Engaging Upper Elementary Students In Activities Aimed To Increase Female Inclusion In STEM

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Abstract: This paper discusses efforts by the Center for the Advancement of Women in Engineering (CAWE) at the University of North Florida (UNF) to increase the inclusion in STEM by engaging 3rd through 5th grade students in outreach activities in the form of field trips. The UNF-CAWE field trips are designed to educate and inspire students in 3rd through 5th grade about engineering using a hands-on approach. The learning materials were designed to be inclusive to a diverse population. The materials included a conversational presentation of what engineering is and how it has helped shape the world we live in today and how engineering is needed to solve some of the biggest challenges our society is facing. The presentation was followed by engineering activities during which the students learned basics of programming a robot and building a hydraulic system capable of lifting heavy weights. The presentation and activities were designed by engineering students and faculty in the engineering and psychology programs and were delivered by engineering, computing, and psychology students with the oversight of the directors of CAWE. A total of six field trips were conducted. Three of the field trips received an additional presentation on unconscious gender biases. For all the six field trips, children with parental consent, participated in an Institutional Review Board (IRB) approved research study to determine if their interest in pursuing a STEM career was affected by the unconscious gender bias discussion. Results from the pilot study reveal that children benefit from participating in outreach activities which provide exposure to engineering, hands-on activities, role models, discussions on how engineering makes the world better, and discussions of unconscious gender biases.

1. INTRODUCTION

Women are underrepresented in engineering and some other STEM fields in the United States with only 12% of engineering jobs filled by women [1]. The need to increase women's participation in the field stems from the need for diversity of thought and from the need to meet the growing demand for engineers. The number of women earning engineering degrees has slowly increased in the last 30 years from approximately 15% in 1985 [1] to about 20% in 2015 [2]. In Computing, the number of women earning computing degrees has declined from 37% in 1985 to 18% in 2013 [1]. This low number of female graduates in engineering and computing is in stark contrast to the percentage of bachelor's degrees earned by women, which has been steady at approximately 57% since late 1990s [3]. Women do not pursue engineering at the same rate as men in part because of unconscious gender biases [4, 5], and lack of female role models [6]. These biases lead girls and women to question their abilities and feelings of belonging. The unconscious biases start at an early age and already at the age of seven, it has been observed that mathematical ability is associated more strongly with boys than girls [7]. These unconscious gender biases are believed to originate from children's interactions with parents, teachers, and media [8]. In a longitudinal study [9], it was found that

teachers perceive boys to be stronger in math than girls and that the performance gap in math between the genders increases through elementary school and that these differences are related to the teacher's perception of math abilities. Additionally, children are exposed to unconscious biases from parents and media. These unconscious biases lead girls to question their abilities and if their gender identity agrees with that of engineering. It is known that when gender identity conflicts with other social identities, self-stereotyping and reduced confidence can result [10, 11], and this may be a contributing factor as to why girls and women steer away from engineering and other STEM disciplines [12, 13], and may even contribute to lower performance. The Center for the Advancement of Women in Engineering was created to help bring gender equality to engineering and other STEM fields.

2. THE CENTER FOR THE ADVANCEMENT OF WOMEN IN ENGINEERING

The Center for the Advancement of Women in Engineering at the University of North Florida is committed to increasing women's participation in engineering through recruitment, retention, and advancement strategies based on research knowledge. By increasing inclusion of women and other minorities, our profession is better able to meet the growing demand for more engineers and increase diversity of though, needed in determining the most important problems to solve and in developing the best solutions. CAWE provides a variety of outreach activities for children in K-12 with the aim to inspire them to consider engineering and other STEM fields as a career. For retention of female students in college, CAWE provides a variety of mentoring opportunities with industry members, faculty, and peers. CAWE is also vested in the advancement opportunities for women in the community and actively engage with them in networking opportunities to share success strategies in how to recruit and retain women.

3. RESEARCH STUDY TO INVESTIGATE IMPACT OF UNCONSCIOUS GENDER BIAS DISCUSSION

To increase the inclusion in STEM, the PIs performed a pilot study by augmenting an existing outreach program called *Introduce a Girl to Engineering Day* by introducing a research component. The pilot study was conducted on 97 girls aged 8 to 12 and 95 parents across two years. While boys were invited to the event, only one attended and did not participate in the study. The research investigated the children's previous exposure and knowledge of STEM and their interest to pursue engineering. An on-line survey in the morning of the event, at the end of the event, and then again three to six months following the event was conducted. The event included, in addition to hands-on engineering activities, a presentation in which gender stereotypes were discussed. The preliminary results led to expanding the pilot study to investigate the effect of inclusion of gender discussions in STEM activities in boys and girls. This expanded research study was conducted on 3rd to 5th grade children attending six separate school field trips at the University of North Florida, with participants from four schools. All field trips were equivalent, except three included a gender discussion, whereas three did not. These field trips included approximately 50% girls and 50% boys.

3.1. Pilot study: Introduce a Girl to Engineering Day (IGED)

The pilot study was carried out on the IGED program offered in two separate years. In both years of the program children were brought to the University campus on a Saturday by their parents or caregivers. The event was broadly advertised on social media, TV, and radio. The day included children completing a pre-program survey, attending a presentation on engineering and a brief discussion of gender biases, and engaging in hands-on engineering projects that related to societal needs. After completion of the projects, the children were asked to take a post-program survey. Parents were also surveyed prior to the program. Three to six months following the event, the children were given a follow-up survey conducted on-line at their home. The surveys were designed to ascertain the children's prior exposure to and understanding of engineering and STEM and to determine whether participation in the program increased their interest in

pursuing engineering. The average results and standard deviation of the pilot study are provided in Table 1. In the table, engineering understanding and aspirations are measured on a 5.0 scale.

Table 1: Results of pilot study

	Pre-survey	Post-Survey	3- to 6-month follow-up
Number of participants	94	97	65
Engineering understanding	3.63 (0.88)	4.46 (0.58)	3.75 (1.15)
Engineering aspirations	3.51 (0.96)	3.68 (0.99)	3.28 (1.36)

These preliminary results of the pilot study indicated that a one-day engineering outreach program with gender unconscious bias discussion, hands-on activities connected to how engineering can improve society, and female role models, increases the girls' interest in pursuing engineering following the activity and their knowledge of engineering. The follow-up survey indicates that a one-time exposure may not be enough. The follow-up study was conducted at home, whereas the pre- and post- study was conducted at the event, which may have an impact on the results. Further, it is known that girls' interest in STEM decreases with age and the follow-up survey does not consider that participants moved to a new grade level and in some cases from elementary school to middle school between the event date and the follow-up survey. The pilot study was conducted on girls only and hence no comparison could be made between genders.

3.2. Expanded study: Girls and Boys can do Engineering! field-trip program

The purpose of the expanded study was to recruit a diverse sample of both boys and girls and to examine whether discussion of gender bias contributes to changes in children's interest in engineering. Children were recruited to participate in this research study as part of a field trip program developed by CAWE. The opportunity was advertised by the Duval County Public School (DCPS) district to school principals. The participants included 69 girls (2nd grade: 2, 3rd grade: 4, 4th grade: 14, 5th grade: 49) and 64 boys (2nd grade: 2, 3rd grade: 7, 4th grade: 15, 5th grade: 44). The children completed a survey prior to the start of the program, then again at the end of the day in the same computer lab, and will complete a follow-up questionnaire three to six months post the program at home. One parent per child has also been asked to complete a similar parent survey. As an incentive for research completion, the children are offered a small gift card. Children were not required to participate in the study in order to partake in the field trip. The research study was approved though a university based Institutional Review Board (IRB) and through a DCPS based IRB.

The program was designed and led by professors in psychology and engineering. Five female students in engineering/computing and five female students in psychology provided the activities on the days of the field trips, with oversight from the professors and an outreach coordinator. The team consisted of women with varied racial and ethnical backgrounds, providing representation of otherwise under-represented groups, and showing that women can be successful in STEM fields.

Questions were asked to assess the child's past exposure to engineering and STEM through previous activities such as reading, games, toys, watching TV shows, and if the child knew an engineer. The children were also asked questions to assess their unconscious gender biases, including their perception of their own and others' strengths. The children and parents were asked to rate the child's interest/likelihood of pursuing a STEM career. The children's surveys were designed to be easy for the children to complete, as demonstrated with the sample questions shown in Figure 1.

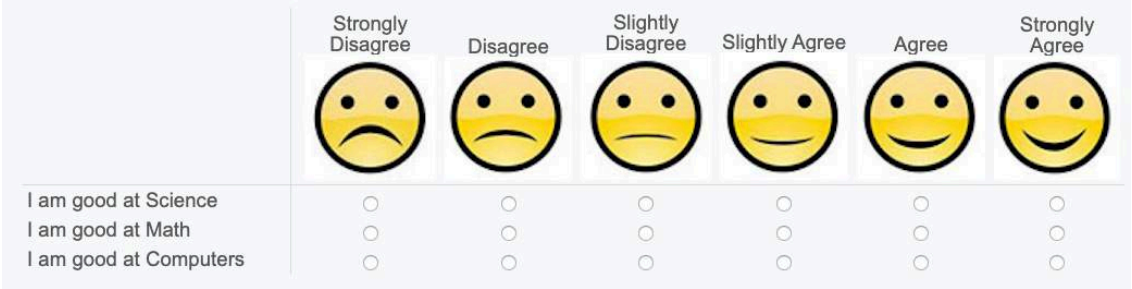

Figure 1: Sample survey questions

4. ACTIVITIES AIMED TO INCREASE INCLUSION IN STEM

After the initial survey, the children were brought back into a classroom designed for engaging children in STEM activities where an engineering student gave an interactive presentation discussing what engineering is. All children attending the field trip attended this presentation as a large group together, with an average of 24 children in attendance for any of the field trips. After an initial explanation of what engineering is, the children drew a picture of their impression of an engineer, and then watched a short video of engineering designed for their age group. At that point, three of the schools attending the field trips were engaged in a discussion on unconscious gender biases and three of the schools continued the presentation without the discussion of gender. The gender component is described in section 4.1. The focus of the engineering talk was to showcase how engineering helps make the world better, how engineering touches all aspects of our lives, and how engineers are problem solvers. A variety of examples were presented, ranging from designing windmills, safer roads, communication devices, prosthetics, biomaterials, and how engineers aid in improving the air and water quality. It was also pointed out the breadth of engineering and the different ways in which someone can contribute in this field. For example, it was shared that engineers can be creative, have a desire to design, have a passion for tinkering and building parts, enjoy solving problems, and be good at math, and that people with different strengths are needed in engineering. Following the discussion of engineering, the students engaged in two hands-on engineering activities; one on robotics, and one on hydraulics.

4.1. Gender Discussion

Half of the groups attending the field trips participated in a slightly longer presentation, which included an unconscious gender bias discussion. Half of the groups did not receive this component and serve as a control group. The purpose of the unconscious bias component was to help make the children aware that women are underrepresented in engineering and some other STEM fields and that they are equally capable to be successful in such fields. The children were informed that only about 12-14% of engineers are women. They were shown a graph indicating that IQ scores and school grades of girls and boys are equivalent. Discussion of gender stereotypes followed, where the children provided their thoughts on stereotypes and the presenter shared how some of those stereotypes may be created. For example, the children were shown images of two magazine covers; one directed at boys and another directed at girls. The messages of the magazines were distinctively different; the boy's magazine was about exploring his future, whereas the girl's magazine was about fashion and looks. The discussion also emphasized the importance of having a diverse group of engineers. One example that illustrated this importance included findings that women are more likely to be injured in car accidents than men, potentially because not as many women have been engaged in the design and safety testing of cars. The gender discussion concluded with ways to engage girls more in engineering and other STEM fields and that the children should think critically about the gender-related messages they encounter so that they can be open minded about career and life decisions.

4.2. Engineering Projects

After the presentation on engineering (and gender discussion for half of the groups), the children were split into two classrooms, and further subdivided into groups of approximately 3-4 children. Teachers were asked prior to the field trips to subdivide their children into groups and to ensure, to the extent possible, that there was gender balance within the groups. Half of the children started with a robotics activity before a lunch break and continued with a hydraulics activity after the lunch break. The other half of the students completed the activities in the opposite order.

4.2.1. Robotics activity:

A computing student gave a short prestation related to coding and robotics and presented how these benefits society and gave an example of how computer scientists are involved with controlling autonomous cars. She then presented the hands-on projects the children would work on. This project was meant to help the children understand how coding can be used to help solve societal problems. They were given a scenario that a hurricane in 2040 would cause much of the sand on the beach of Jacksonville, FL to erode and that the City of Jacksonville was asking that they deliver sand from a stockpile located in northwest Jacksonville to the damaged north section of the beach. The children were given a robot, and a wood frame with the details such as the city beach, the stockpile of sand, and the parking lot for their vehicle. The children were provided detailed descriptions on how to program their robots using the mBlock Blocky App. The instructions included images of the user interface and examples of block codes available to them, as seen in Figure 2.

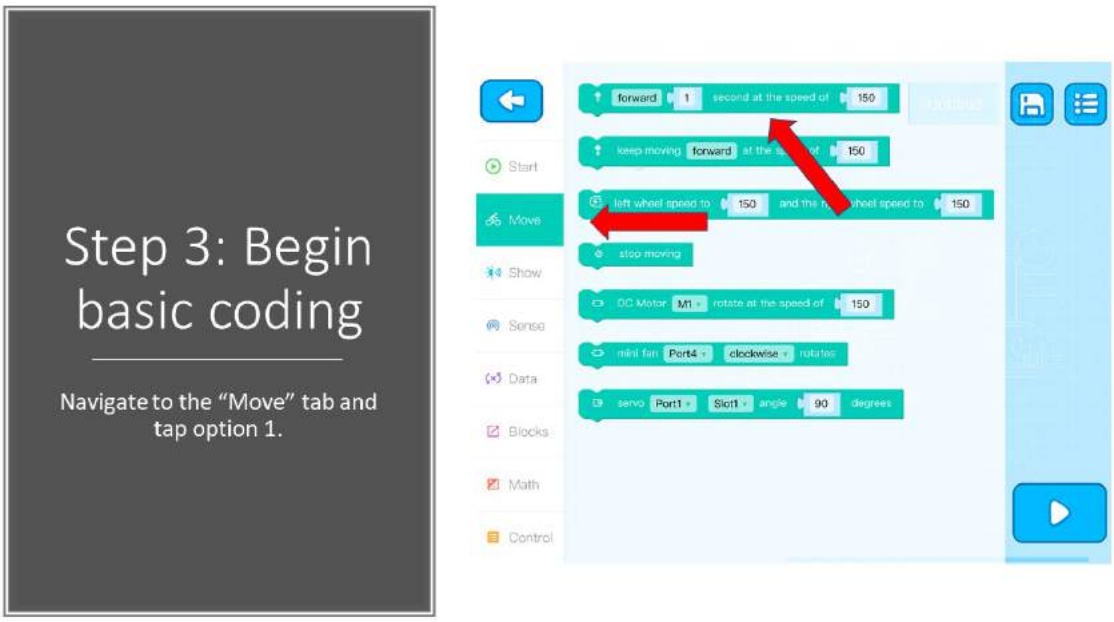

Figure 2: Coding instructions

The children worked in their small groups of approximately 4 children. They wrote code, and then tested it on the wood frame, and repeated the process until they managed to solve the coding exercise. Figure 3 show the children working on this project.

Figure 3: Participants testing their robot on the wood frame

The children demonstrated an ability to learn coding and apply it to solve the problem posted to them. Also, the children were excited to engage in this activity and didn't want to stop when asked to.

4.2.2. Hydraulics activity:

The students also engaged in an activity on hydraulics. First, one of the college students gave a presentation on what hydraulics is and how it is used in applications in our society. Examples such as lifting a car and lifting patients in hospital beds were presented. The children were then asked to build their own hydraulic system that would allow them to lift a heavy weight using only small syringes pushed closed by their hands. The children were provided step-by-step instructions with detailed images on how to build the system and were provided the necessary syringes, tubes, connectors, and wood boards. The final system is shown in Figure 4.

Figure 4: Hydraulics system

The students learned about hydraulics, building, following instructions, and to problem-solve, especially when the system leaked water. In the end, they were happy to see their systems work and impressed that they could lift a person with the push of a few small syringes, as seen in Figure 5.

Figure 5: Children lifting of person with the push of small syringes

5. CONCLUSION

Women are significantly underrepresented in Engineering and many other STEM fields. The objective of this paper is to highlight one approach to increasing the number of women in these fields. Previous research has indicated that the lack of representation of women in STEM may, in part, be related to gender biases that become apparent and exert influence beginning in childhood. The approach summarized in this paper includes outreach activities for children that include the evaluation of gender biases and engineering activities designed to provide children with hands-on experience and access to relatable role models. Preliminary results demonstrate positive trends following exposure and that more than one-time exposure may be needed for lasting effects. These types of interventions may be critical to improving the number of women pursuing engineering and other STEM fields.

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