Informal STEM Experiences: Impact on Diverse Groups of Students and Teachers

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Abstract**—*It is important for society to exhibit diversity in STEM fields because of the different perspectives and unique solutions to problems each individual brings to the situation. Different cultures, environments world-wide, and genders have different needs for innovations to improve their lives. Their unique needs, experiences, and perspectives provide for collaborations that can solve problems on a broader plane and transfer existing innovations for new purposes in different situations. Gender and cultural differences affect interest in engineering and other STEM careers for these reasons as well. Students participated in a summer STEM camp, and teachers participated in professional development directly related to the activities and experiences in the student camp. The research questions for this study were: 1) Among a diverse group of secondary students, to what degree did engineering and other STEM interest increase after experiences in a summer camp? 2) Why did teachers choose to attend the summer camp professional development? How did diversity contribute to their experience? Student interest in engineering and other STEM fields increased. Students and teachers felt that they benefited from the experiences at the camp, including the work with STEM Project-based Learning and collaboration with diverse groups.*

Keywords**—*project-based learning, STEM summer camp, teacher professional development*

I. Introduction

The US is a STEM field leader in the world today. With a highly diverse and rapidly changing demographic makeup, the US is poised to lead the way for innovation in diversifying the STEM workforce. The benefits include improvements in areas such as research, production capacity, and health care changes [1][2]. The demand for college graduates with associate and bachelor's degrees and STEM skills, whether or not the particular job is considered a STEM field, remains high. STEM and non-STEM companies are creating more STEM jobs than non-STEM jobs, and this trend is expected to continue [3]. STEM jobs make up 20% of jobs in the US, and they are predicted to grow 55% faster than non-STEM jobs over the next 10 years. However, only 28% of US science and engineering workers are women, and under-represented ethnic and racial subpopulations make up 10% of those jobs [4]. Demographics in the US are changing, but there has not yet been a similar shift in STEM fields. The unique challenges for those under-represented in STEM fields are not being addressed as well as they should. It is important for engineering and science to have diverse perspectives working together to solve societal problems [5]. There is a positive correlation between diversity in the workforce and sales, compared to competitors without diversity, as might be expected in terms of serving the needs of all groups well. Although there is criticism that diversity in backgrounds creates greater conflict in the workplace, the exchange of ideas from diverse subpopulations increases innovation in solving problems [6]. Female inventors bring a different perspective and have been responsible for such innovations as windshield wipers, coffee filters, and disposable diapers [7]. Many Fortune 1000 companies are experiencing challenges in finding adequate numbers of qualified candidates with STEM degrees. In particular, the expectation is that there will be a shortage of candidates with bachelor's degrees in STEM fields. Likewise, under-representation of women and minorities remains a concern [3].

Recruitment and retention are both challenges for providing diversity in STEM fields. However, there are several strategies that have shown promise. Encouraging voices of diverse populations in the classroom can begin as simply as creating a discussion between mathematics teachers and engineering teachers. Considering a discipline-based difference in perspectives can provide greater insight and illustrate the needs for diversity in solving world problems. Students need to encounter different perspectives and learn how to successfully collaborate with a variety of perspectives. Thus, diversity can be a learning tool in the classroom to encourage more students to pursue STEM studies [8]. Collaboration of university faculty and high school teachers regarding academic preparation of students can help increase diversity in STEM studies [9][5][4]. Engagement through experiences, mentorship, and discussion is important for children to become interested and develop a passion for STEM careers [10]. Mentoring with a matched-background approach is believed to be most successful; however, the type of match is very much an individual preference. Contrary to common belief, ethnic minorities do not always prefer mentors that share that characteristic. Other ways of fostering a feeling of belonging, such as specific scientific interests, may be just as encouraging. Students at a summer camp developed informal mentoring relationships with residential staff, high school teachers, graduate students, and college faculty [11].

This study addresses the impact of a summer camp experience on students and teachers. Informal STEM

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experiences can give students opportunities to learn about societal needs that can be addressed through engineering innovations. Students participated in a summer STEM camp (SC), and teachers participated in professional development camp (TC) directly related to the activities and experiences in the student camp. Those experiences gave teachers additional teaching methodologies and strategies to engage a more diverse student population in STEM content. The teachers were able to observe the students in the camp as they engaged in STEM Project-based Learning (PBL) with an expert facilitator. They participated in presentations and discussions about teaching methodologies to increase learning in their classrooms. The teachers were from diverse cultural backgrounds, and they also taught a variety of subjects, both STEM and non-STEM.

The conceptual framework for the SC and TC follows the integrated STEM education framework for secondary education developed by Kelley and Knowles [12]. It is based on how people learn STEM content. This integrated approach directly provides connections between STEM subjects, applied in authentic real-life problems. Thus the framework involves situated STEM learning, an engineering design process, scientific inquiry, technological literacy, and mathematical thinking, with all elements incorporated in a community of practice. The TC embodied all of these elements through the learning and collaborative sharing and development of PBLs. In addition, teachers observed an expert PBL facilitator working with secondary students during a solar energy class in which students were drawn into scientific inquiry, the engineering design process, learning new technology, and mathematical thinking.

The research questions for this study are: 1) Among a diverse group of secondary students, to what degree did engineering and other STEM interest increase after experiences in a summer camp? 2) Why did teachers choose to attend the summer camp professional development? How did diversity contribute to their experience?

II. METHODOLOGY

Participants in the two-week summer STEM camp were 118 secondary school students, primarily from the US, with a few from other countries across the world. The student camp will be designated by SC. Fig. 1 illustrates the makeup of the students.

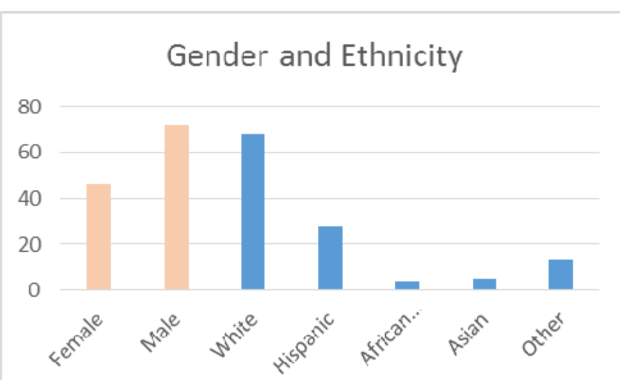

Fig. 1. SC Gender and Ethnic Distributions

Students completed a STEM interest survey at the beginning of the two-week SC. Activities for the camp included solar energy, cosmetic chemistry (see Fig. 2), bridge building, 3D printing, cryptography, video production, and building trebuchets. Students were introduced to the engineering design process and encouraged to use this problem solving process to complete products in their classes. Students completed the STEM interest survey again at the end of the SC.

Fig. 2. Students creating cosmetics

Participants in the one-week Project-based Learning camp were 26 secondary teachers from the US. The teacher camp will be designated by TC. Fig. 3 illustrates the makeup of the teachers. Teachers taught a variety of subjects: 21 taught STEM courses, 2 history, and 2 English language arts.

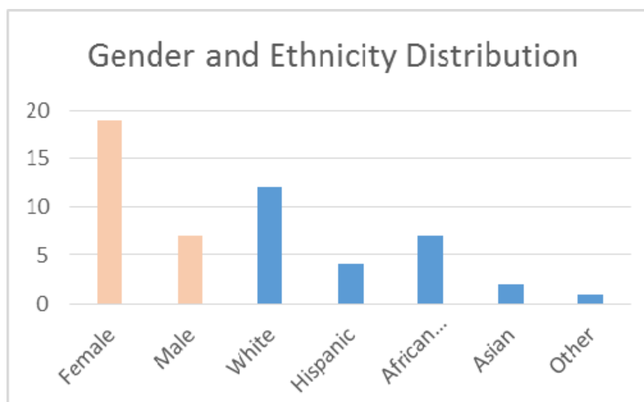

Fig. 3. TC Gender and Ethnic Distributions

The TC was focused primarily on interdisciplinary PBL. Teachers learned how to create a PBL for use in their classrooms. They chose state or national standards in multiple core subjects from which to create an integrated STEM PBL. Some teachers came in teams from one school and worked together to design a PBL that they could all use. After choosing the standards and subject areas to address, they determined the topic of interest on which to focus the PBL. They developed a task with constraints and a final product with criteria to be graded with a rubric. By the end of the camp, most teachers or groups had completed PBLs that they could implement in their classrooms. Nine of the teachers had previous PBL training, and 17 had no previous training. Other activities for teachers included four hours of observing, via live feed, an expert facilitating the solar energy SC class and working with SC participants in 3D printing. Teachers were also given time to collaborate with teachers from the same or other campuses to design PBLs to integrate into their particular courses (see Fig. 4). They were encouraged to develop an interdisciplinary PBL with a teacher in another subject area, whenever possible.

Fig. 4. Teachers working on PBLs

III. Results

Student campers who completed the pre- and post-survey ($N = 94$) showed increased interest in engineering and other STEM fields from the pre- to post-survey. In particular, student ranking on a Likert scale of 1 to 4, with 4 being the most positive, of how well they "liked" engineering and how well they found the subject of engineering "appealing" increased. Table 1 shows the means and standard deviations for these questions. The standard deviations on the post-survey items were smaller, showing less variation in responses after the camp experience.

TABLE 1. SC Means and SDs for Engineering Attitudes

	Pretest Mean (SD)	***Posttest Mean (SD)***
"liked" engineering	3.38 (.869)	3.60 (.766)
found engineering "appealing"	3.43 (.849)	3.55 (.798)

The mean difference on pre- and post-test surveys for "liked" engineering yielded $p < .01$, and for found engineering "appealing", $p = .057$. Although the result for found engineering "appealing" is not statistically different at the 95% confidence level, it is of practical significance, being quite close to that level. Because students were engaged in SC activities all day for two weeks, it is most likely that the SC experience itself was responsible for the increased interest in engineering. Fig. 5 illustrates the means for "liked" engineering, and Fig. 6 shows the means for found engineering "appealing" at the 95% confidence level.

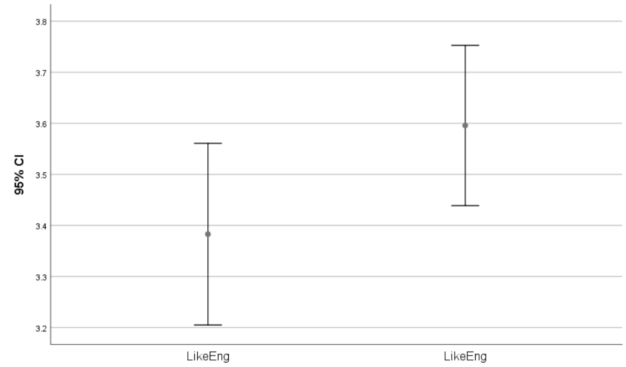

Fig. 5. TC pre and post for "liked" engineering

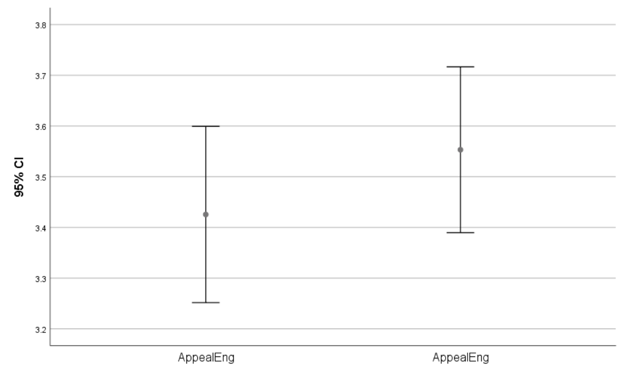

Fig. 6. TC pre and post for found engineering "appealing"

Teachers attended the TC for several reasons including (1) the PBL content, (2) 3D printing, (3) networking with other teachers and college professors, and (4) personal growth. The majority of teachers reported that their reasons for attending the TC were fulfilled. They reported that the most beneficial aspects of the TC were learning 3D software, learning about the 3D printer, and networking with others who were using PBL in their classrooms. Students in the SC benefitted from the 8 hours spent with teachers because they interacted with a diverse group of STEM teachers, which they may not have experienced in their own schools.

IV. Discussion

The summer camp experience was beneficial and enjoyable for both students and teachers. Teachers reported that they enjoyed the time working with the students, learning about interdisciplinary PBL, and writing PBLs for use in their classrooms. Students enjoyed the hands on activities, and their experiences improved their attitudes toward and interest in STEM studies. The gender and ethnicity breakdowns for the camps show a disproportionate number of male student campers and female teachers at the secondary level. The ethnic distribution could be more diverse as well. Underrepresented groups in STEM need opportunities to engage in camps that overlap students and teachers and they should be encouraged to take advantage of opportunities to increase knowledge and interest in STEM fields. Informal experiences can increase interest in STEM fields and result in promoting diversity in the STEM workforce. Universities may do well to provide outreach activities that engage students in authentic problem solving situations and deliver related professional development to teachers alongside the student experience. Participation in camps such as these may help to diversify the STEM workforce over time.

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