Empowering Girls in STEM: Developing an Intervention that Promotes Interest in STEM Topics

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ABSTRACT

While women's participation in STEM fields has made significant headway from 1970 to present day, confidence in technical, scientific, engineering, and mathematical skills have decreased even if a girl or woman expresses interest in the topic. As awareness of gender disparities in STEM continues to grow, organized initiatives have spread to impact women and girls from all walks of life. At the University of Virginia, I co-created and co-lead Mentoring Girls in Computing, an organization with a mission to foster positive relationships among girls at a Charlottesville middle school and inspire them to pursue futures in technology. MGIC holds meetings on grounds at UVA to plan curriculum and visits the middle school for an hour each week to teach these lessons to the girls through hands-on, active learning experiences with the use of Spark, Python, and Lego Education. It is expected that if young girls participate in long-term, active learning programs where they are exposed to positive role models, their interest in STEM topics will increase. Future improvements include collecting empirical data regarding the girls' attitudes and confidence before and after the intervention in order to more accurately determine the success of the club. Additionally, MGIC has plans to collaborate with different schools and organizations to expand its reach.

1. INTRODUCTION

Despite a growing interest in science, technology, engineering, and mathematics (STEM), girls' confidence in their STEM abilities is declining–a troubling paradox that underscores the ongoing struggles to close the gender gap in STEM fields (Inc. ROX, 2024).

In the 1970s, as women began to be admitted into universities in large numbers, they set a trend of increased involvement in these technical fields, in both academics and the workforce. However, in spite of increasing opportunities for women in STEM fields, the increase in women working in engineering occupations has been slight and numbers have decreased for women holding computer occupations.

The antagonist to our ideal STEM environment is bias toward gender, which can begin to play a role in adolescents' lives as early as 5-7 years old. While there is no difference in actual performance between boys and girls in these subjects, boys show a higher motivation in math and sciences (Lazarides et al., 2023). These differences are shaped significantly by parents' and teachers' own stereotypic beliefs about gendered abilities, showing that it is important for young girls to be surrounded by mentors that encourage them and work against gender discrimination.

To mitigate the negative effects of gender bias, initiatives targeting women and girls from all different backgrounds began to organize, with Girls Who Code, Rural Girls in STEM, and SciGirls to name a few. MGIC aims to follow in their footsteps and provide a replicable framework for an intervention to show adolescent girls that pursuing their interests is worth it, no matter the obstacles.

2. RELATED WORKS

While a consensus on the characteristics and goals of initiatives proven to be effective have yet to be derived, due to "little empirical evidence" (Prieto-Rodriquez et al., 2020), some factors indicating successful implementation present across multiple previous interventions.

A study in 2010 designed and evaluated a computer science and engineering course targeting middle school girls to increase engagement and interest in STEM curricula (Marcu et al., 2010). The authors developed a four-week course using PicoCricket Kits and found three features from their course contribute to increasing the girls' interest: hands-on work incorporating creativity, the frequent presence of an audience as a motivator, and having engineering-focused individual roles in group work. When developing curriculum and activities for MGIC, my team and I incorporated Lego Education kits to provide a creative outlet for the middle school girls, mirroring the study's use of the PicoCricket Kits. Additionally, the course incorporated a mentorship structure in which high school girls helped the younger students, inspiring MGIC to form a similar structure with experienced college students and the middle schoolers.

Girls Experiencing Evolution began in 2004 as a week-long session targeting middle school girls as an effort to reduce gender bias. Over the years, the program evolved to include aspects for not only students, but for math and science teachers, parents, and peer mentors. Their work demonstrated that it is necessary to target all avenues through which gender stereotypes travel. Additionally, the 2010 version of the program, structured as a series of 20-hour intensive sessions, found that "over 90% of GEE participants enjoyed their overall experience in the program" (Ivey & Palazolo, 2011). This supports the contention that long-term or repeated participation in interventions is necessary (Prieto-Rodriguez et al., 2020), an aspect that is included in MGIC through our weekly sessions spanning semesters.

Furthermore, a study in Knoxville, TN analyzed voluntary STEM enrichment programs to see if they were effective in increasing female participation in high school and college STEM courses. The researchers found that they did not, in fact, significantly increase the likelihood of girls pursuing STEM in high school and college, as only 38.9% of girls indicated the intention of doing so (Stanberry et al., 2021). These programs were short-term, reinforcing the argument that long-term identity-focused strategies are crucial. The cumulation of conclusions derived from these studies have influenced measures that MGIC has taken, such as providing experienced mentors to build confidence and representation, engaging students through hands-on, creative learning approaches, and repeated participation over an extended period.

3. PROJECT DESIGN

Mentoring Girls in Computing is a volunteer-based organization that offers introductory lessons in coding to students at the Village School, a Charlottesville middle school for girls. The club is composed of women students at the University of Virginia who have experience or interest in computing science. Our first session occurred on October 17, 2023, and we have continued weekly meetings to the present day during the school years.

We utilize the principles of active learning to engage participants in activities, increase their knowledge retention and encourage critical thinking. By creating valuable and fun learning experiences, we hope to show them that it is worthwhile to pursue their interests, no matter the obstacles they come across.

3.1 Curriculum

MGIC follows a CS1 curriculum that explores the fundamentals of programming concepts for those with no previous computer science experience. Methods for delivering content evolved as the girls grew familiar with foundational topics and as the UVA mentors determined the preferred and effective ways the students retained information.

To introduce computing science to middle school girls, the first few sessions were dedicated to Hour of Code lessons. These one-hour coding activities created by Code.org touch on the basics of computer science. Each Hour of

Code comes with a clear set of instructions to complete the activity and CS learning objectives, utilizing block coding or drag-and-drop Python syntax. The purpose of this is to expose students to the basic structure of code while avoiding overwhelming students with the specificities of syntax. The lessons engaged students by taking them through the steps to building a programming project, with the outcome of a self-made game they can play or media they can share with peers.

Once familiarized with the concept of computer science as a whole, the curriculum progressed to utilizing Python as its programming language. Python is an effective language for beginners, as its structure follows English syntax and is designed to be concise. CS1 concepts covered in our curriculum included input/output, conditionals, loops, arithmetic, arrays, string manipulation and functions.

After covering CS1 concepts, MGIC incorporated LEGO Education into our curriculum. The club received a $5,000 grant through the Community Engagement and Outreach Project RFP with the purpose of introducing the girls to a variety of engineering topics outside of computer science. The grant was used to purchase LEGO Education SPIKE Prime Sets for the Village School students, which consist of LEGO building equipment and easy-to-use hardware. To begin, lessons provided by LEGO Education were used to teach the students how to use the LEGO sets while incorporating Python to design the functionality. Going forward, UVA professor guest appearances will introduce topics such as civil, mechanical and biomedical engineering through LEGO lessons tailored to their area of expertise.

3.2 Active Learning

The curriculum was based on the principle that students learn best when they are actively involved in the process, requiring students to apply, analyze, evaluate and create (Edwards, 2015). This aligns with the curiosity and developmental needs of young adolescents. Our activities aim to be purposeful and directly tied to learning objectives, rather than included just for engagement.

The Python lessons discussed earlier utilize active learning to appeal to the students intellectually, socially and physically. We encourage critical thinking and problem-solving by encouraging the girls to talk through potential solutions and problems instead of simply providing answers and lecturing. Projects often have a game aspect, which leverages peer interactions, as they can compete against each other using programs they have created. An example of a Python activity designed to have the girls apply their knowledge is using input/output to develop a Mad Libs game that they can have each other, play fostering peer interaction and collaboration.

Through the incorporation of LEGO Education SPIKE Prime sets, the students can see a physical manifestation of the code they are writing, incorporating movement and hands-on activities.

3.3 Components

MGIC has two primary components to the club's activities: the planning session and the teaching session.

3.3.1 Planning Session

For the planning session, the UVA members of MGIC meet once a week to develop lessons and activities. The dates of these meetings vary by semester depending on the schedule of the active members and last an hour. To begin, members recount the happenings of the last teaching session, determining the perceived effectiveness and enjoyability of the lesson that was taught. Based on this, a plan for the upcoming session is derived, making appropriate adjustments to the curriculum plan. The rest of the time consists of brainstorming and creating interactive activities based on the current introductory computer science topic. If necessary, slides explaining the topic are created to give the students an introduction to the topic before completing the activity.

3.3.2 Teaching Session

The teaching session occurs in person at the Village School every Tuesday from 3:15 to 4:45 PM, granted that the school is open. In the beginning, the session started with a fun ice-breaker activity to facilitate the creation of positive relationships between the students and mentors. If applicable, a short introduction to the CS topic is presented to the group at large, explaining relevant functions, structures and syntax. Following an overview of the activity and its purpose, the girls work on the activity individually or in pairs or small groups, depending on resource necessity or the nature of the lesson. As lessons progressed, the students were split based on level of understanding so that every girl could be mentally challenged. UVA members of MGIC assist the girls with questions and problems that arise, and probing questions and prompts encourage the girls to think through a problem and apply the information they have learned.

4. RESULTS

Student engagement and informal, testimonial feedback from Village School students indicate that the club is both fun and educational. Through attendance tracking, it was determined that there was a 27% school participation rate in weekly sessions, and a majority of girls are repeat participants. This implies satisfaction and positive experiences with MGIC. Additionally, frequent, informal check-ins with the girls reveal first-hand opinions. Participants relate their enjoyment to UVA mentors, often expressing excitement to share their finished project with parents and friends, indicating pride and a sense of accomplishment with their programming projects. Open and comfortable discussions between students and MGIC mentors also suggest a success in forming positive relationships with the girls at the Village School.

5. CONCLUSION

As young girls' self-efficacy in STEM activities decreases and as they are discouraged from pursuing their interests, it is imperative to mitigate these effects of gender bias with intent and foresight. Common features have been observed in successful interventions, such as length, mentorship and peer engagement. Mentoring Girls in Computing implements a club that incorporates these themes, as it lasts multiple school years, connects middle schoolers with women student mentors and utilizes active learning to ensure knowledge retention. As the participants have been observed to express enthusiastic engagement and pride in their programs, the framework and materials used in MGIC can be replicated to produce similar results for other schools and organizations. Not only do such clubs teach these adolescents crucial programming knowledge and encourage the growth of interest, but they also give mentors the ability to play their part in bringing the next generation of women into STEM.

6. FUTURE WORK

At the end of this semester's sessions, a survey will be conducted with the students to assess their interest in the club, as well as their interest in continuing an education in computer science. We expect the survey to demonstrate an increased or continued interest in STEM subjects as a result of CS lessons and engineering-centered activities. The outcome will be useful to MGIC moving forward, as it will give insight into which aspects of the club should be modified and which should remain the same in order to ensure continued engagement and enjoyment. A limitation assessing the effectiveness of the intervention arises in the lack of empirical data collected, preventing an in-depth analysis. Additionally, as the structure of the club proves effective and the participation of UVA students grows, MGIC looks to expand its reach to other schools and organizations.

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