Enhancing Knowledge, Interest and Self-Efficacy in STEM through a Summer STEM Exploration Program

Ms. Christine Burwell-Woo, Cañada College

Chris Burwell-Woo joined The STEM Center at Cañada College in 2011 after 30 years in industry primarily focused in the area of program and client services management. She currently serves as the Program Coordinator for Math Jam a one-week intensive Math placement/course preparation program and the STEM Institute a summer STEM exploration program for high school students; in addition to her activities as a Retention Specialist in The STEM Center at Cañada College. Prior to her role with Math Jam and the STEM Institute Chris worked on a Veterans Employment Assistance Program grant connecting student veteran engineering majors with campus resources and provided student support for the campus MESA (Math, Science, Engineering Achievement) Program.

In addition to her work at Cañada College, Chris actively supports local education having acted as a board member for the Healthy Cities Tutoring Program, San Carlos Education Foundation, Sequoia High School Education Foundation, and the Sequoia High School AVID Advisory Committee.

Mr. Ray Lapuz, Canada College

Ray Lapuz has been teaching math for 20 years. He coordinated the math department of the Academic Excellence Honors Program, a program for underrepresented students in the sciences at UC Santa Cruz. He also developed math curriculum and taught in the UCSC Summer Bridge through the Educational Opportunity Program for 5 years. In 2000, he began working at Cañada College as a math instructor and MESA Co-coordinator. He eventually transitioned into a full-time faculty position and has been involved in many academic initiatives such as Student Learning Outcomes, Basic Skills, Ethnic Studies Committee, Honors Program, and the Curriculum Committee. Most recently, he developed curriculum for a new Path to Statistics course designed to accelerate the math sequence for non-STEM majors. Additionally he serves as faculty advisor for the Cañada College robotics team and has also been instrumental in developing and designing ePortfolios for Cañada College students to help with their self-efficacy in STEM. One of the founding math faculty of the award-winning Cañada College Math Jam program, Ray has participated in Math Jam since its inception in 2009, and has taken a lead role in the development of upper level math curriculum for students pursuing STEM courses and majors. For the last 2 years Ray has taught the math module in the Summer STEM Institute program creating hands-on experiential math curriculum for high school students.

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Tracy Huang is an educational researcher in STEM at Cañada College. Her research interests include understanding how students become involved, stayed involved, and complete their major in engineering and STEM majors in general, particularly for students in underrepresented populations.

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(Research to Practice) Strand: Other

Abstract:

Many researchers believe that career interests and career plans start developing as early as middle school. However, high school students often passively eliminate technical career options with course choices that do not meet the needs of a STEM academic path. Consequently, providing career exploration programs in the last two years of high school is often too late to give students time to adequately prepare for further study in STEM fields, which may potentially result in depleting the ranks of future STEM majors especially in underrepresented populations. Researchers further believe that fostering an early interest in STEM, supporting student success and confidence in STEM, and providing an improved understanding of STEM career paths will encourage students to pursue STEM careers at a time when they can still make academic choices that will enhance their potential for future success.

In an effort to increase subject matter knowledge, interest and self-efficacy in STEM, a federally designated Hispanic-serving community college in the San Francisco Bay Area developed the STEM Institute, a three-week program for current high school freshmen and sophomores interested in exploring Science, Technology, Engineering and Math (STEM). The program introduces STEM through experiential learning using hands-on/real-world projects, classroom/lab instruction, speakers, on-campus field trips and workshops in five STEM fields of study.

This paper describes the evolution of the STEM Institute, including challenges encountered and strategies employed to overcome those challenges. It also examines the effect that the program had on student interest and self-efficacy in STEM, employing non-parametric statistical tests to compare repeated measurements of student interest and self-efficacy. Program impact on the subject matter knowledge of student participants is also discussed. The paper further highlights best practices that have been developed at the STEM Institute host college to assist other institutions in developing a similar program to increase subject matter knowledge as well as interest and self-efficacy in STEM.

1. Introduction

Increasingly publications describe our nation’s compelling need for “home-grown” STEM professionals while at the same time condemn the lack of preparedness of most graduates for these jobs. Experts are also concerned that that the aging workforce and a reduced labor pool will impact professionals available for the federal STEM workforce. Moreover, despite high unemployment rates, STEM jobs “are going unfilled simply for lack of people with the right skill
sets.”²², further emphasizing the need to train a population of qualified STEM graduates. However, current trends in engineering enrollment reflect a decrease from 6.3 to 5.4 percent of the total degrees conferred.³ The 2012 President’s Council of Advisors on Science and Technology (PCAST) report, “Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics,” indicates that the United States needs to prepare one million additional STEM professionals in the next decade to maintain its dominance in science and technology.⁴ One important strategy for increasing the qualified STEM graduate population is to improve students’ preparedness for the rigorous STEM course loads they will face in college. However, when asked in the 2012 Lemelson-MIT survey of Americans 16-25 what factors might prevent them from pursuing innovation-driven fields, “28 percent said their education left them unprepared to enter these fields”⁵ – at least in part because they did not take advantage of course choices needed for preparation to pursue a STEM academic path. The hierarchical nature of math coursework, for example, requires students to enter the STEM pipeline in middle school by taking 8th grade algebra.⁶ Currently not all school districts encourage or require algebra in 8th grade. Therefore, students potentially miss their chance without even knowing it.

While many researchers believe that career interests and career plans start developing as early as middle school⁷-¹², high school students continue to passively eliminate technical career options with course choices that do not meet the needs of a STEM academic path. Consequently, providing late high school career exploration programs is often too late to give students the time needed to adequately prepare for further study in STEM fields potentially depleting the ranks of future STEM majors especially in underrepresented populations. Moreover, underrepresented students are often limited by financial and transportation barriers when searching for STEM exploration opportunities outside of school and compete with students who already have access to more advanced and specialized courses before applying for such programs.

In addition to encouraging high school students to prepare for a STEM career by increasing their early interest and knowledge in the fields, it is also important to improve their STEM self-efficacy. Self-efficacy is another compelling predictor of STEM academic success and the willingness of students to set challenging goals like a STEM educational pathway.¹³ Defined as one’s belief in one’s own capability to complete specific tasks, perceived self-efficacy is defined as “people’s beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives”.¹⁴-¹⁵ Research suggests people who have strong self-efficacy have a high sense of commitment to the goals they pursue. The more confident one feels about a subject, the more likely one will be drawn to participating in and committing to that subject area.

Experiential programs have also shown to increase STEM self-efficacy.¹³ Thus to improve the STEM pipeline we must both prepare and inspire students to investigate and study STEM and
thereby spark them to pursue STEM careers. To further enhance the STEM pipeline, those encouraged to follow a STEM path must include girls and minorities who are currently underrepresented in these fields. A successful technique for fostering interest in STEM and inspiring student preparation are summer individual and group experiences. This paper will detail the development and treatments of the Summer STEM Institute, which was designed to improve student STEM knowledge and self-efficacy and inspire students to pursue STEM careers when they are still able to make choices that will adequately prepare them for future academic success. This study investigates the effect and significance this program had on the participants’ STEM knowledge, interest and their levels of self-efficacy. The paper will also highlight best practices and challenges overcome during program implementation.

2. The STEM Institute

In the October of 2011, Cañada College a Hispanic-Serving community college in Redwood City, CA was awarded a US Department of Education Hispanic Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) grant. The grant was entitled the California Alliance for the Long-term Strengthening of Transfer Engineering Programs (CALSTEP) and was implemented by faculty and staff in the Division of Science and Technology at Cañada College. Grant goals include improving low levels of preparation especially for underrepresented and educationally disadvantaged students, and early recruitment of students into STEM fields, especially engineering. An initial proposal included the development of a summer junior engineering academy for high school freshmen, sophomores and possibly even middle school students. Later it was determined that for students of this age the program should be expanded to include other STEM disciplines as students interested in many STEM fields might discover engineering applications and careers via the program. Moreover, those who discover engineering applications and careers early in high school will still have time to participate in both summer and academic year engineering opportunities while in high school including the engineering academy for older high school students offered by our own college in collaboration with San Francisco State a large comprehensive urban university. As a result, the STEM Institute program for high school students was designed to increase student interest in STEM careers at a young age, improve student science, technology, engineering and math (STEM) knowledge and awareness, emphasize the importance of taking advanced STEM courses while still in high school, encourage students to take advantage of STEM college courses available to high school students through the Middle College and Concurrent Enrollment programs, and enhance self-efficacy in STEM.

In the summer of 2012 the STEM Institute was piloted including modules in Chemistry, Computer Science, Engineering and Math. Students were initially recruited via a local high school “STEM Academy” program and students joined the existing on campus intensive math preparation program for a week of morning activity. In 2013 the STEM Institute was modified as follows:
• Reworked recruitment process
• Replaced existing on campus math preparation program with a more interactive/hands-on Math module
• Added Earth Science module
• Included ePortfolio work product collection and reflections
• Hosted end-of program family presentation luncheon gala
• Added a program coordinator and student intern staff members
• Enhanced lunch activities to promote some physical activity and artistic engagement
• Extended day from 9am-3pm to 9am-4pm to facilitate student transportation
• Limited enrollment to high school freshmen and sophomores

In June 2013 we conducted the modified the STEM Institute program for rising high school sophomore and junior students and in June 2014 conducted the modified program for rising high school sophomores only. The program focus was again to improve STEM knowledge, interest and self-efficacy by exposing participants to careers in Science, Technology, Engineering and Math through hands-on projects, classroom/lab instruction, speakers, on campus field trips, and workshops in Chemistry, Computer Science, Earth Science, Engineering and Math via both individual and group activities. They were able to use all of the information presented during the mini-lectures by college professors to complete tasks, all while exploring many possible careers in the STEM disciplines. In addition, participants were exposed to the resources available on a college campus through interactions with currently enrolled college students as well as faculty members and a STEM counselor.

The Modules and Reflections

The Summer STEM Institute is divided into five modules: Chemistry, Computer Information Science, Earth Science, Engineering and Math. A college success component is embedded in the program as well. Exit outcomes and representative activities corresponding to each individual module are listed below.

General Goal:

The goals of the Summer STEM Institute program are:
  Increase student awareness and interest in STEM as possible career options.
  Increase students’ awareness of the tools, skills, and resources they need to be successful college students and those courses and resources available to high school students.
  Develop a community of learners and improve self-efficacy among program participants.

Program SLOs:

  Modified perception of STEM disciplines based on newly acquired knowledge.
  Utilize STEM tools, skills and resources to prepare for and be successful in College.
Chemistry Module Student Exit Outcomes:

Students who complete the Chemistry Module will

- Develop appreciation for the role of Chemistry in science and everyday life.
- Apply the scientific method to design experimental work.
- Understand the microscopic nature of matter and its effect in macroscopic behavior.
- Classify chemical reactions.
- Apply gas laws and pH concepts to design a model air bag.
- Make inferences from experimental results to improve a designed model air bag.

Computer Information Science Student Exit Outcomes:

Students who complete the Computer Science Module will

- Gain familiarity with 3D animation and object-oriented programming.
- Learn correct usage of programming constructs.
- Incorporate a scene, characters and other objects into an animation.
- Produce and reflect on a 30-second 3D animated ad.

Earth Science Module Student Exit Outcomes:

Students who complete the Earth Science Module will

- Gain familiarity with geology and topographic maps.
- Identify minerals, the three classes of rocks and the rock cycle.
- Recognize fossils.
- Analyze geologic phenomena like earthquakes and landslides.
- Explore geology in real life outdoor environments.

Engineering Module Student Exit Outcomes:

Students who complete the Engineering Module will

- Identify the major fields of engineering and types of projects and responsibilities that are the most appropriate for various engineering disciplines.
- Use engineering tools such as Computer-Aided Design (CAD) spreadsheets, and simulation software to analyze and solve simple engineering problems.
- Apply the engineering design process, and work effectively as a part of a design team to develop original solutions to engineering problems.
- Read and write elementary engineering drawings, instructions, and reports.
- Perform simple experiments analyze and interpret data, and prepare a report summarizing the results of the experiments.

Math Student Exit Outcomes:

Students who complete the Math Jam Module will
Gain familiarity with math needed to pursue degrees in science and engineering. Practice creating and defending mathematical arguments in a group environment. Gain experience using math to solve a real world issue which might be addressed by STEM career professionals. Record and reflect on data and experiences and create permanent storage tool for projects and reflections.

**College Success Exit Outcomes:**

Students who complete the College Success lunch learning opportunities:

- Become aware of the tools, skills, and resources needed to be successful college students.
- Learn ways to effectively choose a STEM college major.
- Participate in team building exercises and activities.
- Try out areas that can use/add STEM creative/active skills (Art, Dance, Yoga, Frisbee)

**The Engineering Module**

The Engineering Module includes projects corresponding to four major areas of engineering (civil, electrical, mechanical and robotics). Each student receives a short introductory lecture describing the area of engineering and then works alone or in a team on a related project. Project groups range in size from 3 to 5 students depending on the complexity of the project. Groups also include a current community college student who acts as project mentor. Each mentor receives project training and is involved in planning daily activities related to project completion. Below is a description of the engineering module projects used during the last two years of STEM Institute.

- **Civil Engineering – Balsa Bridges**

  Students are asked to implement engineering concepts as they designed and constructed a balsa wood bridge that will carry the maximum load for the least resources. All bridges are tested until failure occurs. Teams

  - Sketch a bridge design including a substructure and superstructure within the dimension limitations provided.
  - Construct the designed bridge. Teamwork and time management are emphasized here. The students are encouraged to do concurrent construction of substructure pieces.
  - Compute the cost of the bridge based on materials used.
  - Present their bridge results, reporting on price and performance of the design, including analysis of the failure mode under terminal load.

- **Electrical Engineering – Circuit Boards**

  Students learn basic circuit principles using an Electronics Learning Lab (ELL). Teams
- Create a simple circuit using the ELL.
- Experiment with the ELL to create circuits that emit light, generate sound, enhance light and sound, convert light energy to sound energy and amplify sound.
- Demonstrate their circuit.

**Mechanical Engineering – AutoCad**

Students are introduced to 3D design using SolidWorks. Students

- Create and model a 3D Part.
- Explore 2D sketching and 3D features.
- Modify a 3D Part.

**Robotics Engineering – Lego Mindstorm Robots**

Students learn how math and science are applied to control robots at the same time they learn to build, program and troubleshoot using Lego Mindstorm Robot Kits. All robots are tested for speed through the maze. Teams

- Build their robot.
- Test the various sensors available in the Mindstorm Kit.
- Write a simple program to perform object detection and obstacle avoidance using an infrared distance sensor.
- Program their robot to autonomously travel through a maze.
- Test their robot in the maze and modify their program for quicker and more reliable completion.

Recent research encourages instructors to “embed reflection” when working with high school students, as even influential events like fairs, field trips and summer programs can be forgotten if students are not asked to intensely ponder the activity and its impact on them.\(^{17}\) As a result, the 2013 and 2014 STEM Institutes included an ePortfolio and presentation component. Students were allotted time each week to reflect on their favorite project in each of the week’s two modules. Reflections included writing, graphs, photographs and related online data. At the end of the session each student selected their top project and presented alone or with a partner at the “Presentation and Award Luncheon Gala”.

**3. Results**

**Recruitment**

The 2012 STEM Institute pilot program initially relied on a local high school “STEM Academy,” which was unsuccessful in filling the available spaces leading to a last-minute recruitment resulting in a student population that did not reflect our desire for traditionally
underrepresented or economically disadvantaged students. In addition, the resulting wide range of ages made it difficult to develop curriculum that was appropriately leveled to all students.

Consequently for the 2013 and 2014 STEM Institutes, recruitment via “nomination” was developed and spaces were limited to rising sophomores and juniors in 2013 and rising sophomores only in 2014. Requests for nominations were extended to two local high school districts as well as clubs and youth organizations. Email requests for nominations were sent to:

- High School STEM Instructors
- High School STEM Academy Teachers
- High School AVID/MESA Leaders
- High School Counselors
- Club and Student Group Advisors

Recruitment also included classroom visits to local area high school math and science classrooms, presentations at high school math and counseling department meetings, college night recruitment tables, summer programs fairs and presentations during on campus high school student visits and tours.

Additionally, program brochures and fliers were distributed and program information and nomination materials made available via the program website - (http://canadacollege.edu/STEMcenter/steminstitute.php)

Along with program participant recruitment, we actively recruited and hired five or six student interns to assist faculty and students during the STEM Institute. Finally, family orientation sessions were added to ensure parental commitment and authorization for participation. More than 25 positions were filled for both the 2013 and 2014 (as compared to approximately 20 in 2012) and the size of our underrepresented/ economically disadvantaged student population grew as well.

**Demographics**

Students were nominated to participate in the STEM Institute by teachers and counselors from high schools in the college’s local service area. From those nominations, more than 25 students were selected to attend the institute each year. The participants were 54% male and 46% female, and the majority of participants identified ethnicity as “Hispanic”, Asian or “White” with “Hispanic” representing by far the largest percentage (Table 1.1).
Table 1.1 – 2013 and 2014 STEM Institute Participant Ethnicity and Gender

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>21.05%</td>
</tr>
<tr>
<td>Black (Non-Hispanic)</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1.75%</td>
</tr>
<tr>
<td>Filipino</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3.51%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>10</td>
<td>13</td>
<td>23</td>
<td>40.35%</td>
</tr>
<tr>
<td>Multi-Race</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>5.26%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1.75%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3.51%</td>
</tr>
<tr>
<td>White</td>
<td>4</td>
<td>9</td>
<td>13</td>
<td>22.81%</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>31</td>
<td>57</td>
<td>100%</td>
</tr>
</tbody>
</table>

Completion

Of the 56 of 57 (98%) students who were enrolled in the program, completed the program.

STEM Subject Efficacy

In 2014 a survey instrument designed to measure student subject efficacy in STEM was added and administered on the first and last day of the three week long program in order to quantify the effect participating in the program had on student subject efficacy. 17 of 27 program participants completed both the Pre and Post survey. The survey questions were added to an existing self-efficacy instrument,\(^{18}\) that required the respondents to indicate their level of agreement with statements related to their confidence in their ability to be successful in STEM related courses or activities. For purposes of this paper we will focus on the STEM subject efficacy aspects of the survey. The subject efficacy portion of the survey required the respondents to indicate their level of agreement with statements related to their knowledge and ability in STEM Institute subject modules. Questions were based on module student exit outcomes. The five available response values were:

Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1).

Table 2.1 delineates the Pretest and Post-test score comparisons for each module including mean and standard deviation and the mean difference.
The survey responses were exported into the Statistical Package for the Social Sciences (SPSS). A Wilcoxon signed-rank test (a non-parametric statistical test used to compare repeated measurements on a single sample) was administered to compare the pre and post-test responses for each of the subject efficacy questions. The results indicated that: a) the participant’s subject efficacy score on all 7 measures improved between the first and second application of the instrument, b) the increase in participant subject efficacy was statistically significant (P<.05) on all 7 measures as well.

**Student Perceptions and Satisfaction**

On the final day of the program students completed an online survey. The survey included questions designed to measure participant satisfaction with the program. All aspects of the program received greater than a 4 rating on a 5 point scale with the community college student staff receiving the highest ratings. 21 of 22 would refer the program to a friend. We believe these results support the importance of including student mentors in programs of this kind.
Table 3.1 - 2014 STEM Institute Participant Satisfaction with Program Elements
Scale 1-5 (1=very dissatisfied to 5 very satisfied) or (1=too easy to 5=too difficult)

<table>
<thead>
<tr>
<th>Satisfied with…</th>
<th>N</th>
<th>Minimum Statistic</th>
<th>Maximum Statistic</th>
<th>Mean Statistic</th>
<th>Std. Deviation Statistic</th>
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</thead>
<tbody>
<tr>
<td>Speakers / instructors</td>
<td>22</td>
<td>2</td>
<td>5</td>
<td>4.18</td>
<td>.853</td>
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<tr>
<td>Topics covered</td>
<td>22</td>
<td>3</td>
<td>5</td>
<td>4.36</td>
<td>.658</td>
</tr>
<tr>
<td>Quality of food</td>
<td>22</td>
<td>3</td>
<td>5</td>
<td>4.41</td>
<td>.734</td>
</tr>
<tr>
<td>Staff</td>
<td>22</td>
<td>4</td>
<td>5</td>
<td>4.59</td>
<td>.503</td>
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<tr>
<td>Lunch time activity</td>
<td>22</td>
<td>2</td>
<td>5</td>
<td>4.14</td>
<td>1.037</td>
</tr>
<tr>
<td>Helpfulness of orientation</td>
<td>22</td>
<td>3</td>
<td>5</td>
<td>4.50</td>
<td>.673</td>
</tr>
<tr>
<td>Chem. Activity Difficulty</td>
<td>22</td>
<td>1</td>
<td>4</td>
<td>2.91</td>
<td>.921</td>
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<tr>
<td>CIS Activity Difficulty</td>
<td>22</td>
<td>1</td>
<td>5</td>
<td>3.14</td>
<td>.941</td>
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<tr>
<td>ES Activity Difficulty</td>
<td>22</td>
<td>1</td>
<td>4</td>
<td>2.41</td>
<td>.734</td>
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<tr>
<td>Eng. Activity Difficulty</td>
<td>22</td>
<td>1</td>
<td>4</td>
<td>2.77</td>
<td>.869</td>
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<tr>
<td>Math Activity Difficulty</td>
<td>22</td>
<td>2</td>
<td>5</td>
<td>3.14</td>
<td>.889</td>
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<table>
<thead>
<tr>
<th>Would refer to a friend</th>
<th>N</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22</td>
<td>21 (95%)</td>
<td>1 (5%)</td>
</tr>
</tbody>
</table>
Summary and Conclusions

The change to a nomination process for program recruitment resulted in improved total numbers as well as the number of underrepresented/economically disadvantaged program participants. Participation from traditionally underrepresented students improved in 2013 and again in 2014 which supports the success of the new nomination recruitment process.

After a year of measuring student self-efficacy the addition of a subject efficacy survey further enhance our data set as it relates to program impact on participants’ STEM knowledge. With statistically significant improvements in all seven areas of measurement, STEM Institute proved to be successful in improving participant subject efficacy in STEM. We plan to continue to measure participant subject efficacy for the duration of the program. Along with subject efficacy improvement, participant satisfaction results reflect overall positive opinions on the program. Open ended survey comments included such statements that also reflect a change in participants’ perception of STEM classes and careers.

“Attending the STEM institute was beneficial to me. It was because it helped me have a better understanding of the classes I'm going to take next year.”

“. . . this program helped me explore new career options.”

“. . . it gave me a broader perspective on the different fields in STEM.”

“I liked the engineering unit the best”

In addition, the 98% completion and recommendation rate bode well for the future of the STEM Institute.

Cañada College will continue to offer the program for the remainder of US Department of Education Hispanic Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) grant. The curriculum and activities will be modified and improved based on feedback from participants, families, faculty, student interns and STEM Center staff. Program personnel will work even more closely with local high schools, youth organizations and past participants to identify and recruit students from the traditionally underrepresented and underserved communities who could most benefit from participating in the STEM Institute program.

Perhaps most importantly we look forward to the future when we will be able to survey graduates to determine the long-term impact of the STEM Institute program.

Acknowledgements

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Bibliography


