) expressed a desire to continue working in teams to solve problems. Figure 10 shows the results for both years. Participants expressed their enjoyment of discussions, test runs, and solutions during the workshops. Students were more engaged in coding and trial runs with the robots through discussion with teammates. For example, in the treasure hunting workshop, once they saw the robot moving on the path correctly, they next started to discuss the speed of the robot and what parts of the code they would have to change to increase the time to finding treasure.

Every student was able to complete the block coding activities to make the robot play soccer or follow a line successfully. Each team uploaded their program to their named robot then tested how their robot functioned. Although

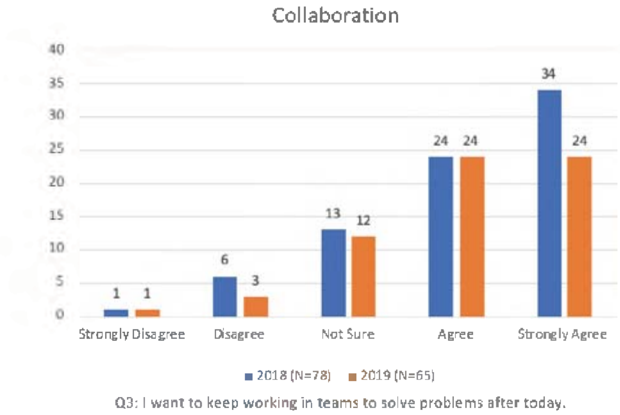

Fig. 10. Collaboration

time was short during these workshops, students were able to experience a new dynamic learning environment through trial and error. This is a fundamental problem-solving skill applicable widely as a person. Using tangible objects including robots, sensors, and wires provided a stronger construction experience than a more traditional programming/software-only learning activity. The student responses were mostly excited ones such as "Wow, it moves!" and "We did it!". The successful movement of their robot led them to feel fun, excitement, confidence, and a genuine sense of teamwork. More than 80 percent (Agree: 28.20% in 2018 and 24.62% in 2019, Strongly agree: 53.84% in 2018 and 56.92% in 2019) of participants wanted to keep working with robots in the future. Figure 11 shows the participants' desire to work with robots in the future.

Integrating robots with coding leads to a dynamic and playful learning environment. A few volunteer assistants commented that they felt more comfortable with the workshop environments as not being only about "geek boys". We certainly do not advocate for girls-only activities in standard classrooms, nor do we suggest that that female-only teams are superior. However, during the workshops, we did hear from both the students and the volunteers that there are ongoing gender-based stereotypical situations in their day-to-day learning environments. The students felt much more comfortable during the workshops where such negative behaviors were absent. Providing more opportunities for learners of all genders to explore and experiment in freedom may ultimately lead to a reduced gender gap in CS and engineering fields.

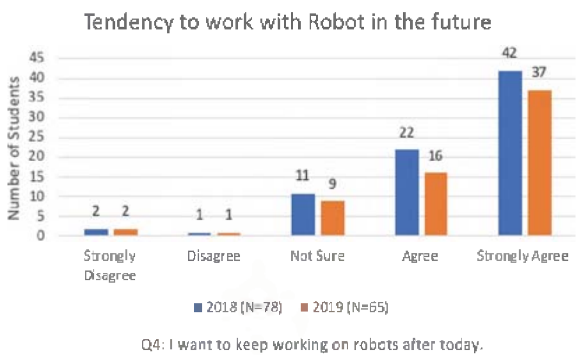

Fig. 11. Student's Tendency to Work with Robots in the Future

V. Conclusion & Future Work

Closing the gender gap and increasing the number of women in CS and engineering is crucial to building an equitable future for all. Doing so will require a significant societal shift in K-12 education, higher education, the private sector, and the public sector. Such shifts, however, are ultimately accomplished by encouraging one person at a time. The workshops described in this paper were developed over several years as part of a larger Girl Scouts of America initiative. It is the hope of the authors that workshops and techniques like those presented will be beneficial to the larger educational ecosystem and encourage others to pursue similar efforts in their own communities. The more important and immediate result is that these workshops have already positively impacted the lives of several young women who are now more likely to utilize CS in the future.

Looking ahead, this work will be extended to address other related issues in STEM fields. Women are not the only underrepresented groups in CS and engineering. The clear next step is to adapt the workshops for these additional groups. This should include looking for partners similar to the Girl Scouts of America that can leverage existing outreach and/or extracurricular activities to expose a broader and more diverse audience to CS through playfulness. For example, the authors' local communities include many Latinx students. Subtle changes can be made to the workshops to ensure that this population of students would have the same fun and engaging experience as the girl scouts did. Local K-12 schools or other professional societies that are already providing positive STEM reinforcement would make ideal partners for these workshops. The long-term goal is to reach every student on their own terms through play, to ensure that every possible future is open to them.

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