Work in Progress- STEM engagement for middle and high school young women- Implementation, Challenges and Lessons learned

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Introduction

Women make up about 22% of students pursuing and completing Engineering or Technology degrees in the STEM (Science, Technology, Engineering, and Mathematics) fields. Analysis of data showed that only about 6% of these degrees were awarded to women of color who are about 37% (in the 18-24 years old range) of the total female population based on the 2019 census [1]. Engineering and technology have always had an important role in addressing the needs of society, it is now gaining recognition for addressing societal problems. This is recognized and enhanced by an increased representation of women especially women of color. This change will result in a positive outcome by bringing more diverse ways of thinking and innovation to the classroom as well as companies that employ them.

Literature shows that there are many different reasons for lower recruitment and retention rates for women in Engineering and Technology which include preconceived notions on the nature of work and gender stereotypes in these fields. Additionally, there is a lack of access to women role models and mentors, seeing women that look like them is a significant factor in both recruitment and retention [2, 3]. Data showed that in the U.S. only 6% of 15-year old young women are interested in engineering careers [1]. Researchers believe that the low level of interest in young women is due to lack of exposure and the belief that it is too hard and by engaging young women with university faculty and women engineers in the industry as early as middle school could result in a higher interest to pursue engineering education in the future [2]. A program at Worcester Polytechnic Institute showed that early intervention was associated with better engineering and university recruitment outcomes [4]. Another study showed that a sustained intervention led to enhanced awareness of STEM careers and interest among young women [5]. Researchers further believe that an intervention that is designed to be sustained over a period of six months or longer and that encompasses the sociocultural environment around the student will lead to a better outcome.

Motivation to Develop Program

Outreach activities at the researcher's department are mostly one-week summer camps or a day long visit by the local middle and high schools for a 'Techie Day' or a 'Day in College'. These activities are very focused on recruitment and benefit students who have made up their minds about their academic pursuits. Additionally, it was observed that very few young women (10-16%) attended these sessions. There was an urgent need to engage with this cohort and to do things differently in the sense that the outreach and engagement were more holistic.

Research Questions

Considering existing literature and the motivation behind developing this program encouraged the researchers to ask the following questions:

1. Did the sustained intervention cause a shift in the perception of Science and Math in young women?

2. Did a higher percentage of young women from the cohort pursue an Engineering or Technology degree in their undergraduate program?

Framework of Student Engagement

Researchers chose Kahu's framework with the focus on the educational interface [6]. Kahu's framework of student engagement identifies four main factors that influence a student's experience with the intervention and the success of the intervention. These are self-efficacy, emotions, belonging, and wellbeing. These factors are not independent of each other e.g. self-efficacy is related to self-confidence in one's academic abilities and also affects, emotions, belonging, and wellbeing of the student and their perception towards a particular field of study. Belonging is also key as it brings down psychological barriers for a young woman when she sees herself associated with the institution.

This study is dual faceted with the intent to instill confidence in students, and expose students to the world of work and education vis-a-vis guest speakers and interaction with university faculty. This paper presents the implementation of the pilot and discusses the initial findings, challenges and lessons learned.

Methodology

The program activities were designed to emphasize self-efficacy and belonging and will be described next. Faculty researchers developed partnerships with local organizations working with young women with a focus on women of color, in grades 6-12th. Based upon partner scheduling and the academic calendar a twenty week/year program was developed. Students will attend an in-person session (two and a half hour duration) every other week, with take home materials the week after. The hands-on exercises are based on peer reviewed activities that are also open source [7]. A kit was developed as part of the intervention with take home activities for students to explore and sustain their curiosity and encourage familial involvement.

The enrollment in the program was open to young women who came through the community partners. There was no selection process for the participants. The initial enrollment in the program were nineteen students which was the capped limit of the program, with a grade level distribution shown in table 1. STEM semantics survey was used to gather data about the interest of the cohort in STEM before starting the program [8].

The first ten weeks' intervention materials were focused on raising interest and awareness in the areas of Mechanical and Electrical Engineering, Physics, and Leadership through team based and project-based learning and are detailed in table 2. To support the in-person intervention, guest speakers were invited who shared their stories with time for discussion and interaction.

The next ten weeks' activities are in the areas of computer engineering technology and industrial engineering technology where the students will be challenged to design a website and design an efficient assembly line.

Table 1- Distribution of the grade levels in the cohort.

Grades 6-8	12
Grades 9-12	7

Table 2- In-person and at home activities during the first ten weeks of the program.

Topic	In-person session activities	At home activities
Electrical Engineering-Energy	Faculty conducted a short lecture where different types of energy sources were discussed. The students were then probed about why do they thought some were better than others? They looked into where their home's energy came from. The lecture was followed by a discussion about energy sustainability. A publication from an energy company was made available to the students [9] Lastly, they discussed about what might happen in an extended blackout and were asked to suggest ideas on how to be prepared for such a scenario.	The homework consisted of an energy worksheet and a hands-on exercise where they used materials from the kit to make an emergency phone charger. Then they completed the worksheet by observing the charging of a device using the homemade charger.
General Engineering-Leadership	A discussion on leadership was conducted by the faculty. The students were asked the question: What is leadership? Individual students were asked to write their personal idea of what a leader is. Then they were asked to write about someone whom they knew personally and they considered a leader. Lastly, they were asked to brainstorm as a cohort and write down qualities of a leader. This session had a guest speaker who was a minority woman, working in engineering. She was also the current state beauty queen.	The homework consisted of a worksheet on leadership. For the hands on project the students made a circuit-based game similar to the operation game.
Physics- Fashion	A lecture on Newton's Laws of Motion was conducted by faculty. This was followed by a hands-on activity where the students investigated how to measure and calculate static force and pressure. They also discussed with the faculty how these factors influence shoe design.	The homework consisted of a shoe design worksheet. For the hands-on exercise the students designed a shoe from the materials in the kit.
Mechanical Engineering-Building models	The students participated in a discussion about what mechanical engineers do. This was followed by a hands-on activity where they created a 3D model	The homework consisted of working on a presentation. The students picked an activity of their choice and wrote their reflections about

	of a simple object using a process similar to a 3D printer. This session had a guest speaker who was a mechatronics engineering technology student and a minority woman. She shared her experience of internship at an electric car company and discussed and shared her own experience as a student in engineering and technology.	it. This was the activity that they presented to their guests during the last week.
Documentation & presentation	The students worked on preparing presentations in the computer lab at the college with the faculty. On the final day, they presented their work to invited guests mostly family and faculty.	

Findings

The survey questions were based on the STEM semantics survey [9] and are shown in appendix A. The reliability of the STEM survey ranges between 0.84 to 0.93 which was deemed suitable for data acquisition. The questions utilize a 1-7-point Likert scale to measure the perceptions of the participants regarding Science, Technology, Engineering, Math, and STEM careers.

Table 3 provides an analysis of the pre-survey responses for a sample size n = 19. A mean of <4 indicates a positive perception of the subject, a mean of 4 indicates a neutral perception and >4 indicates a negative perception of the subject. Additionally, the lower the score the higher the degree of interest or positive perception of the subject. The data analysis showed that the cohort had a positive perception of Technology, Engineering and a STEM career with smaller sample variance for these questions on the survey. It also indicated neutral to negative perception of Science and Math with a much larger variance in the data.

During the course of the intervention twelve students dropped out and seven students completed the first ten weeks. Main reasons cited for the dropout were low interest in the subject, transportation, and COVID-19. Table 4 provides the survey results after ten weeks of the program. The post survey was completed by seven participants. Again, a mean score between 1 to 4 indicated a positive perception of the subject, the lower the score the better the perception of the subject. The science and math questions had a mean score of 2.53 and 3.22 indicating an improvement of 28.2% and 25.6% in the positive perception of science and math. The results for the other survey questions also showed a positive shift in the perception of Engineering (by 30.2%), Technology (by 39%), and career in STEM (by 43.6%). One reason for the improvement in perception can be that the participants who completed the 10-week program may have started out with a more positive perception of STEM than the participants who dropped out. This will be investigated in further studies as more data is collected.

Table 3- Pre-survey statistics

Survey question	Mean	Sample variance	95% confidence
To me SCIENCE is:	3.54	5.31	0.77
To me MATH is:	4.33	6.37	0.94
To me ENGINEERING is:	2.78	5.17	0.76
To me TECHNOLOGY is:	2	2.07	0.53
To me a career in STEM (is):	2.75	3.63	0.68

Table 4- Post event statistics

Survey question	Mean	Sample variance	95% confidence
To me SCIENCE is:	2.53	3.64	0.98
To me MATH is:	3.22	4.06	1
To me ENGINEERING is:	1.94	1.23	0.55
To me TECHNOLOGY is:	1.22	0.83	0.21
To me a career in STEM (is):	1.55	1.32	0.57

The students also recorded their reflections on the program activities that provided qualitative data about their engagement with the program. Their reflections on the take home activities provided insight on the interactions that took place at home. For example, one participant noted “I liked it because I got the opportunity to mess around with a little bit of electricity and got to test what happens if you do not match the correct wires together”, another noted “Yes I want to make a charger on our own”. Some parents and other caretakers at home became involved in the activities by playing the games that the students made or by helping them in HW. Research has shown positive outcomes for student self-efficacy and belonging when parents are part of the learning process.

Lessons Learned

Some of the lessons learned so far are that the students in the 6^{th}-8^{th} grade were more engaged than the older students in the program. Future programs will be separated into 6-8th grade and 9-12th grade and the authors will further refine the intervention and activities carried out by the invited speakers focusing on the differences of these grade levels. The faculty also needed a better understanding of community

partners' roles in participant support and engagement, e.g. attendance became an issue when the students from one organization were dependent on only one adult for transportation.

Future Work

Since this is a work in progress the future work will continue to answer these two research questions, raised earlier. Did the sustained intervention cause a shift in the perception of Science and Math in young women? Did a higher percentage of young women from the cohort pursue an Engineering or Technology degree in their undergraduate program?

Other instruments will be evaluated that could be used with the STEM semantics survey to improve the accuracy of the measurements. For example, the researchers plan to track the enrollment of the cohort in Project Lead the Way program at school that could be a short term predictor of STEM interest.

References

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Appendix A

Question 1. To me, SCIENCE is

1.	fascinating	1	2	3	4	5	6	7	mundane
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	exciting	1	2	3	4	5	6	7	unexciting

Question 2. To me, MATH is

1.	fascinating	1	2	3	4	5	6	7	mundane
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	exciting	1	2	3	4	5	6	7	unexciting

Question 3. To me, Engineering is

1.	fascinating	1	2	3	4	5	6	7	mundane
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	exciting	1	2	3	4	5	6	7	unexciting

Question 4. To me, Technology is

1.	fascinating	1	2	3	4	5	6	7	mundane
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	exciting	1	2	3	4	5	6	7	unexciting

Question 5. To me, a career in science, technology, engineering, or mathematics (is):

1.	fascinating	1	2	3	4	5	6	7	mundane
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	exciting	1	2	3	4	5	6	7	unexciting