Innovative Mars Exploration Education and Technology Program: Development of an Informal Learning Curriculum (Work in Progress)

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Abstract

The Innovative Mars Exploration Education & Technology (IMEET) program is being developed with the goal of inspiring students, specifically students of underrepresented populations, to learn science, technology, engineering, and mathematics (STEM) content. IMEET is a 3-year project funded by NASA to develop and implement real-world informal STEM education content for high school students and teachers. The content is taught in science museums, planetariums or similar Informal Education Institutes (IEI) where participants collaborate on hands-on projects that engages them in engineering design and manufacturing processes. The curriculum teaches key principles of systems engineering, robotics, digital design and manufacturing, and social product-development using cloud-based infrastructure using Mars exploration as the central theme.

This paper briefly describes the IMEET Program including the first-year deployment of the curriculum in summer camps at four participating IEIs. The paper concludes with the preliminary results of the Year 1 evaluation and outlines the work to be done in Years 2 and 3.

Background and Motivation

The need for a well-prepared workforce in fields related to Science, Technology, Engineering, and Math (STEM) remains at an all-time high. The challenge at hand is to increase student interest in STEM education while studies continue to show the declining interest [1]. Many have shown the success of utilizing programs in informal learning settings to promote desire and success in STEM professions [2]. Research on Social Cognitive Career Theory [3] has found that science, math, and engineering (SME) self-efficacy predicts academic achievement, career interests, college major and career choices [4], and that it is associated with motivation [5]. Therefore, we are examining students’ SME self-efficacy - beliefs about their ability to organize and execute actions to attain desired levels of academic performance in science, math and engineering fields [6] - and their SME outcome expectations - beliefs about what is likely to happen if they pursued a career in a STEM field.

The Innovative Mars Exploration Education & Technology (IMEET) Program encompass three phases:

1. Development of curriculum tutorials to engage students and STEM educators in learning about NASA’s high priority technology areas;
2. Implementation of curriculum during summer camps;
3. Transition summer camp facilitation from developers to STEM Educators.

The program started in 2017 as an effort to provide high school (grades rising 9–12) students with an out-of-school immersive STEM learning experience. The main objective of the IMEET summer camps is to expose high school students to a variety of STEM areas and STEM professionals, through authentic, hands-on project-based learning with the end-goal of motivating them to pursue a career in STEM. The 3-year funding, provided by NASA, allows IMEET to focus primarily on the students from underrepresented populations. In addition, the IMEET summer camps engage high school STEM educators with the aim that they gain
exposure and utilize parts of the program curriculum at their own schools.

**The IMEET Summer Camp Overview**

IMEET summer camps were developed to expose high school students to real-world informal STEM education content. The content is taught in science museums, planetariums or similar Informal Education Institutes (IEI). The participants collaborate on hands-on project work incorporating key principles of systems engineering, robotics, digital design and manufacturing, and social product-development using cloud-based infrastructure - with NASA’s Journey to Mars - the Mars exploration program, as its central theme.

The IMEET curriculum is implemented in two-week long, geographically dispersed, collaborative summer camps, where the students from multiple venues work together to design and build collaborative robots that have the mission to assist with operations on a future Martian mission. Since the goal is to both educate and inspire, instead of using traditional classroom setting, the material is presented through a series of short, you-tube style videos, interactive websites, and hands-on activities designed to keep students continually engaged and interested in the material being taught. During summer 2017, the summer camps ran four times, twice in Florida in June, and twice in Georgia in July; each over a two-week period. At each camp venue, 25 high school students and 5 high school STEM teachers were recruited as participants. There were no participation or registration fees for students and free lunches were included as part of the program. The recruitment process was handled by each participating venue independently, however, the selection criteria were collectively determined by the entire grant management team. High school teachers were paid stipends for their two weeks of participation.

**Curriculum and Activities**

The 2017 summer camp curriculum was divided into two main phases: 1) Instructional phase (Days 1-3), and 2) Collaborative Prize Challenge phase (Days 4-9). In the Instructional phase, the students learn how to design parts (for example LEGO bricks, wheels, blades) in CAD program (CATIA) and then use 3D printers to create them. Students are also introduced to Ground and Aerial Robotics through LEGO Mindstorms kit and off-the-shelf toy quadcopter kit respectively. Students learn the functional/physical decompositions and synthesis of these moderately complex systems, a key concept of systems engineering. Students also learn how to operate both systems, how to tweak the programs/inputs and make observations on how the change in inputs result in the response of the systems. Such exercise builds their confidence and understanding of how the electromechanical systems work. After students are familiar with the technology and concepts, in the learning phase, they are introduced to the history of NASA’s space exploration through series of NASA’s excellent video content available through multiple of NASA’s web resources [7]. Also, students are given opportunity to interact with NASA’s engineers through a live webinar and Q&A session to learn about NASA’s Journey to Mars program.

In the second phase, students are required to work on hands-on team project (aka, the prize challenge) which allows them to implement core concepts learned in the first phase. The theme of the prize challenge is NASA’s past, current and future Mars-based missions; a sample challenge playfield is seen in Figure 1. The teams are required to complete aerial and ground missions which mimic real-world Mars missions’ scenarios. For example, during its exploratory
mission, the NASA Curiosity rover faced unusual wear and tear while navigating through the adverse Martian terrain [8]. The IMEET prize challenge requires students to design and 3D print new wheels which would enable the rover to go over the “rocky” terrain on the playfield on which standard LEGO wheels do not work (Figure 2).

Figure 1. IMEET Prize Challenge Field Layout and students testing their robots on the playfield

Figure 2. 3D CAD wheel model (left) and the robot with 3D printed wheel(right) in action on “rocky” terrain during the prize challenge

Similarly, a drone is required to fly for scouting and beacon-dropping mission. To complete this mission, students need to design and 3D print the drone frame and drop-off mechanism that they can attach to the drone. On Day 9, the student teams compete in the judging round. On the last day of the camp, student teams present their work before their parents, instructors, and other guests.

**Evaluation Plan & Preliminary Results**

The main goal of the IMEET Program is to educate and inspire the next generation of STEM students and educators. This is aligned with goals of NASA’s Space Technology Mission Directorate (STMD), focusing on cultivating the next generation of inventors, engineers, and technologists who will revolutionize space exploration.
The deliverables of the IMEET Program have the following intended long-term outcomes:

Students will:
- demonstrate increase knowledge about STEM principles and common practices;
- report an increase interest in advanced study and career paths related to STEM;
- demonstrate increase confidence in their ability to succeed in STEM careers;
- report more positive outcome expectations about participating in STEM-related activities;

STEM educators will:
- report increased knowledge in technology areas;
- report increased confidence in their ability to teach the developed STEM curriculum.

Data was collected on students’ science, math and engineering (SME) self-efficacy, outcome expectations, and critical thinking skills prior to the summer camp and after the completion of the summer camp. The data was then evaluated to see if SME self-efficacy, positive outcome expectations, and critical thinking skills increase after participation in the camp.

The students received pre/post surveys based on well-established instruments [9, 10, 11]. At the conclusion of the program, the students also received an assessment of their content knowledge as well as a form to provide feedback. STEM educators also received pre/post surveys which were based on the Gibson and Dembo’s [12] teacher self-efficacy scale, Riggs and Enochs’ [13] science teaching efficacy beliefs, Bandura’s [14] teacher self-efficacy scale and the Tschannen-Moran and Hoy’s [15] Ohio State teacher efficacy scale.

Students’ responses to the measures of math/science self-efficacy, math/science outcome expectations, and critical thinking were examined over time to see if there were significant changes from the pre-test completed prior to the camps to the post-test that was completed at the end of the two-week camps. Of the 98 students who completed the pre-test surveys, 67 had matching post-test data for analyzing changes on the outcome variables over time. Results revealed that students exhibited statistically significant increases in two of the three variables. Over the two-week period, students’ belief in their ability to complete math/science tasks, and their use of critical thinking skills significantly increased while the values for their positive expectations for pursuing a math/science degree or career remained approximately unchanged.

Similarly, the STEM Educators’ responses to the measure of STEM teacher self-efficacy were examined over time to see if there were significant changes from the pre-test to the post-test. The results are based on the 15 teachers who had complete pre- and post-test data. Results revealed that teachers exhibited a statistically significant increase in overall teacher self-efficacy for STEM, as well as statistically significant increases in all of the subscales of STEM teacher self-efficacy from pre-test to post-test.

The post-test given on the last day of the program included an open-ended response section focused on providing feedback regarding the experience. Students were asked to think back to the whole two weeks of the program and tell us one thing they learned. Students who responded provided an array of examples highlighting programming, CAD, and teamwork. Four students mentioned CAD directly in relation to 3D printing. Two of the responses made direct mention of Mars, while none of the students referred to NASA or space.
A follow-up question asked the students what they enjoyed the most. By enlarge, the comments reflected a sense of satisfaction at completing the challenge and seeing something they designed built. A sizable percentage also mentioned the people they worked with as the best part. Three students made reference to the trip to NASA; there were no other mentions related to the location at which the camps were held.

When STEM Educators were asked what worked well - the responses were highly positive. A couple educators mentioned they enjoyed watching the students work with each other and collaborate with the instructors and the STEM educators. Most of the STEM Educators commented on the Lego building and thought it was a fantastic way for students to exercise their sense of creativity and ability to work in teams. Additionally, STEM Educators commented that it was helpful having aids (instructor assistants) who were experienced in the software and programming language- it made it easier for the students to learn and enjoy the 3D software.

Overall, STEM Educators agreed that there was alignment between the activities and topics completed during the camp and their own classroom activities. Most STEM Educators mentioned they would implement activities like those of the camps in their curricula for the school year. STEM Educators expressed interest in using some of the materials from the camp such as Lego Mindstorms and CATIA. Some STEM Educators expressed they would not have time to complete the tasks in their own classrooms because of the “standards” they would need to cover before completing the tasks and the lack of materials available to them.

Conclusions

The IMEET Program successfully completed the Year 1 deliverables. This included development of curriculum for deployment, enrollment of a diverse set of students and STEM educators, and first year deployment of curriculum at 4 different camp sites. Holding the camps in two phases (June and July) proved useful as [program] developers were able to take feedback from the first phase and make changes for the second phase. The data collected showed positive increases in self-efficacy, outcome expectation, and critical thinking skills for the students. Similarly, the data for the STEM Educators showed a significant improvement in the self-efficacy in STEM over various scales.

As the structure of the curriculum and the logistics for the camps are now set, it will be easier for the evaluation team to include student work in the evaluation data collected. It is important, however, that all sites function under the same framework (i.e. cross-camp collaboration, final presentations, etc).

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