STEM High School: Does multiple years of high school engineering impact student choices and teacher instruction?

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STEM High School: Does multiple years of high school engineering impact student choices and teacher instruction? (Research to Practice)

Strand: K-12 Engineering Resources: Best Practices in Curriculum Design

K-12 engineering programs are rapidly increasing around the nation, particularly at the high school level. Integrating opportunities for high school students to repeatedly practice engineering skills has been suggested to increase students' interest in pursuing a career in engineering. However, little research exists to show the real impacts on the students' attitudes towards engineering and where they end up after high school. Also, as the number of programs increases, so does the need for qualified teachers to instruct those courses.¹ The majority of K-12 teachers do not have a background in engineering; more times than not, they do not know what an engineer does, nor do they have knowledge of the different disciplines of engineering, thusly making it difficult to effectively encourage their students to pursue engineering as a career.^{2,3} One challenge for schools wanting to better implement the "E" in STEM is the training required of teachers to effectively teach engineering in the classroom.

This paper examines 76 students who completed engineering courses in a targeted STEM Academy program over four years of high school. Data is analyzed from multiple sources, including semester surveys that provide an in-depth look at students' changing interests and attitudes towards engineering over four years in the Academy, retention rates of students in the program, and what intended career path these students chose after graduation. In addition, the STEM Academy teachers who taught this group of students over four years provide their views on their students' growth and progress, as well as their opinions of the STEM Academy's progression and effectiveness.

This paper examines how an integrated four-year engineering program in high school impacts students over multiple years, as well as gives insight into the effectiveness of this kind of program when taught by teachers of varying backgrounds trained in partnership with a local university. Specifically, this paper addresses the following question, "Does four years of engineering education at the high school level, when taught by qualified teachers, significantly increase students' interests and attitudes towards engineering, as well as increase the number of students who pursue an engineering-related path after high school?"

Introduction

K-12 engineering education research has been steadily increasing in the U.S. as both the importance of the STEM pipeline *and* the fact that K-12 youth have the resources available to navigate a STEM pathway are realized. A vital component of the STEM pathway includes teachers who are well trained in engineering education such that they are able to direct students not only towards a degree *in* engineering but *within* engineering to a specific field.

The STEM Academy program is implemented at Skyline High School, a large suburban high school in Longmont, Colorado, to provide a program for students to gain up to four years of engineering-related experience as part of their daily school curriculum. The courses in this program are taught by teachers who have worked with engineering faculty and PhD students at the University of Colorado Boulder's College of Engineering and Applied Science to both develop hands-on, design-based engineering classes and to learn how to successfully teach engineering concepts and principles to students.⁴

The STEM Academy partners with CU-Boulder's TEAMS Program—Tomorrow's Engineers... creAte. iMagine. Succeed. The goal of this program is to provide in-class, hands-on engineering instruction in grades 3-12 in high-needs schools in order to have engineering exploration become an integral part of every child's education. The TEAMS Program was first implemented in Centaurus High School's Pre-Engineering Academy, in Lafayette, CO, for four years before its focus shifted to the STEM Academy program—as it still is today. The STEM Academy was created in part to bolster the preparation of its students to successfully pursue career opportunities in fields related to science, technology, engineering and math and has also been a catalyst in attracting students to open enroll in Skyline High School in order to participate in the program. During their 8th grade year, students in the area high schools, and particularly the two middle schools that feed into Skyline High School, have the opportunity to visit the STEM Academy and learn about the academic benefits, as well as the requirements to participate in the academy, as a high school student. Also, for more distant schools in their district, STEM Academy presentations are provided to 8th grade students, showcasing the STEM opportunity at Skyline High School. Subsequently, interested 8th grade students are invited to apply to the STEM Academy and must include in their application recommendations from teachers who can speak to their STEM abilities and academic motivation. The students who enter the STEM Academy reflect the diverse demographics of the area, which is a goal of the program.⁴

The STEM Academy engages its students in challenging math, science, foreign language, computer science, and engineering design curricula. The structure of these high school engineering design courses is intended to develop the skills to be successful in a first-year engineering program *at the college level*. Four years of fundamental engineering design courses are required to earn a STEM Academy certificate at Skyline High School; each course is designed in collaboration with the University of Colorado Boulder's College of Engineering and Applied Science.

Students begin their engineering sequence with the *Explorations in STEM* (grade 9) course, during which they explore the engineering design process and learn the importance of teamwork in engineering. Grades 10 and 11 offer the STEM Academy students a range of semester-long *Creative Engineering* and *Advanced Engineering* courses—with discipline-specific topics ranging from biomedical engineering to environmental or robotics—modeled after CU-Boulder's First-Year Engineering Projects course curricula. Additionally, one of these design courses is offered in the summer for students to take full advantage of the engineering course options in the STEM Academy.

The culminating *Senior Capstone Design* course provides students with the opportunity to research and design a year-long engineering project in teams. These projects are developed in collaboration with the district's *Innovation Center*, a new initiative whereby students bring to fruition R&D ideas from local businesses and develop into a project with the goal of taking the idea to production, and potentially, the marketplace. Each of the engineering courses concludes with an Engineering Design Expo, where the high school students showcase their final products and display posters to an audience of practicing engineers, school district officials, university faculty and K-12 students from other schools.

The Skyline STEM Academy opened in fall 2009 with 80 freshman and 12 sophomores, and has continued to grow to 340 students enrolled in fall 2013, comprised of 35% female, 35% minority, and 23% free- and reduced-lunch students across grades 9-12. The first of the STEM

Academy students to engage in the program over four years graduated from Skyline High School in May of 2013. Survey data from these graduates are analyzed to give further insight into the impacts of completing four years of the STEM Academy program.

Research from the Literature

Research in K-12 engineering education has increased in recent years. However, there still exist gaps in this research with respect to best practices and teacher professional development. While research has looked at the benefits of engineering and STEM education on student achievement, as well as the benefits of trained teachers teaching these classes, there is not much meaningful research that looks at actual data from students who have been exposed to an engineering education track throughout their high school years.

Although the idea of bringing STEM into K-12 curriculum is appealing to teachers, many lack the formal training and knowledge of fundamental STEM principles.^{2,5,6} Few teachers have been properly introduced to the realm of engineering and, therefore, do not actually know what an engineer does, nor can they describe the different engineering disciplines and what they entail. Because of this lack of information, they cannot effectively encourage their students to pursue a specific discipline of engineering—based on interest or complementing skills—or even engineering in general.³ A vast majority of teachers do not feel comfortable introducing, nor are they capable of integrating, STEM teachings into their classrooms; consequently, they may lack the ability to use engineering as a means of connecting other STEM subjects across their curriculum. For example, many elementary school teachers who facilitate students' early exposure to STEM have had little to no STEM education themselves, leaving them struggling with how to incorporate certain STEM ideas into their classrooms.² Previous research shows that holding workshops and conferences for teachers to receive some basic engineering education training has greatly increased the confidence and self-ability these teachers have in relating to and teaching students about engineering.^{2,3}

Research also suggests that exposure to engineering education at the K-12 level increases a student's motivation to not only enroll, but to succeed, in math- and science-related courses in middle and high school, as well as pursue engineering and other STEM careers.¹ *Engineering Our Future NJ* (EOFNJ) is a program established to ensure K-12 students receive engineering education as an integral part of their curriculum. The main purpose of EOFNJ, a New Jersey statewide initiative, is to provide students with engineering experiences, with a focus on innovation. EOFNJ is an example of a state legislative effort to improve K-12 engineering education—a positive turn for New Jersey's education.¹

There have also been studies suggesting that the means by which K-12 students receive education and experience in STEM is too expensive and requires too much time away from school, and that more effective and exciting ways to reach out to students are needed.⁷ One such pedagogy is to engage students in an intentional engineering education track through all four years of high school, focused on following a design process that scaffolds on the previous years' experience. Several programs of this nature have emerged, including the one described in this paper, as well as other high school programs that immerse students in engineering throughout their high school years—in particular, a program in partnership with the Center for Engineering and Education Outreach at Tufts University, another at the Dos Pueblos High School

Engineering Academy in Goleta, California, as well as the *Project Lead the Way* curricula used in states nationwide, to name a few.^{8,9,10}

Research Question

This research is being done to help improve the experience and quality of K-12 engineering education, specifically at the high school level. This paper addresses the question “Does four years of engineering education at the high school level, when taught by qualified teachers, significantly increase students’ interests and attitudes towards engineering, as well as increase the number of students who pursue an engineering-related path after high school?”

Methods

Participants

Survey data from 80 students who graduated from Skyline High School, who participated in the school’s STEM Academy and started in the 2009-2010 academic year was analyzed. Of these 80 participants, 23 were females (30%) and 54 were males (70%); 3 students were removed from the database due to survey incompleteness (see *Statistical Analysis* section). For this analysis, majority students included both female and male Caucasian and Asian students (n=52, 68%), while underrepresented minority (URM) students included female and male African American, Hispanic, Native American and multicultural students (n=25, 32%).

Along with the statistical analysis of survey results, a focus group of six junior and senior students currently enrolled in the STEM Academy was held and a series of attitude questions relating to their opinions about the STEM Academy and changes in their attitudes about a STEM future were asked. Their feedback provided answers to questions on the quality of their engineering exposure as well as the value they placed on participating in the STEM Academy. Qualitative focus groups are generally exploratory in nature and analyzed using a scissor-and-sort technique to determine common themes and enduring impacts of knowledge and skills gained; this technique was used for analysis of our focus group data.¹¹

Teachers, clearly, are also instrumental stakeholders in this endeavor. While teachers did not complete attitude surveys pre- and post-semester, they were also engaged in a small focus group for this paper (n=2). The teachers (three total) have been in the STEM Academy since its inception.

Instrument Design

Students in the Skyline High School STEM Academy are given an online engineering attitude survey during class in the first and final weeks of each semester, with choices on a five-point Likert-type scale for survey questions ranging from “not at all” to “definitely.” To clarify, students who participated in the Academy all four years of high school—and for whom data was analyzed for this research—would have had multiple opportunities to take the survey. Students took the survey an average of six times over four years. The survey was designed to measure change in student attitudes towards engineering as a result of exposure to the different engineering courses available in the STEM Academy.¹²

Students typically completed the survey instrument within ~20 minutes. The surveys were in part modified from existing instruments already in use by the University of Colorado Boulder's College of Engineering and Applied Science to evaluate their *First-Year Engineering Projects* course.¹³ Several survey components from the existing undergraduate engineering literature are integrated into the high school survey, including the Engineering Identity Survey developed by Chachra et al., which assesses the degree of participants' group identification with engineering; the Community Service Attitudes Scale (validated), which assesses the degree of participants' attitudes regarding community service; as well as the Academic Pathways Study (APS) and the Assessing Women and Men in Engineering Project (AWE), designed to examine how student attitudes, skills, and efficacy change over time.^{14,15,16,17} The 53 total items comprise the dependent variables in this study. Various demographic data were also collected, such as gender, ethnicity, and number of years in the Academy, grade, and teacher.

Surveys and focus groups for all participating students and teachers are conducted under the University of Colorado's Institutional Review Board (IRB) approval, reviewed annually by external and internal evaluators. Student responses are coded to protect participant identity.

Variables in Analysis

The independent variables in this paper were previously selected on the basis of empirical research and confirmed through factor analysis. A Principal Components Analysis (PCA) was conducted and reported on in previous research to discern whether particular instructional methods (specifically PBSL) were more impactful on this population's student attitudes as compared to conventional design topics.¹² The resulting five-factor solution includes items related to students' identity with the STEM Academy and engineering (Identity), awareness that there are needs that can be met by engineering (Awareness), efficacy with engineering skills (Efficacy), confidence in engineering-related skills such as math and science (Skills), and attitudes towards community service (Community Service). The PCA also suggests a weak correlation may exist between attitudes towards community service and students' awareness of needs that can be met by engineering. The average of the items that loaded on a given factor is used as independent variables in the remainder of this analysis.

The five factor subscales are examined in this paper with respect to changes in attitudes for one cohort of students over their entire experience in the STEM Academy. Example survey items for each factor are presented in Table 1. Other variables collected in the survey include grade, teacher, years in the STEM Academy, gender, and ethnicity.

Table 1. Factors, related questions and constituent items for the STEM Academy survey.

Factor, Question, and selected constituent items
How much do you agree with the following statements?
Identity (12 items)
<i>In general, being a STEM student is an important part of my self-image.</i>
<i>I am glad I belong to a group of engineering students.</i>
<i>I identify with the students in my engineering class.</i>
Awareness (10 items)
<i>I think engineers create things for the benefit of society.</i>
<i>I understand the impacts of engineering design on the local community.</i>
<i>There are people in the community who need help.</i>

Efficacy (11 items)

I can succeed in an engineering curriculum.

I am good at designing things.

I know what an engineer does.

Skills (7 items)

I am good at problem solving.

I am good at math.

I will succeed (earn an A or B) in my science courses.

Pretend you are going to volunteer for community service sometime in the next year. Rate how you feel about the following.

Community Service (13 items)

Improving communities is important to maintaining a quality society.

I am responsible for doing something about improving the community.

It's my responsibility to take some real measures to help others in need.

Statistical Analysis

The data was analyzed for missing values and data entry errors. Any missing values were examined for patterns, and no student skipped more than one or two items in each administration of the survey. Few students skipped any questions, and there were not any substantial differences between those skipped items. Missing survey data was handled during subsequent analyses with list-wise deletion. Any missing demographic data was retrieved from the high school student database. The survey was voluntary, and any students who only completed one survey over the course of their four years in the Academy were removed from the data set entirely (n=3).

Paired sample t-tests were used with each analysis to determine mean, standard deviation, correlations, and paired differences. Effect sizes were calculated as Cohen's *d* to measure the practical significance of the relationship between initial and final survey administration, independent of the statistical analyses. IBM SPSS statistical software package (version 22) and Excel were used for all analyses in the paper.

Results*Overall Retention Rates*

Initial descriptive statistics unearthed some notable trends in the data. First, we began with 80 students who engaged in the STEM Academy as 9th graders during the 2009-2010 academic year; these students made up part of the 2013 graduating class of seniors from Skyline High School. As expected, attrition would occur over time, and some students would leave the STEM Academy engineering courses—some movement would be voluntary, other involuntary, due to family circumstances. We were curious if such voluntary leaving occurred after a student's 9th grade course(s) or later. Table 2 offers a look at the retention rates of these 80 students from the engineering courses over time.

Table 2. Student retention rates from 2009-2013 (starting N=80).

Year	Students enrolled in STEM classes (N)	Percent of total students in inaugural STEM Academy
2009-2010	80	100
2010-2011	77	96
2011-2012	61	76
2012-2013	37	46

It is important to note that the majority of students remained for the semester-long engineering courses during their 10th and 11th grade years. Overall, the data reveals that students who entered the STEM academy as 9th graders in fall 2009 tried at least two discipline-specific engineering design courses during subsequent years, but 54% of the students left the engineering course track before their senior-year capstone course. Anecdotal feedback from the teachers and students indicate that many who left the program decided to focus on careers outside of an engineering-specific path.

Change in Attitudes over Time

Next, the aggregated survey results per factor were examined over survey administration. Initial data screening generated descriptive statistics on each of the factors shows trends for the overall cohort of students (see Table 3). A paired-samples t-test was used to analyze the within-person differences in factor scores. The resulting paired-sample correlations indicate that students who scored higher on the pre-survey also scored higher on the post-survey. The paired-sample means also demonstrate no significant change in attitudes between the scores from the first and last surveys.

The pre- to post-mean scores of the 77 Skyline High School students who entered the program in fall 2009 (and who took more than one survey during their four years in the Academy) in Table 3 demonstrate an insignificant gain over time in all self-rated attitudes. This entire cohort, therefore, displays a high initial level of response for all factors. The resulting graphical interpretation over all survey administrations is presented in Figure 2.

Table 3. Overall results.

Variable	N	First Survey Mean (SD)	Final Survey Mean (SD)	Mean Difference	Effect Size
Identity	77	4.01 (0.60)	4.05 (0.77)	0.04	0.03
Awareness	77	4.54 (0.37)	4.58 (0.42)	0.04	0.05
Efficacy	77	4.21 (0.49)	4.28 (0.59)	0.07	0.06
Skills	77	4.01 (0.38)	4.06 (0.61)	0.05	0.05
Community Service	77	4.27 (0.54)	4.31 (0.70)	0.04	0.03

Cell entries contain mean scores, (standard deviations), mean difference, and post-survey effect sizes for overall student participation in the Skyline High School STEM Academy on variables of interest.

Figure 1. Factor mean scores over survey administration.
Mean scores of survey factors by survey administration, N=77

Per paired t-tests, the only significant gains ($p < 0.05$) in self-reported attitudes occur for *Identity* between the first and second, as well as the fifth and sixth, survey administrations ($p = 0.002$ and $p = 0.012$, respectively; $n = 77$ and $n = 42$). Significant gains for *Efficacy* occur between the first and second (9th grade) survey administrations ($p = 0.020$; $n = 77$) and for *Engineering Skills* between the second and third survey administrations ($p = 0.040$; $n = 77$). *Awareness* shows a significant gain between the fourth and fifth administration ($p = 0.010$, $n = 51$). There are no significant gains for *Community Service* attitudes.

Change in Attitudes over Time for Seniors

The survey results reported in this section are from matched pre- to post-surveys of the 33 of the remaining 37 students enrolled in the senior capstone course for the STEM Academy (fall 2012 to spring 2013). These students completed the requirements for the STEM Academy certificate at Skyline High School. Of the 33 enrolled students, 28 of the students took their initial survey during their first semester (August) of their 9th grade year, while five students took their initial survey during their second semester (January) of their 9th grade year. Participants included 10 females (30%) and 23 males (70%). There were 26 majority female and male Caucasian and Asian students (79%), and seven underrepresented minority (URM) female and male African American, Hispanic, Native American and multicultural students (21%).

Table 2 provides descriptive statistics on each of the factors for this subset of students. Again, paired-samples t-tests were used to analyze the within-person differences in factor scores. The paired-sample means demonstrate no significant change in attitudes between the scores from the first and last surveys.

The pre- to post-mean scores of the Skyline High School students in Table 4 demonstrate a small, insignificant change over time in all self-rated attitudes. This subset of Academy

graduates displays a similar initial high level of response for all factors, as compared to the overall cohort. The graphical results of each survey administration for these 33 students are represented in Figure 3.

Table 4. Results for seniors.

Variable	N	First Survey Mean (SD)	Final Survey Mean (SD)	Mean Difference	Effect Size
Identity	33	4.06 (0.66)	3.99 (0.85)	-0.07	-0.05
Awareness	33	4.62 (0.33)	4.64 (0.38)	0.02	0.03
Efficacy	33	4.24 (0.50)	4.29 (0.60)	0.05	0.05
Skills	33	4.15 (0.34)	4.26 (0.65)	0.11	0.11
Community Service	33	4.35 (0.54)	4.29 (0.77)	-0.07	-0.05

Cell entries contain mean scores, (standard deviations), mean difference, and post-survey effect sizes for overall student participation in the Skyline STEM Academy on variables of interest.

Figure 2. Factor mean scores over survey administration for seniors.
Mean scores of survey factors by survey administration, N=33

Per paired t-tests, the only significant gains ($p < 0.05$) in self-reported attitudes occur for *Identity* and *Efficacy*, between the first and second survey administrations—during their first engineering-discipline specific design course ($p = 0.026$ and $p = 0.037$, respectively; $n = 33$). There is also a significant gain in *Identity* between the fifth and sixth survey administration ($p = 0.037$ and $n = 28$). There are no significant gains for *Awareness*, *Engineering Skills*, and *Community Service* attitudes.

The students who remained in the engineering courses through the senior capstone course have similar trends in scores over their four years to the overall cohort. Initial gains in attitude scores are somewhat larger than later surveys for all students, suggesting that the impact regarding engineering attitudes and awareness on students occurs early on during their exposure to engineering. Also, scores begin to creep up again after the sixth survey administration (somewhere during their 11th grade year), suggesting that the 10th grade courses (where students are still new to a semester-long engineering design project) is when students are still developing their attitudes about engineering.

These seniors were also given an additional survey during the fall of their senior year, inquiring about their specific interests post-graduation from Skyline High School. From this survey, twelve students were intending to major in an engineering discipline in college (36%), twelve students were intending to pursue a STEM discipline outside of engineering (36%), one student was trying to decide between engineering and another STEM field (3%), and eight students were planning to pursue degrees outside of STEM altogether (24%). In other words, approximately 75% of the seniors in this senior capstone course were headed to STEM fields post-graduation.

Student Focus Group

The focus group held at Skyline High School included six students, all of whom were currently seniors in the STEM Academy. Example questions included:

- Have you/will you be in the STEM Academy for all four years of high school?
- What is your favorite part of being in the STEM Academy/favorite class?
- What type of engineering do you find most interesting?
- Have you noticed a stereotype related to being a part of the STEM Academy?
- What do your friends who aren't in the STEM Academy think about it?
- Do you want to pursue engineering in college?

All six students had some idea about what they would like to pursue in college. These interests included: biomedical and mechanical engineering, computer science, physical therapy, and business. Even for the students who did not think they would directly pursue engineering, they said that the skills they learned in their four years in high school could not compare to anything they would have learned had they not been a part of the STEM Academy. They talked about their favorite classes, and many of them said that the optional summer STEM classes were their favorites.

The students also talked about their favorite parts of participating in the STEM Academy. The students all agreed that they liked the hands-on aspect of the program—that the engineering design classes gave them a chance to take a hands-on, real-life approach to their learning. The project-based curriculum was a favorite part of the STEM Academy for the students in the focus group, all enjoying different, more specific parts of the curriculum. The students enjoyed the open-ended nature of the projects, as well as the creative aspect of coming up with a solution to a problem given certain materials and constraints. They also liked the opportunities that the STEM Academy gave them, such as gaining technical experience working in the *Innovation Center*.

Next, they talked about any stigmas related to being in the STEM program and what the students' friends and their community thought about the program. If there is a stigma related to

STEM, they said, it was definitely a positive one. They perceived that the community holds the STEM Academy students in high regard because they know the time and commitment required to complete the program. A prestige exists about the STEM Academy, which is excellent news for Skyline High School since greater numbers of students will desire to become involved in the program as that reputation for academic excellence continues to grow. Within the high school, students in the STEM Academy perceive themselves as smart and do not feel that other students stereotype them as “nerds.” The group of seniors involved in the focus group felt that the STEM Academy students reflect the diverse students in the school and community.

Additionally, two students from this cohort who subsequently enrolled as first-year undergraduate engineering students at the University of Colorado Boulder (n=2, 50% female) provided feedback on their experiences with the STEM Academy, one semester post. They reported that the STEM Academy greatly influenced their decision to study engineering in college. If not for the STEM Academy, one student said, “I would not have known what an engineer is or have been interested in studying engineering at all.” They both responded that the most valuable aspects of the STEM Academy were practice working in teams and solving problems collaboratively, as well as improving their public speaking skills. Some insightful advice these students had for the STEM Academy instructors was to allow students to explore the different engineering majors in more depth to gain a better understanding of the variety of disciplines, as well as to increase the project scope from the first year in the program to the final senior project course. “Going from assigned challenges and fixed materials lists, to choosing our own problem and working with materials of our choice was a large challenge in and of itself.” Overall, they agreed that the Academy was beneficial to the pursuit of their undergraduate degree. One of the students said, “The concept of working within engineering constraints—deadlines and/or milestones—also proved to be helpful this year in my (University) engineering classes.”

Teacher Focus Group

The opinions of the teachers in the STEM Academy are also important to consider, as it is insightful to learn how they perceive their qualifications to teach, and further promote, an engineering-based curriculum. A focus group of two—out of an initial three—STEM Academy teachers revealed insights to the training involved in teaching project-based engineering courses and their subsequent experiences teaching those courses. Both teachers have undergraduate degrees in engineering and received additional training through their partnership with the University of Colorado Boulder’s College of Engineering and Applied Science in the proper pedagogy required for teaching project-based engineering design. This multi-day training, held in August, included discussion on identifying and explaining the different engineering disciplines and practice in teaching hands-on engineering activities. Teachers also learned what makes a good engineering student and how to effectively teach different engineering habits of mind. As a result, these teachers knew more than the average high school teacher about what engineering is, what the different disciplines entail and how to explain an engineering career path to students. In short, the training gave them the confidence necessary to encourage students to think about and prepare for careers in engineering.

Example focus group questions included:

- How comfortable do you feel teaching engineering-related education?

- What are the hardest and most rewarding parts about teaching an engineering-specific class?
- What is your favorite part about teaching in the STEM Academy?

When asked about the rewards of teaching engineering-related classes to high school students, along with their favorite parts of teaching in the STEM Academy, the teachers had much to contribute in terms of feedback. Some of their comments were, “It is rewarding to watch certain kids realize that the capabilities they have are far beyond what they originally thought.” and “These kids realize that anyone can do engineering if they are willing to put the work in.” Another positive outcome of the STEM Academy is that it helps students learn valuable life skills that go beyond engineering. These include public speaking, working and communicating effectively and efficiently with peers (teamwork), and presenting in front of a group.

The teachers reported that they have seen many high achieving students enter the program who are extremely smart but lack the skills necessary to become an engineer. By the end of their four years, certain students who had none of these skills to begin with change dramatically and learn to utilize all the above-mentioned skills in everyday life. For students who did not end up pursuing an engineering or STEM-related field, the Academy still taught them valuable skills that they will carry with them throughout their lives. They further stated that one of the hardest parts of teaching in the Academy was balancing the skills and interests of high school students. “It is a challenge to make a project hard enough so that the fast workers do not finish too early and become bored, and easy enough so that slow workers can have enough time.”

The teachers also talked about the stigma related to engineering among the rest of the teachers in the school. Other non-math or science teachers make comments to the STEM students telling them that engineering is hard and is only for really smart people. The STEM teachers state that they would like to educate the other teachers about engineering, informing them that any motivated student with a good work ethic can achieve success in a STEM-related field. To help alleviate these preconceived, negative stigmas about engineering, the STEM teachers plan to spend more time informally educating their school staff about the field of engineering, that it is for any student who is willing to work hard and dedicate themselves to it; it is not just for “really smart” people who are good at math.

Limitations of Study/Further Questions

The findings of these analyses should be placed within the limitations of this study. The cohort of participants is drawn from students attending Skyline High School in Longmont, CO. Students self-select into the program at this high school by applying to the STEM Academy during their 8th grade year. While 8th grade teachers and counselors are knowledgeable about the STEM Academy and make recommendations to diverse students to apply, this still limits the generalizability of the findings.

Students did not all take the survey at the same time, instead taking the survey pre and post of each semester that they enrolled in an engineering design course. Since students select the 10th and 11th grade engineering courses that are of interest to them, from a variety of discipline-specific topics, the experiences they have are varied throughout these middle two high school years as well. Additionally, the online survey was voluntary for students, and they were given classroom time to complete the survey. Due to this voluntary nature, students may have

unfortunately missed a survey administration at the beginning or end of a semester course due to absence from class that day or by choosing not to complete the survey.

There is attrition throughout the four years of the Academy. To tell the story of a participant's first and final attitude towards engineering, we used their first and last survey responses, completed between 2010-2013 in most of our analyses. While we also used the interim survey responses in graphically depicting the relatively stable attitudes over time, it would be useful to survey the students who left the STEM Academy during their senior year to determine if attitudes persist, even if the coursework does not (as suggested in the focus groups).

Also, it is difficult to differentiate the learning that went on between the sections of the course, due to instructor variability. The courses referenced in this paper were taught by three separate instructors over the four years of this study. The teachers were trained in partnership with the University of Colorado Boulder's College of Engineering and Applied Science in teaching engineering design, and two of the teachers had engineering undergraduate degrees. They also worked closely together on a daily basis on the courses, shared an office space, and sometimes engaged (i.e., co-taught, in some cases) in each other's classes. Newer teachers to the STEM Academy program do not exclusively have engineering backgrounds but still engage in summer engineering training. Anecdotal evidence indicates that all these teachers are highly regarded by students, but variability still exists in their teaching styles.

Conclusion/Discussion

This paper examines multiple facets of the first graduating class of students in a four-year high school STEM Academy program. We look at retention rates of students in the program and semester attitudes surveys towards engineering. We also consider the qualitative discussions of both teachers and students in the STEM Academy, and their opinions of the program quality and structure. Specifically, this paper addresses the question, "Does four years of engineering education at the high school level, when taught by qualified teachers, significantly increase students' interests and attitudes towards engineering, as well as increase the number of students who choose an engineering-related path after high school?"

Overall, we find that students are not deterred by their initial foray into engineering, but remain in the STEM Academy to try a second and often third engineering design course. This supports similar experiences of which we have heard anecdotally from our other high school partner programs—that students take a few electives and then pursue other interests outside the confines of the certificate program. Of the original cohort, 46% persisted to a senior capstone course; however, some of the original students were still not intending to choose engineering as their college career path. This is unfortunate, but realistic in that we cannot expect that all students will choose an engineering career path. Of those that took the senior capstone course, 36% voiced an interest in pursuing engineering in college—these numbers reinforcing the reality that not all students who engage in engineering design courses in high school will persist to an engineering college degree. One fact remains, however: the hands-on, team-based, problem-solving practices learned during engineering courses in high school are perceived as valuable and applicable to other career pathways—whether or not a student pursues a STEM field.

The semester surveys revealed the following: little change over time in students' identity with STEM and engineering; an awareness that there are needs that can be met by engineering;

students' efficacy with engineering skills; students' confidence in engineering-related skills, such as math and science; and finally, their attitudes towards community service. The results showed only significant gains during early design courses for any factor. For the 33 students who took the senior capstone course and completed the STEM Academy surveys, similar trends are seen. The data suggests that the early courses are the most impactful on the students' attitudes during the engineering design sequence, and that *deep attention on offering students real engineering experiences should be integrated into the initial engineering exposure for high school students*. Based on this research, and supported by anecdotal feedback from students, we suggest that later courses instead focus on the skill building that is useful to succeed in any college degree program, such as teamwork and creative problem solving.

Lastly, focus group results suggest that students who engage in engineering design courses in high school do not feel isolated from their peers, but, in fact, perceive their involvement in the program as prestigious, offering that others look to them as school leaders because of the time and effort required to complete the STEM Academy curricula. The focus group discussion also supports the long-term benefits of learning STEM topics through open-ended engineering on other disciplines, relating that they feel adequately prepared for any challenging STEM discipline post-graduation. And, teachers' focus group results report positive growth for students regardless of their intent to pursue an engineering or STEM-related career path, a positive result by any means. They also reported that the training provided by their partnership with the University of Colorado Boulder gives them added comfort to teach to kids' strengths as well as confidence to engage in discourse with students about engineering as a career.

In summary, the results of our research indicate that a systemic four-year program is not essential to the long-term impact on a student's choice to pursue an engineering or STEM-related future, but that such deep and broad exposure does no harm to their collegiate, or life, successes. From a college perspective, having students gain engineering awareness *before* they commit to the demands of a college engineering course of study is a valuable outcome by any measure.

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