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# Impact of a Hands-On, Exploratory Engineering Outreach Program on Knowledge and Attitudes of High School Students (RTP)

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RESEARCH INTERESTS: Include teaching and learning cognition skills, informal learning environments and strategies, and curriculum design.

# Impact of Hands-on, Exploratory Engineering Outreach Program on Knowledge and Attitudes of High School Students (RTP)


## Abstract

Four years ago, the Computer and Electrical Engineering and Computer Science (CEE/CS) Department of California State University, Bakersfield (CSUB) began an outreach program targeted towards high school students interested in engineering. The intent of the program was to encourage local students, particularly underrepresented minorities and women, to attend college and pursue engineering degrees. The outreach program was modeled after previous work that was shown to increase interest in engineering disciplines for women and underrepresented minorities. A major focus of the program was the use of hands-on activities to engage students. Surveys were conducted in each year of the program to assess knowledge of engineering concepts and attitudes towards engineering and college. Ninety-eight percent (98%) of the students were already interested in attending college at the start of the activity, but interest in attending CSUB increased as a result of participating in the activity. Students demonstrated a strong gain of engineering knowledge as a result of participating in the activity. The engineering knowledge gain was greater for concepts that were directly reinforced by the hands-on activities in the program.


## 1 Introduction

Four years ago, the Computer and Electrical Engineering and Computer Science (CEE/CS) Department of California State University, Bakersfield (CSUB) began an outreach program targeted towards high school students interested in engineering. This program was created as part of the grant activities for one of CSUB's grants from the U.S. Department of Education Minority Science and Engineering Improvement Program (MSEIP) [1], which concluded in September 2015. The intent of the program was to encourage more local students, particularly underrepresented minorities and women, to attend college and pursue engineering degrees.

Engineering programs were introduced to the curriculum beginning 2011, in response to local need for high-quality engineering programs. CSUB is located in a region that is marked by low educational achievement and low preparation for college. According to the U.S. Census Bureau [2], only 72% of the population have a high school diploma and only 15% of the population have a university degree. This is well below the national average. The region is also highly diverse, with 63% underrepresented minorities, and CSUB is both a Minority Serving Institution and a Hispanic Serving Institution. The region is also rapidly growing, with a 32% growth since the 2000 Census. Industry demand for highly qualified STEM workers and engineers is high, but the region does not currently have the workforce to meet that demand.

The outreach program was modeled after previous work [3] [4] [5] [6] [7] [8] [9] that has shown the effectiveness of outreach activities on interest in engineering disciplines for women and underrepresented minorities. Anderson and Gilbride [3] and Gilbride et al. [4] focused on

outreach to women and found the activities were effective at increasing both interest in and awareness of engineering. Thompson and Consi [8] found that presenting engineering as fun and exciting was effective for outreach. Furthermore, Yilmaz et al. [9] demonstrated that the effectiveness of the program was affected by the quality and diversity of hands-on activities.

Building on the effective measures presented in the literature, a major focus of the program was the use of hands-on activities to engage students. As we previously reported [10], the first year of the program focused on robotics and in subsequent years we enhanced the program to incorporate a wide variety of engineering projects. The last three years of the program have utilized engineering projects in the areas of electronics, combustion engines, electromagnetism, power systems, and robotics.

This paper focuses on the overall impact of the program on students, now that the grant activities have concluded. In Section 2, the outreach activities are described. Section 3 discusses our survey instruments and data collection methodologies, while Section 4 analyzes the survey results. Section 5 looks at the overall impact of the activities on the participants. Finally, Section 6 gives our conclusions and key findings.

## 2 Outreach Activities

As detailed in [10], the first summer of the outreach program was a 4-week activity on robotics that concluded with a robotics competition between participating students. During the activity, students assembled a robotic arm kit and learned how to program the robotic arm.

Based on feedback from the first activity, the program was enhanced to include a more diverse set of engineering topics and hands-on projects for the remainder of the program. The program was shortened to three weeks, which allowed it to better accommodate the summer schedules of local students. Additionally, upper-division students from CSUB participated in the program as peer mentors to the high school students.

The enhanced program focused on four major areas of engineering: electronics, mechanics of engines, electromagnetism and power generation, and robotics. These areas are described in further detail in Table 1.

| **Electronics** | **Mechanics** | **Electromagnetism** | **Robotics** |
|---|---|---|---|
| ✓ Intro. to basic electronics.<br>✓ Labs that apply electronic components.<br>✓ Use of modern measurement equipment. | ✓ Intro. to combustion engine design.<br>✓ Diesel, four stroke, and two stroke engines.<br>✓ Principles of hybrid systems. | ✓ Intro. to electromagnetism.<br>✓ Principles of power generation and transmission.<br>✓ Building a DC motor. | ✓ Intro. to robotics.<br>✓ Assembling a robotic arm.<br>✓ Programming and its applications in robotics. |

Table 1: Overview of engineering areas in outreach program.

Each area was presented to the students through a series of lectures and reinforced through hands-on activities. The following hands-on activities were developed:

1. Electronics: Use of bench instruments such as oscilloscopes.
2. Electronics: Create a book light circuit.
3. Electronics: Create a night light circuit using a solderless breadboard.
4. Mechanics: Assemble a combustion engine kit and observe its operation.
5. Electromagnetism: Build a DC motor from coiled wire and a magnet.
6. Robotics: Assemble a robotic arm kit and program it to pick up ping pong balls.

Students who completed these six activities before the end of the program were given additional hands-on projects to complete, such as creating an audio amplifier circuit using the solderless breadboard.

A field trip to a National Aeronautics and Space Administration (NASA) facility was also arranged as a part of the enhanced program. Students met with a diverse group of NASA specialists and saw work-in-progress happening on NASA missions. Students were able to observe NASA scientists, engineers, and mathematicians in action, and participate in discussions with mission specialists. The intent of the NASA visit was to expand the students' views of STEM fields and to expose the students to what a STEM career entails.

## 3 Survey Instruments

Students participating in the outreach activity completed pre- and post-surveys during the activity. After analyzing the surveys for the initial year of the program, the surveys were retooled in the 2012/13 academic year to capture more data. The updated annual surveys contained questions to assess knowledge of engineering concepts and attitudes towards engineering and college, as well as background information questions.

The annual pre-survey contained background information questions related to the student's academic level in high school, mathematics and science courses they had taken, other science and engineering outreach activities they had previously participated in, and the name of their high school.

The pre- and post-surveys had matched attitudinal questions to see if the activity had any immediate effect on students' attitudes. The attitudinal questions are summarized in Table 2.

| **Question** | **Response Options** |
|---|---|
| Choose one statement that best describes how interested are you in attending college at this time. | Scale (Very interested to Definitely not interested) |
| Have you applied to college? | No/Yes/Yes and accepted |
| If you have applied to college, what major/s did you select? | List of STEM majors |
| If you have NOT yet applied to college, what major/s might you consider in college? | List of STEM majors |

| | |
|---|---|
| If you applied to a college other than CSUB, if you were not accepted to that college, would you consider CSUB as an alternative college? | Yes/No<br>Also a comment box for open-ended comments |
| If you have not yet applied to college, would you consider CSUB as your first or alternate choice? | Yes/No<br>Also a comment box for open-ended comments |
| Who (relative, teacher, friend, celebrity, etc.) has influences you the most regarding your interest in engineering? What was it about this person that influenced you? | Open-ended comment |
| What interested you about this summer engineering program? (pre-survey) / What did you find most interesting about this summer engineering program? (post-survey) | Open-ended comment |
| What do you expect to do and learn during this summer engineering program? (pre-survey only) | Open-ended comment |
| How well did this summer engineering program meet your expectations? (post-survey only) | Exceeded / Met / Did not meet |
| When you think about mathematics, what do you think about? | Open-ended comment |
| When you think about engineering, what do you think about? | Open-ended comment |
| When you think about the relationship between mathematics and engineering, what do you think about? | Open-ended comment |
| If there were another week to add to the program, on what program topic would you have liked to spend more time? (post-survey only) | Open-ended comment |
| If there were another week to add to the program, and there was another STEM topic not covered in this program that you would like to have explored, what would that topic/s be? (post-survey only) | Open-ended comment |
| Would you recommend this program to other students, or a friend? (post-survey only) | Yes / No / Unsure |

Table 2: Attitudinal questions on annual pre- and post-surveys given to participants.

The engineering knowledge questions were also matched on the pre- and post-surveys. These questions are summarized in Table 3.

| **Question** | **Response Options** |
|---|---|
| Engines: Diesel and Gas engines operate the same way with respect to the fuel they use. | True / False / Not sure; Also a comment box for open-ended comment |
| Engines: How does a combustion engine work? | Open-ended comment |
| How does a transistor work? | Open-ended comment |
| How does a diode work? | Open-ended comment |
| Do you know how to use a “breadboard?” | Yes / No / Unsure |
| How does an X-Ray Machine work? | Open-ended comment |
| How does an Oscilloscope work? | Open-ended comment |
| How do you measure an electric current? | In series / In parallel / Not sure |

Table 3: Engineering knowledge questions on annual pre- and post-surveys.

After the completion of the 2015 program, a final program survey was conducted with all participants in the enhanced program (the summers of 2013, 2014, and 2015). This survey assessed their current interest in STEM fields in general, and Engineering fields specifically. The final survey also had background information questions to determine the participants current academic level. Participants were contacted by phone and by email for this final survey.

The final survey contained the attitudinal questions listed in Table 4.

| **Question** | **Response Options** |
|---|---|
| The summer engineering program provided you with an understanding of what you need to study in college to become an engineer. | Likert scale |
| The summer engineering program provided you with a better understanding of what a career in engineering would involve. | Likert scale |
| The summer engineering program influenced your interest in attending college. | Likert scale |
| The summer engineering program made you interested in STEM fields. | Likert scale |
| The summer engineering program made you interested in engineering. | Likert scale |
| What is your major in college? (Only asked of participants currently in college) | List of STEM majors |
| The summer engineering program influenced your choice of college major. (Only asked of participants currently in college) | Likert scale |

Table 4: Attitudinal questions on final survey.

## 4 Analysis of Survey Results

The results for the updated surveys from the summers of 2013 to 2015 are analyzed in this paper. A total of 55 students completed the annual pre-survey and 51 students completed the annual post-survey. The majority of the participants had just completed either their sophomore or junior year of high school, as shown in Figure 1a. A majority had completed mathematics through Algebra 2 or higher, as shown in Figure 1b. Most had also completed biology and chemistry courses. Less than half of the students had participated in previous STEM activities.

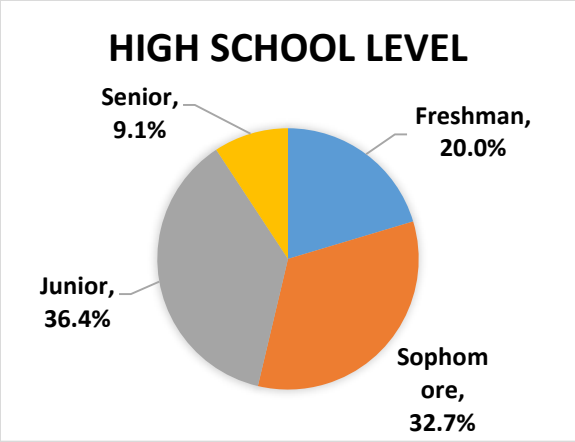


Figure 1(a)

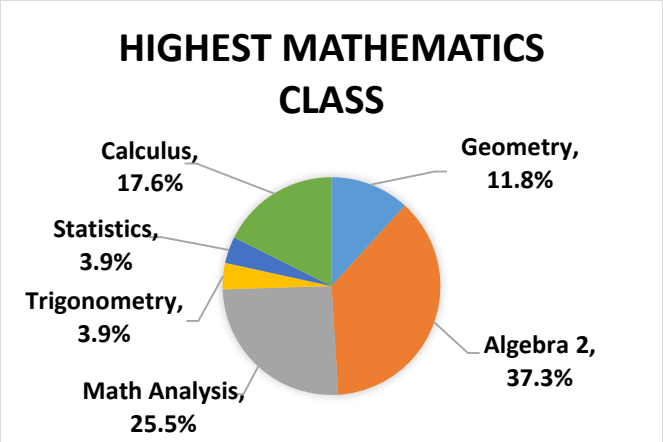


Figure 1(b)

Figure 1: Background information on the high school student participants. Figure 1(a) is the level of high school the students just completed before participating in the program. Figure 1(b) is the highest mathematics course the students completed before participating in the program.

On the pre-survey, 98% of the students were interested or very interested in college, so the pool of students participating in the summer activities were already highly interested in attending college at the start of the activity. However, after comparing the responses on the pre- and post-surveys, the interest in attending CSUB increased as a result of participating in the activity. In the pre-survey, most students indicated that CSUB was only a backup plan, or that they would take lower division courses and then transfer to another university. In the post-survey, some students had similar responses, but others had responses such as "[a] college education is a college education, no matter where it is", "[t]here are good programs here and it's local", and "[t]his college has a good Engineering program." These responses indicate that the outreach program increased awareness about the quality of the new engineering programs at CSUB.

With respects to interest in specific majors, 72.7% of the pre-survey respondents indicated an interest in engineering as a major, while 68.6% of the post-survey respondents were interested in engineering as a major. Even though this slight decrease was observed, there was a corresponding increase in the interest in other STEM majors, such as mathematics and science, on the post-survey. This implies that the program helped the students to better understand the field of study associated with STEM majors, while still maintaining a high level of interest in engineering.

When asked about the person or people who most influenced their interest in engineering, 51% of the students indicated that a relative was their primary influence. Parents were listed as the primary familial influence, but siblings were also a strong influence for 9.8% of the participants. Students also indicated that their high school teachers, or teachers their family knew, were strong influences, with 25.5% of students indicated a teacher influenced their interest in engineering.

The most significant impact was observed in the engineering knowledge questions. The engineering knowledge questions, as shown in Table 3, were graded using a rubric designed for each question. The scale used for all of the rubrics was 0 for an "unsure" or "don't know"

response, 1 for a "novice" response, 2 for an "apprentice" response, 3 for a "proficient" response, and 4 for an "exemplary" response. The definition of "novice", "apprentice", "proficient", and "exemplary" was decided by engineering faculty for each specific question. The average rubric score for all of the questions increased from 1.2 ("novice") on the pre-survey to 2.8 ("apprentice/proficient") on the post-survey, as shown in Table 5. This was a significant increase in engineering knowledge as a result of participating in the outreach program.

| **Engineering Knowledge Question** | **Pre-Survey** | **Post-Survey** | **% Increase** |
|---|---|---|---|
| Diesel and Gas engines operate the same way with respect to the fuel they use. | 1.1 | 2.7 | 139.0% |
| How does a combustion engine work? | 1.6 | 3.1 | 100.8% |
| How does a transistor work? | 1.0 | 2.4 | 149.2% |
| How does a diode work? | 0.5 | 2.0 | 295.9% |
| Do you know how to use a "breadboard?" | 1.2 | 3.6 | 191.8% |
| How does an X-Ray Machine work? | 1.8 | 3.1 | 74.7% |
| How does an Oscilloscope work? | 1.1 | 2.2 | 109.1% |
| How do you measure an electric current? | 1.7 | 3.4 | 100.7% |
| **Overall** | **1.2** | **2.8** | **127.6%** |

Table 5: Average rubric score for the engineering knowledge questions on the pre- and post-surveys, plus the percentage increase in knowledge over the course of the outreach program.

Since many students did not write an answer for all of the knowledge questions or answered "unsure" or "don't know" (a 0 score on the rubric) on the pre- and post-surveys, the percentage of unanswered questions and "unsure" responses was also tabulated. These responses are a strong indicator of a lack of knowledge. As shown in Table 6, the overall percentage of unanswered questions and unsure responses decreased from 60.5% on the pre-survey to 22.3% on the post-survey. Looking at individual knowledge questions, the decrease in unanswered questions and unsure responses was greater for engineering concepts that were directly reinforced by the hands-on activities, such as constructing a model of a combustion engine, building a DC motor, and creating a circuit on a solderless breadboard.

| **Engineering Knowledge Question** | **Pre-Survey** | **Post-Survey** | **% Decrease** |
|---|---|---|---|
| Diesel and Gas engines operate the same way with respect to the fuel they use. | 58.2% | 5.9% | 89.9% |
| How does a combustion engine work? | 58.2% | 9.8% | 83.1% |
| How does a transistor work? | 74.5% | 29.4% | 60.5% |
| How does a diode work? | 85.5% | 51.0% | 40.3% |
| Do you know how to use a "breadboard?" | 21.8% | 7.8% | 64.1% |
| How does an X-Ray Machine work? | 60.0% | 25.5% | 57.5% |
| How does an Oscilloscope work? | 74.5% | 39.2% | 47.4% |
| How do you measure an electric current? | 50.9% | 9.8% | 80.7% |
| **Overall** | **60.5%** | **22.3%** | **63.1%** |

Table 6: Percentage of respondents who did not answer a question on the pre- and post-surveys or who answered with an "unsure" or "don't know" response for a question.

Students also indicated a high level of satisfaction with their experiences in the post-survey. An overwhelming 98% of the students indicated that the program met or exceeded their expectations and said that they would recommend the program to their friends. When asked what they would have liked to have spent more time on, 36.7% said they would have liked to have worked more on the robotics section and 26.5% said they would have liked to have worked more on the circuits section.

The final survey had 19 respondents, with 1 response from the summer 2013 participants, 11 responses from the summer 2014 participants, and 7 responses from the summer 2015 participants. Due to the difficulty in contacting the summer 2013 students, 16 of the students who completed the final survey were still in high school. Most of the respondents indicated that their interest in engineering fields in particular and STEM fields in general increased as a result of participating in the outreach program. Respondents who did not indicate an increase in interest stated that they were already highly interested before participating in the program.

Given the difficulty in contacting the summer 2013 participants, these students were also tracked at the university level to see if they enrolled in CSUB's high school concurrent course programs, were admitted to CSUB, or attended CSUB. Two of the students enrolled in the high school concurrent course programs in computer science and geology. Two of the students participated in the concurrent course programs in calculus and were also admitted to CSUB, but did not attend. Three were admitted to CSUB, but did not attend. Four of the students were admitted to CSUB and attended; three in engineering and one in biochemistry. Two of those four are still currently students at CSUB.

## 5 Conclusion

The annual surveys and the final survey show that the high school summer outreach activity has had a positive impact on interest in engineering and STEM fields. Participants are also more interested in attending CSUB.

The activity also significantly increased engineering knowledge among participants. This was reflected in both an increase in the quality of answers given to the knowledge questions and a decrease in the percentage of unanswered knowledge questions. The decrease in unanswered questions was greater for engineering concepts that were directly reinforced by the hands-on activities in the outreach program.

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