Informal STEM Camp Influences on Engineering Confidence

Ali Bicer, Sandra B. Nite *, Robert M. Capraro, Luciana R. Barroso**, Mary M. Capraro, Jeffrey E. Froyd***
Aggie STEM
Texas A&M University
*Mathematics; **Civil Engineering, ***Engineering
College Station, TX, USA
alibicer@tamu.edu, snite@math.tamu.edu, rcapraro@tamu.edu, lbarroso@civil.tamu.edu, mmcapraro@tamu.edu, froyd@tamu.edu

Abstract— Multiple national reports have firmly established the need for more baccalaureate engineering graduates. One approach to increasing the number of engineering graduates is to increase the number of students that enter college with engineering as their chosen major. To improve recruitment, many summer experiences for pre-college students have been offered to increase (i) knowledge about engineering and career opportunities that an undergraduate engineering degree offers, (ii) student interest in engineering and related fields and/or motivation to study engineering, (iii) student self-efficacy in engineering and related fields, and (iv) student ability in specific aspects of engineering and/or related fields. Both outcomes and instructional approaches for these summer experiences vary widely. A distinctive aspect of the summer experience presented in this paper is the emphasis on project-based learning (PBL) and student engagement with 3D printing. Students are often unaware of the range of applications of 3D printing beyond component fabrication, e.g., medical applications. The paper describes the summer experience to expand on how PBL and 3D printing were used to achieve the goals of the summer program. It also presents results from pre-and-post test results that showed students in the summer experience increased student confidence and perceptions of their ability in engineering over the course of two weeks.

Keywords—recruiting, calculus, engineering education, mathematics placement, summer program

I. Introduction

A. Engineering Workforce

Innovation and productivity in STEM fields is the foundation of economic progress in the 21st century. Since the beginning of the United States, this fact was well understood. The Constitution of the United States illustrated this by granting authority for the issuance of patents to inventors [1]. More than a century later, the National Science Foundation was created, renewing emphasis on promoting innovation in science and technology. Recent presidents have established additional initiatives to increase access to STEM education and promote growth in the STEM professional arena [2].

Although before the 21st century, half of patent holders did not have a college degree, between 2000 and 2003, 94% did, and engineering degrees were a significant portion of those. These inventors are critical to keeping U.S. business in the forefront of technological development [2].The demand for engineers has been high historically. In recent years, there have been some reports that the demand is less in some engineering fields, but biomedical engineers, civil engineers, and environmental engineers were still in demand [3]. Barriers for women and minorities have impeded increased diversity in the STEM workforce [4]. However, the emergence of pre-engineering courses in high school and informal learning experiences with engineering focus have provided more access for underrepresented populations to understand opportunities in engineering careers [5].

B. Pre-College Informal STEM Experiences

Informal STEM experiences can be instrumental in increasing student interest in engineering and other STEM fields for many students, especially those underrepresented in STEM careers. Such experiences provide exposure to real life problems and problem solving strategies they may never encounter in formal education. Several characteristics of impactful informal STEM programs were identified: informal mentoring, making learning fun, learning to manage time, applying mathematics and science, feeling accomplishment through competition, building confidence, and camaraderie through collaborative efforts [6]. Informal STEM experiences have broadened secondary students' knowledge about applications of mathematics and science and what engineers and other STEM professionals do in their jobs. In addition, they have provided exposure to iterative design processes that are used in engineering. Students enjoyed and benefitted from the collaborative opportunities that are rarely available in formal educational settings [7][8]. Informal engineering opportunities have increased secondary students' interest in pursuing engineering careers as they learned more about the tasks engineers perform, experienced collaboration, and engaged in design challenges [7][9]. Unfortunately, even though there has been a continued need for informal STEM learning, only 20% of households have children who have been able to engage in afterschool STEM programs [2].

Creativity in informal STEM activities engages a broader spectrum of students in having fun and building confidence because students typically do not associate STEM fields with creativity [7]. Some activities and projects that encourage creative solutions include bridge building, creating marketing brochures for concrete products, and 3D software and printing [10]. .

C. 3D Printing and Project-Based Learning

Instructional methods such as project-based learning (PBL) have increased content knowledge, interest in STEM fields, and 21st century skill levels [11] [12] [13][14]. Students were more responsible for their own learning, while teachers served as facilitators of that learning [15] [16] [17]

STEM projects that are fun, based on real life situations and problems, and involve cutting-edge technology engage a diverse student population. 3D printing is a cutting-edge technology [18].[10]. It allows much more freedom in the design to manufacturing process and has become a key component of prototyping new designs quickly and efficiently [19]. In addition, 3D printing is becoming more and more useful for printing actual parts to be used in a variety of contexts. Although the first 3D printer was built in the 1980s and cost more than $100,000, the technology has recently become more affordable and increased in popularity with the general public. In addition, formal and informal STEM education uses have become abundant. 3D printers have been used to create models of the heart, skull, and other body parts for teaching anatomy [20]. Students have used 3D printers to create useful and items such as cell phone covers, key chains, and knick-knacks [10][20]..

II. PURPOSE AND RESEARCH QUESTIONS

The purpose of this study is to determine influences of a summer STEM camp that included 3D printing and project-based learning on the confidence level of students in their ability to learn engineering. The research questions are:

1. To what extent did the STEM camp with 3D printing and PBL affect student perceptions of their abilities to pursue engineering study?
2. How did student perceptions of their abilities differ with regard to gender and ethnicity?

III. METHODOLOGY

One hundred and six (106) high school students (35 female and 71 male) enrolled in a two-week long STEM summer camp in 2015. The camp was held in the southern part of Texas, and it accepted students regardless of their prior academic and social achievement background. Unfortunately, not all students were accepted due to the logistic limitations, so the program only accepted students who registered before the enrollment limit was reached. A diverse student population was served in term of their ethnic background (57 White, 6 African American, 34 Hispanic, and 3 American Indian). The camp consisted of students who would be entering grades 9 to 12 in the fall. A survey administered prior to the beginning of the camp revealed reasons why students attended this two-week long STEM summer camp. Reasons included, but were not limited to, prior interest in STEM fields, parental reinforcement, and additional needs in STEM courses.

A. Intervention

Students engaged in 3D printer theory and application courses during the two-week camp. In the theory portions, students learned how to use SketchUp and XYZ software to design their own objects. Then, they learned how to use a 3D printer to print their 3D models. Each student worked on individual laptops. Two teachers were present in the classrooms at all times. While one teacher taught, the other one helped students who needed additional support to catch up. Students were expected to print their objects and be able to show distinctive features, explain the mathematics and science background, and present strengths and weakness of their designs.

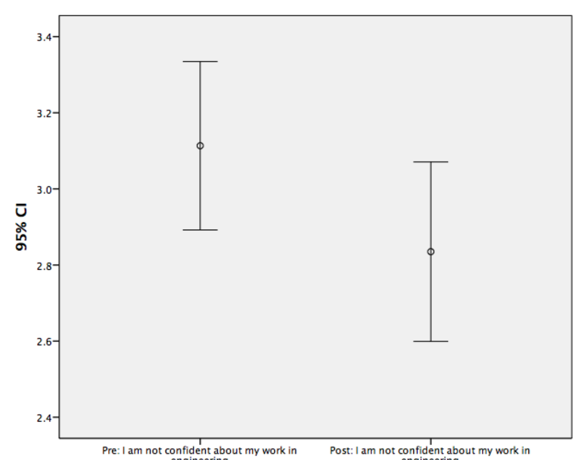
B. Assessment

A pre- and-post-survey was administered to the participants through Qualtrics. The survey questions consisted of Likert-scale items. Students took the pre-survey one week before the camp started and the post-survey on the last day of the camp. Two items were employed to measure differences in confidence and perceived ability in engineering.

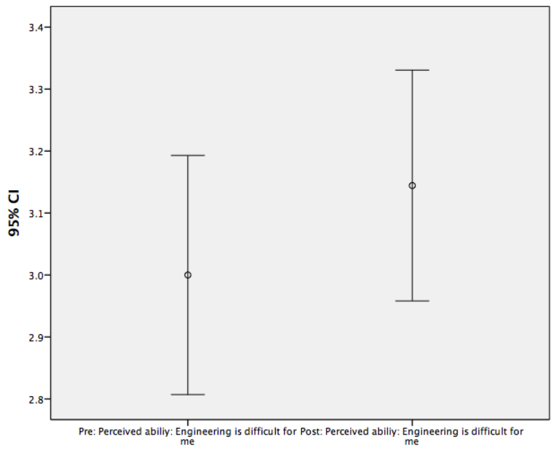
SPSS 23, was used for statistical analysis. To determine pre-to-post differences on survey items, a paired-sample t-test was used. Cohen's d effect sizes and confidence intervals were reported.

IV. RESULTS

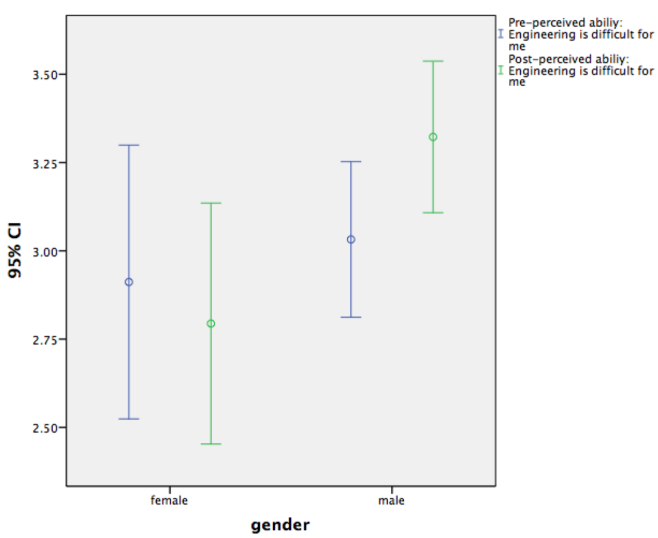
Results from the study revealed that students' pre-to-post confidence about their work in engineering increased significantly ($p < .05$, see Figure 1). The Cohen's d effect size for this difference was 0.25, and the confidence interval associated with this effect size was (-0.02, 0.53).



On the other hand, the pre-to-post perceived ability in engineering decreased, but the change was not statistically significant (p > .05). The Cohen's d effect size for this difference was -0.15 with the confidence interval (-0.12, 0.43).



Results were disaggregated by gender and ethnic background. Pre-to-post changes in confidence and perceived ability in engineering were not significantly different (p > .05) among students who come from four ethnic backgrounds (Asian, A frican American, Hispanic, White, and Native American). Pre-to-post changes between male and female students were not significantly different (p > .05). Female students had attained more positive perceived ability on the post-test than males after receiving 3D printer intervention although their perceived ability from pre-test scores revealed no statistically significant (p < .05) difference prior to the intervention. The Cohen's d effect size was found as 0.51 associated with gender differences on their perceived ability (see figure 3) in engineering was favoring female students.



V. Conclusions

Informal learning experiences held during the summer can increase high school students' interest in engineering with the intent that more students will enroll in engineering. Numerous variations in these informal summer experiences have been tried. Usually, these experiences reflect expertise of the organizers or intent to offer innovations. This two-week summer camp emphasized PBL and 3D printing. The PBL instructional approach emphasized multiple solutions to the challenge presented to the student. Emphasis on 3D printing allowed students to engage with cutting-edge technology. Pre-to-post differences in confidence and perceived ability in engineering were noticeable. There were no significant differences in the changes based on either gender or ethnic background. The study showed that students benefit from the instructional approach and technological emphases of the two-week summer camp.

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