First Year Engineering Experiences of the STEM-Inc Project

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Abstract **- This paper presents the first-year engineering experience for "*STEM-Inc: Science, Technology, Engineering and Mini-business Incubator*", an after-school strategies program mainly targeting traditionally-underrepresented students in 7th and 8th grades. The STEM-Inc project combines engineering and business entrepreneurship concepts. STEM-Inc students work in teams and are mentored by college majors, in partnership with school teachers. The college majors are trained and supervised by faculty members at California State University Fullerton. The technical skills training component of the program for year-1 of the project included mobile application development, introduction to robotics, and 3D printing. It also involved enrichment activities such as industry speaker sessions, University field-trip, logo design and annual project showcase. Surveys were used to record project data and student perceptions. The program witnessed healthy participation at the end of the first year (83 students). 64.1% and 66.6% of responding students (N=81) gave a score of at least 8 on a 0-10 scale (highest=10) to indicate that, to them "*engineering is interesting*" and "*means a lot*", respectively. 68.2% of respondents (N=82) reported that they are interested in becoming an engineer or a scientist. At least 71% of the respondents (N=60) rated their University visit of November 2015 as either "*helpful*" or "*very helpful*" with regard to STEM content and interest in STEM careers. 68.2% of the respondents reported that they were at least somewhat interested in pursuing a career as a scientist or an engineer. The evaluation of the outcomes indicated that learning was taking place across most outcomes.**

Index Terms - Engineering, computer science, junior-high schools, STEM.

INTRODUCTION

The innovation and competiveness of the United States (U.S.) in the areas of science and technology is dependent on a large and strong Science, Technology, Engineering and Mathematics (STEM) workforce [1]. STEM occupations are expected to witness faster growth as compared to all occupations [2] in the coming years. According to the National Science Board Science and Engineering indicators, women and traditionally underrepresented groups are now playing an increased role in the fields of science and engineering. However, these groups are still underrepresented in the science and engineering fields as compared to their participation in the overall workforce [3]. In the coming years, the United States is expected to become more racially and ethnically diverse. For example, the population of Hispanics, who constitute a traditionally underrepresented group in science and engineering, is expected to grow to 28.6 percent of the total U.S. population in 2060 from 17.4 percent in 2014 [4]. In this context, it is imperative to devise and implements strategies that will ensure a strong STEM workforce in the future. This involves strategies that can improve the participation of students from traditionally underrepresented groups in STEM education and, later, in the STEM workforce.

Interest or disinterest in STEM often begins early in the K-12 phase of education [5]. For many students, interest begins to wane around age 11 and part of this could be attributed to the manner in which science is taught formally in the classroom [6]. According to a report from the President's Council of Advisors on Science and Technology (PCAST) in 2010, many American students feel that STEM is difficult and are left unprepared to meet the challenges of the future [7]. One of its recommendations includes creating additional STEM education opportunities for students through individual and group experiences outside the classroom. In this paper, we present the first-year experience in a project aimed in this direction. This project named "*STEM-Inc: Science, Technology, Engineering and Mini-business Incubator*", is an after-school project that mainly targets traditionally-underrepresented students in 7th and 8th grades. It combines engineering and business entrepreneurship concepts and is being implemented as a 3-year project with support from the National Science Foundation through the ITEST Strategies grant [8]. STEM-Inc is currently being implemented by California State University Fullerton (CSUF) in partnership with Anaheim Union High School District (AUHSD) across four junior-high schools.

The remainder of this paper contains the following sections: The next section discusses the rationale for this work. This is followed by a section that describes the methods used in the project, followed by the discussion of results and a concluding section

RATIONALE

It has been observed by researchers that informal math and science programs outside the classroom can be very beneficial, especially for those who are economically disadvantaged and attend low-performing schools [9]. It has also been observed that field trips can positively influence the motivation of students towards science [10]. Furthermore, it has been observed that including computer programming and engineering design enhances their motivation to succeed, work with sophisticated technology and improves higher order thinking [11], [12]. It has also been reported that entrepreneurial education can contribute towards decreased high school drop-out rates and increased positive entrepreneurial attitudes [13]. In addition to this, it has been reported that STEM after-school and enrichment programs are very beneficial for students as they help in improving attitudes towards STEM, increasing STEM knowledge and skills, and increasing the likelihood of pursuing STEM careers [14].

The STEM-Inc project builds on several past research experiences to make STEM-learning an enjoyable and meaningful experience for junior high school students (7th and 8th graders). It aims to involve and engage students in exciting real-world engineering and/or computer science (ECS) projects and experiences. Importantly, it combines the ECS part with business entrepreneurship. This combination with business entrepreneurship is included so that the participating students can experience how ECS projects in the real-world have to consider market/business requirements, and how those requirements help in shaping the final product. By combining business entrepreneurship and ECS, the project provides a platform for the students where they can relate their ECS projects to real-life experiences, which could increase their motivation for STEM-learning. It also engages the parents of participating students through outreach events.

METHODS

STEM-Inc students were mentored by college majors, who were, in turn, trained and supervised by CSUF faculty. The mentors worked in partnership with school teachers for the implementation of the after-school program. Training sessions were conducted for the school teachers and the college student mentors to familiarize them with the program. The training sessions included mobile application development using the *MIT App Inventor* [15], introduction to robotics, and 3D printing. The participating junior-high students were first taught mobile application development using the MIT App Inventor, followed up by hands-on experiences with mobile-app development. They worked in teams to develop sample mobile apps. They also received instruction and hands-on training for programming and robotics. They were then engaged in brain-storming, planning and implementation of engineering projects that aimed to solve a real-world problem. Student teams were organized in the form of business entities. A student-peer-leader acted as the Chief Executive Officer (CEO) of the "business entity". The other student team members played other major roles. Throughout the year, the student participants of STEM-Inc also took part in enrichment activities such as industry speaker sessions, University field-trip, logo design and annual project showcase. Surveys were used to record project data and student perceptions.

RESULTS

The STEM-Inc program witnessed healthy participation during the first year (83 students). At the beginning of the program, in fall 2014, the majority of the participants (64%) were from grade 7. The representation from grade 8 was 36%, as depicted in figure 1. These percentages witnessed a slight change towards the end of the first year (July 2015), with the percentage of 7th graders decreasing slightly to 60.2% and the percentage of 8th graders increasing slightly to 39.8%., as shown in figure 2. At the end of the year, there were 67.9% males and 32.1% females in the program (the number of respondents for this query was 81).

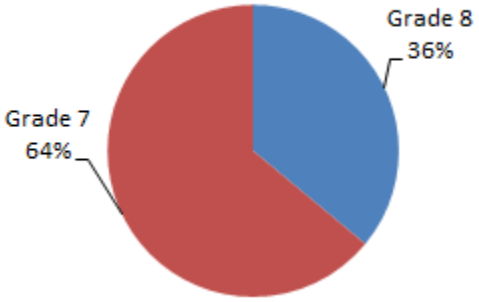

FIGURE 1
DISTRIBUTION OF 7TH GRADE AND 8TH GRADE PARTICIPANTS OF STEM-INC AT THE BEGINNING OF YEAR-1 (FALL 2014).

At the start of the program in fall 2014, when the junior-high school students were asked about the number of times they had participated in various STEM-related enrichment programs or experiences prior to their participation in STEM-Inc, a majority of students reported that they had no prior participation experience. The queries used included a variety of STEM-related programs and experiences, as shown in figure 2. A smaller percentage of students reported to have had one other experience. The percentage of students who reported participating in two or

more enrichment programs was less than 10% for each type of STEM-related experience that was queried. The responses of students for these queries are summarized in figure 3 through figure 6 below. These figures indicate that the STEM-Inc program was successful in attracting many students with moderate to little prior STEM experience.

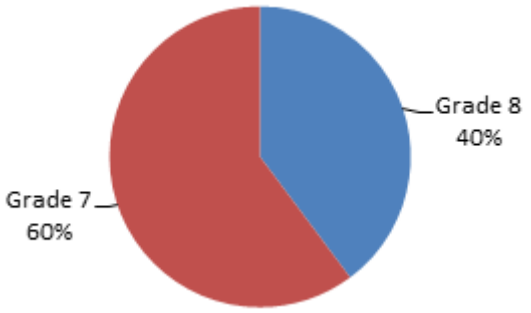

FIGURE 2
DISTRIBUTION OF 7TH GRADE AND 8TH GRADE PARTICIPANTS OF STEM-INC AT THE END OF YEAR-1 (JULY 2015).

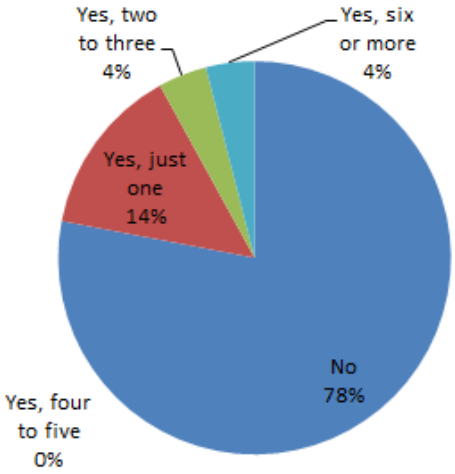

FIGURE 3
PRIOR PARTICIPATION EXPERIENCES IN OTHER AFTER-SCHOOL OR SUMMER STEM PROGRAMS (N=50).

As far as attitudes and engagement towards and engineering and/or computer science are concerned, the first year of STEM-Inc revealed interesting and valuable data. A significant number of students student gave good ratings based on their personal attitudes towards multiple computer science-related attributes at the end of the year (good is defined as a rating ≥8 for some queries, and a rating ≤ 2 for some queries; range is 0−10): The percentages of students who gave high scores for the queries "*computer science is interesting*", "*computer science is fascinating*", "*computer science means a lot"*, "*computer science is appealing"*, and "*computer science is exciting"* were 58.2%, 49.4%, 65.8%, 51.9%, and 49.4%, respectively. The number of respondents, n, for each of these queries was 79. For queries related to engineering, the percentages of students who gave a high score for the queries "*engineering is interesting*", "*engineering is fascinating*", "*engineering means a lot"*, "*engineering is appealing"*, and "*engineering is exciting"* were 64.1% (N=81), 50.6% (N=81), 66.6% (N=81), 58.8% (N=80), and 55.5% (N=81), respectively. These results, summarized in Table I, indicate higher percentages for the engineering attributes.

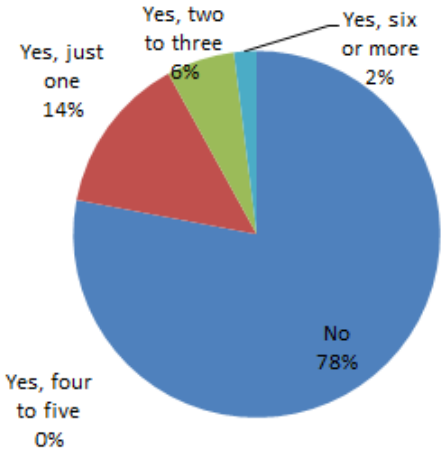

FIGURE 4
PRIOR PARTICIPATION EXPERIENCES IN ROBOTICS COMPETITION OR CAMPS (N=50).

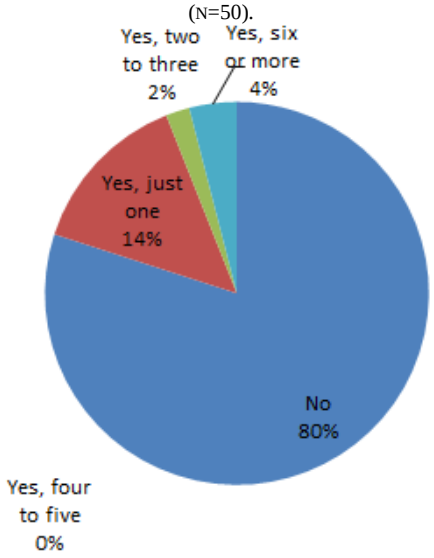

FIGURE 5
PRIOR PARTICIPATION EXPERIENCE IN A STEM PROGRAMS DURING SCHOOL (N=50).

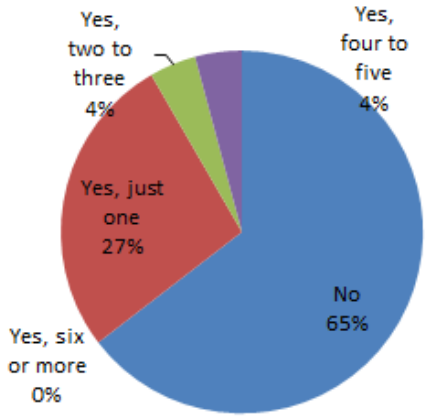

FIGURE 6
PRIOR PARTICIPATION EXPERIENCE IN MOBILE TECHNOLOGY DEVELOPMENT, ROBOTIC ENGINEERING, OR OTHER COMPUTER SCIENCE/ENGINEERING DESIGN PROGRAMS (N=48).

TABLE I
STUDENT ATTITUDES TOWARDS VARIOUS COMPUTER SCIENCE AND ENGINEERING ATTRIBUTES AFTER YEAR-1

	To me, computer science is	To me, engineering is
Interesting	58.2% ;N=79	64.1% ; N=81
Fascinating	49.4% ; N=79	50.6% ; N=81
Means a lot	65.8% ; N=79	66.6% ;N=81
Appealing	51.9% ; N=79	58.8%; N=80
Exciting	49.4% ; N=79	55.5%; N=81

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Students were also asked to respond to queries regarding their attitudes towards STEM careers and the impact of STEM in the world. These queries and the percentages of respondents who responded with either "*agree"* or "*strongly agree"* are summarized in Table II below (possible choices were "*strongly disagree"*, "*disagree"*, "*neutral"*, "*agree"*, and "*strongly agree"*). It can be seen that majority of students agreed or strong agreed with each of the statements in Table II. Most students agreed that a career in STEM would be challenging but, in spite of –the challenge, had very positive feelings about having a STEM for themselves.

TABLE II
STUDENT ATTITUDES TOWARDS STEM CAREERS AFTER YEAR-1

Statement	Percentage *agree* or *strongly agree*
"A career in STEM would enable me to work with others in meaningful ways"	64.6% ; N=82
"Scientists make a meaningful difference in the world"	76.3% ; N=80
"Having a career in STEM would be challenging"	62.2% ; N=82
"My parents encourage me to study STEM"	64.7% ; N=82
"I would love to have a career in STEM"	63.4% ; n=82

When asked to state their level of interest in a career as a scientist/engineer, 68.2 % of the respondents (N=82) responded with either "*Somewhat interested"* or "*Extremely interested*, with 40.2% of these students responding with "*Extremely interested*.

As part of their technical activities for STEM-Inc, students received hands-on training and experience with programming and robotics. At the end of the year, a significant number of students reported that they were able to develop specific skills relating to robotics, programming, and the engineering design process. Some of the queries that were used to obtain the related data are included in Table III. This table also includes the percentages of respondents who "*agreed*" or "*strongly agreed*" with the statements in those queries,

The STEM-Inc enrichment activities included a visit to the main campus of California State University, Fullerton in November 2015. At least 71% of the respondents (N=60) rated their CSUF visit of November 2015 as either "*helpful*" or "*very helpful*" with regard to both STEM content and interest in a STEM career. The individual percentages corresponding to STEM content and interest in STEM careers were 88.3% and 71.7%, respectively.

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STUDENT SKILL DEVELOPMENT IN STEM AT THE END OF YEAR-1

Statement	Percentage *agree* or *strongly agree*
"I know what a microcontroller is"	61% ; N=82
"I know how to program a robot using a microcontroller"	57.3% ; N=82
"I know how to use a Mobile App development platform to develop a Mobile App "	62.2% ; N=82
"I know how to build a Mobile App that can communicate to another device (for example, a robot)"	39% ; N=82
"I know how to evaluate an Engineering/Computer Science product based on a set of requirements"	53.7% ; N=82

Evaluation of the Engineering and Computer Science (ECS)-related outcomes by the advisory board members indicated that most outcomes were being met to a significant extent. These outcomes are as indicated below:

1. "*learned how to identify the connections between math, science and engineering*"
2. "*learned how to identify alternative applications/projects that use similar math, science and engineering concepts*"
3. "*learned how to formulate specifications for a project*"
4. "*learned how to verify the correctness of a solution and apply remediation as necessary*"

5. "*learned how to bring a project/design/problem solution to closure*"

The possible results for each of these outcomes were "*Agree*", "*Strongly Agree*", "*Disagree*", "*Strongly Disagree*", and "*Don't know*". Outcomes were evaluated on the basis of student interactions by the advisory board members. The number of responses measured was 68 (N=68). The results of these outcome evaluations in percentages (rounded) are included in figures 7 through 11. It can be observed that for a majority of outcomes (1 through 3), the combined percentages of "Agree" and "Strongly Agree" evaluations equaled or exceeded 67%. This indicates that most of the participating students of STEM-Inc were able to identify the connections between math, science and engineering concepts, were able to identify applications or projects that used math, science and engineering concepts, were able to formulate specifications, and were able to bring project/design/solution to closure, all of which are important attributes in real-world engineering and computer science. Only outcome 4 resulted in a combined percentage of less than 50%.

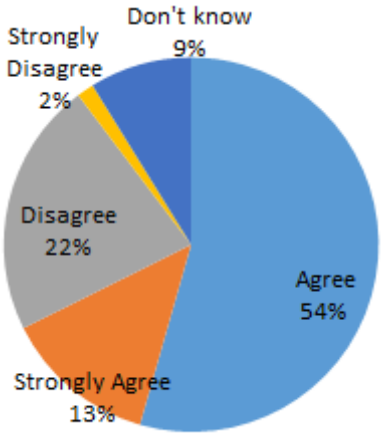

FIGURE 7
DISTRIBUTION OF EVALUATION RESULTS FOR OUTCOME 1 (N=68).

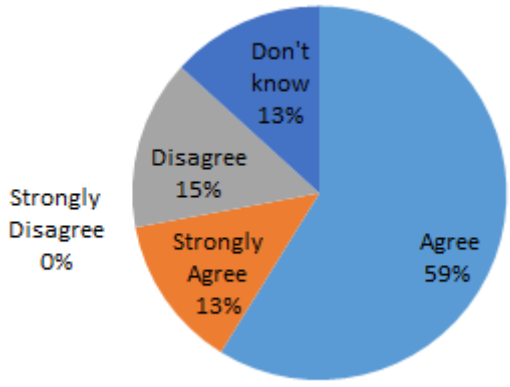

FIGURE 8
DISTRIBUTION OF EVALUATION RESULTS FOR OUTCOME 2 (N=68).

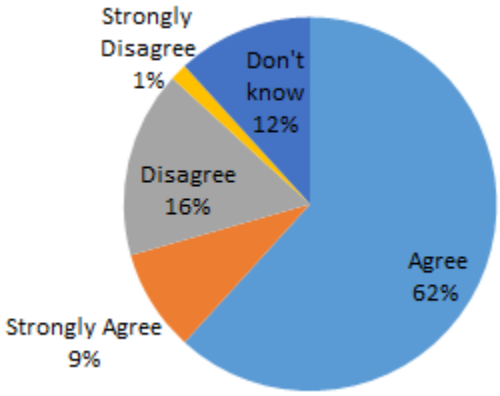

FIGURE 9
DISTRIBUTION OF EVALUATION RESULTS FOR OUTCOME 3 (N=68).

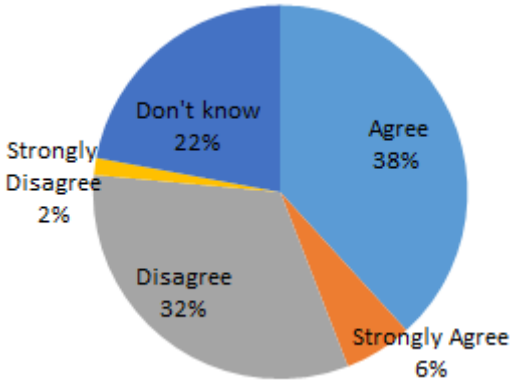

FIGURE 10
DISTRIBUTION OF EVALUATION RESULTS FOR OUTCOME 4 (N=68).

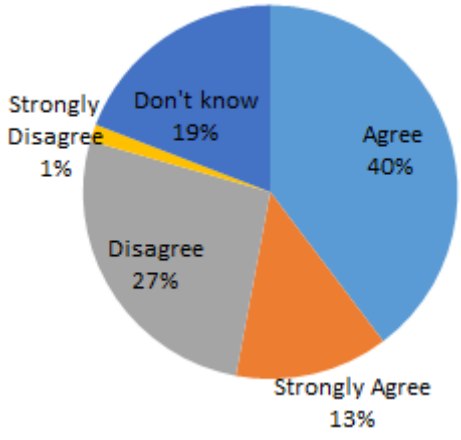

FIGURE 11
DISTRIBUTION OF EVALUATION RESULTS FOR OUTCOME 5 (N=68).

CONCLUSIONS

This paper described the first year experiences in the STEM-Inc program, which is the first experience of its kind for a majority of its participants. As a result of participation in the program, a substantial number of students reported having multiple positive experiences with regard to their engagement in STEM activities. A significant portion of these participants gained specific engineering and computer science skills related to robotics and mobile app development during the program, and expressed interest in pursuing a STEM career. Most engineering and computer science outcomes were achieved to a significant extent.

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