An Engineering Summer Program for Underrepresented Students from Rural School Districts

Matthew E. Elam, Brent L. Donham, Stephanie R. Solomon
Texas A&M University-Commerce

Abstract

A two-week summer program designed to promote interest and learning in the Science, Technology, Engineering, and Mathematics (STEM) fields is documented. The program included a week-long engineering emphasis. Students and teachers from ten rural and financially disadvantaged school districts participated in the program. Three middle school and three high school students were chosen from each district. Students were selected by their districts based upon interest and/or perceived potential in STEM fields, with an emphasis placed on underrepresented and first-generation college students. Additionally, one middle school and one high school mathematics or science teacher from each district participated in the program, enabling the program's curriculum to be transferred back to the secondary classrooms. Pre- and post-student surveys and parent surveys were administered to assess the success of the program. Results indicated the program had a positive impact on students' attitudes towards engineering.

KEYWORDS

engineering summer program, pre-college students, underrepresented students, rural schools

Introduction

The growing concern for the shortage of engineers in the United States has led to a heightened awareness for the need for engineering education in secondary schools. This is evident in a National Academy of Engineering (NAE) and National Research Council (NRC) report underscoring the critical need for engineering education in K–12 classrooms (NAE & NRC, 2009). This report communicated that engineering education could result in improved student achievement in science and mathematics, increased awareness and interest in engineering, and an increased level of technical literacy (NAE & NRC, 2009).

This has resulted in the development and implementation of specialized high school programs such as the STEM academies established in Texas under the Texas Science, Technology, Engineering, and Mathematics (T-STEM) Initiative (Texas High School Project, 2011). With the high success rate of the approximately three dozen academies, as measured by the state's academic standards, additional funding is being made available to double the number of academies over the next few years (Office of the Governor, 2011). Universities and educational-based companies are actively engaged in developing curricula for secondary programs. Examples include Project Lead the Way (Project Lead the Way, 2011), The Infinity Project (The Infinity Project, 2011), and Engineering Your Future (Gomez et al., 2006).

Despite the continued growth in this area, participation and accessibility to these programs remain a concern. This is evident from a 2009 federal initiative's goal to improve participation and performance in the STEM areas, especially for underrepresented groups (The White House, 2011). The focus of this paper is on these groups in rural areas. It is reported that 56% of public school districts are in rural areas, which serve 21% of all public K–12 students (Provasnik et al, 2007). Student population and available resources often limit courses and programs available to rural students. An example of this is that 69% of rural students were enrolled in schools offering Advanced Placement (AP) courses compared to 96% and 93% of the students at suburban and city schools, respectively (Provasnik et al, 2007). Rural school districts will face similar challenges implementing specialized engineering programs (Provasnik et al, 2007).

Research indicates students' educational and occupational aspirations are shaped in part by their experiences and exposure to given career fields (Haller & Virkler, 1993, McCracken & Barcinas, 1991, Reid, 1989, Roscigno & Crowley, 2001). One study showed no differences in occupational aspirations between rural and non-rural students except in the areas of professional and technical careers (Haller & Virkler, 1993). A similar study concluded that students pursuing a higher education seemed to choose areas they had been able to observe or experience (McCracken & Barcinas, 1991). Given the typical industries found in a rural community, as well as limited access to specialized STEM programs, these studies imply rural students may be less likely to pursue engineering without some form of intervention. A number of programs outside the formal school setting, including summer programs, have been and continue to be employed as a means to promote career and educational awareness for students with limited access or exposure to technology and the STEM fields (Abdel-Salam et al., 2009, Martinez & Hibbs, 2003, Matson & DeLoach, 2004).

This paper documents a two-week summer program called X-TEEMS (eXtra Technology, Engineering, Education, Mathematics, and Science) designed to promote interest and learning in STEM fields, with an emphasis on engineering. The program was funded by grants from the Greater Texas Foundation and the Texas Higher Education Coordinating Board (THECB). An earlier version of this paper, mainly without the following literature review and TOSRA (Test of Science-Related Attitudes) analyses, is in the American Society for Engineering Education Gulf-Southwest Annual Conference proceedings (Donham & Elam, 2010).

Literature Review

A number of papers in the research literature document summer opportunities for pre-college students to be introduced to STEM fields. Research publications searched were *Advances in Engineering Education,* the *American Society for Engineering Education Annual Conference Proceedings,* the *Journal of Engineering Education,* and the *Journal of STEM Education: Innovations and Research*. The following categories of papers emerged from the search: summer programs, research experiences, internships, and programs for transitioning from high school to college.

A paper from Louisiana Tech University illustrated a residential summer program that recruited seventh and eighth graders from disadvantaged parishes of Louisiana for additional mathematics and science learning. Areas touched on during the program were problem solving, fatigue, design, prototyping, Charpy impact testing, and properties of plastics. All areas involved mathematics and science to implement a cornerstone for engineering. Assessments were taken pre- and post-program that displayed increases in students' mathematics and science skills, as well as interest in engineering (Jordan & Sundberg, 2004). This is one of many papers demonstrating how summer programs were used to change attitudes towards engineering. Included among these are Bachman et al., 2008; Beck et al., 2010; Bottomley & Parry, 2002; Burtner, 2001; Burtner & Relyea, 1998; Das, 1997; Dimitriu & O'Connor, 2006; Enriquez, 2010; Estrada & Leelani, 2005; Green & Taylor, 2005; Harriger, 2008; Hurtado et al., 2009; Jordan et al., 1999; Kuyath et al., 2005; Kuyath & Sharer, 2006; Liles et al., 2010; Madihally & Maase, 2006; McGrann et al., 2010; McLaughlin, 2006; Pierson et al., 2002; Rabb & Rogers, 2010; Truax et al., 2008; Vallas et al., 2006; Yelamarthi & Mawasha, 2008; and Zhe et al., 2010.

One paper focused on research experiences for undergraduates (REU) at Northwestern University and Vanderbilt University. Funded by the National Science Foundation (NSF), the summer program focused on research, ethics, and communication of engineers. The students had a research project throughout the summer that related to their prior background. They created education materials for middle schools, high schools, and higher education programs. All students were supervised by a VaNTH (Vanderbilt, Northwestern, University of Texas at Austin, and Harvard-MIT Division of Health Sciences and Technology) administrator throughout the program. Concept maps were used to express the students' learning in the courses. Students showed expansion of knowledge in ethics and communications. It was also shown through this summer program that students were able to achieve core competency understanding by participating in such programs without taking formal courses (Hirsch et al., 2005).

Another paper denoted how research was a vital part of the educational process in the engineering field. The Dwight Look College of Engineering at Texas A&M University held a four-week summer research program for teachers who worked predominately with Hispanics and African Americans. It focused on research, laboratory experiences, real world applications, and implementation in the classroom. The participants were introduced to current faculty researchers to gain insight and expand their research abilities. They also were taken on-site to different industries to experience engineering first hand (Price et al., 2004). Additional papers also present the importance of research in engineering, including Autenrieth et al., 2009, Dann et al., 2007, and Grimberg et al., 2008.

Iowa State University (ISU) provided an NSF-funded internship program for female high school students to help recruit them to an engineering or science degree. The students stayed on campus for six weeks to either work in the ISU research lab alongside an ISU student mentor or to work directly with a corporate mentor in relation to the company's work to develop STEM lesson plans for K–12 students. Students visited companies to experience how science and engineering were being used in product development and production. The internship program proved its success by recruiting the high school interns into STEM majors in college (Genalo & Smith, 2003).

A paper reported a summer transition program (STP) funded by NSF. Virginia Commonwealth University held a four week summer transition program for twenty-two underrepresented incoming freshmen. Entrance into the program was based on high school GPA, mathematics placement test scores, and chosen major. The main focus of the STP was to prepare the students for college life and to increase their retention rate. Students participated in college academic courses, were helped with coursework by tutors, listened to speakers from STEM fields, and took field trips. A few students were able to participate in research opportunities with a mentor in a topic of interest. To track student success and opinions during the STP, a survey was given at the end of the second and fourth weeks. Results varied among the students according to their level of mathematics achievement and study habits the students practiced, but overall the surveys showed better performance in mathematics courses than those not involved in the STP. Upon completing the STP, students had six credit hours of college coursework and a better understanding of college life to help ensure a higher success rate (Alkhasawneh & Hobson, 2009). Other references for STPs include Enriquez, 2010, Gleason et al., 2010, Reisel et al., 2010, Russomanno et al., 2010, Shy et al., 2008, and Vallas et al., 2006.

Some summer opportunities had more than one of the characteristics of summer programs, research experiences, internships, and programs for transitioning from high school to college (e.g., see Bualuan, 2007 and Jackson et al., 2008). A directory of pre-engineering summer programs listed by state is available from the Engineering Education Service Center website. The directory includes program descriptions and contact information.

Methods

Students from ten rural and financially disadvantaged school districts participated in XTEEMS. Three middle school students and three high school students were selected from each school district. A total of 62 students participated in the program (two alternates replaced students who were unable to complete the program due to family issues). Table 1 shows the grade level completed for the program participants.

Students were selected by their school districts based upon interest and/or perceived potential in STEM fields, with an emphasis on underrepresented and first-generation college students. Female students totaled 28, or 45.16% of the participants, and male students totaled 34, or 54.84% of the participants. The percentage of female participants was large considering only 18.0% of the Bachelor of Science degrees in engineering were awarded to females in the United States in 2008 (ASEE 2009). Tables 2 and 3 show the participants' ethnicity and the highest education level achieved by their parents, respectively. Data for ethnicity and parents' education level was comparable to the national statistics for rural locales (Provasnik et al., 2007).

In addition to the students, one middle school and one high school science or mathematics teacher from each school district was selected to participate in X-TEEMS. Teachers were introduced to the principles of Project Based Learning, which they were able to apply to subsequent activities during the program. The purpose of involving the teachers was to enable the transfer of the activities and instructional strategies back to their classrooms. This leveraging allowed the efforts of the program to be exposed to students who did not participate in it.

The first week of the summer program had an engineering focus, which was followed by an introduction to other STEM areas during the second week. The activities for the engineering week were designed to promote awareness of

Grade Level Completed	Number	%
5	2	3.23
6	7	11.29
7	20	32.26
8	7	11.29
9	11	17.74
10	8	12.90
11	7	11.29
Total	62	100.00

Table 1: Grade level of the X-TEEMS participants

Ethnicity	Number	%
American Indian/Alaskan Native	1	1.61
Asian or Pacific Islander	2	3.23
African-American	2	3.23
Hispanic	10	16.13
White	45	72.58
Other	1	1.61
No Response	1	1.61
Total	62	100.00

Table 2: Ethnicity of the X-TEEMS participants

Education Level	Mother (%)	Father (%)
Not a High School Graduate	8.06	12.90
GED	6.45	8.06
High School Graduate	25.81	29.03
Some College	32.26	24.19
Associate's Degree	6.45	4.84
Bachelor's Degree	16.13	8.06
Master's Degree	3.23	4.84
Doctoral Degree	0.00	0.00
No Answer	1.61	8.06
Total	100.00	(rounding) 99.98

Table 3: Parents' education level for X-TEEMS participants

the various engineering disciplines and careers through hands-on experience illustrating engineering and scientific principles. The format for the engineering activities included introduction of a key concept and/or principle, participatory activity demonstrating a practical application, and promoting career awareness through interaction with engineers and/or industry tours. The primary activities and competitions employed during the engineering week of the program follow:

- Structure Design – Student teams designed and constructed a basic structure out of newspaper. Structures were evaluated based upon meeting the design specifications and originality.
- Egg Bungee – Using principles in an engineering design process, student teams designed, created, and tested an egg bungee apparatus. Tteams competed to see how close an egg, dropped from a specified height in the bungee apparatus, came to the floor without breaking.
- Kite Design – Using basic engineering design principles, simulation software, and fundamentals of aerodynamics, student teams designed, built, and tested various kite designs.
- GPS Scavenger Hunt – Student teams participated in a scavenger hunt on campus using GPS technology.
- Robotics – Using Lego Mindstorms robotic kits, student teams designed and built a robot to accomplish a defined mission. The specified mission required students to employ basic robotic, mathematical, mechanical, and programming principles. Teams were judged not only on how the robot performed the required task but also on required design documentation in an engineering notebook.
- Semiconductor Manufacturing Technology – A hands-on, interactive presentation on semiconductor manufacturing, which included an overview of the manufacture of an integrated circuit, application to current technology, and a smocking (bunny suit) demonstration.

In addition to these activities, students received a guided tour of a food manufacturing plant and a construction site. The tours highlighted careers and engineering disciplines associated with industrial manufacturing and the construction industry. Also, discussion panels comprising engineers from local companies spoke to the students and answered questions about their fields and careers. Engineering disciplines represented on the panel included mechanical, chemical, electrical, civil, industrial, and microelectronics.

A feature of X-TEEMS was the team design project. During the course of the program, teams from each school district developed a proposal for a design project, which was presented at the end of the X-TEEMS program. The project was then designed and implemented by the students and teachers during the school year. The program culminated with a demonstration and final presentation at the summer site of the program. Design projects included robotics, hovercraft, alternative energy sources, aerodynamics, RFID technology, GPS technology, and sustainable materials.

Results

Assessments were administered to both students and parents to gauge the success of the X-TEEMS program in positively influencing their attitudes towards STEM disciplines. The most statistical of these assessments was a pre- and post-program student assessment called TOSRA (Test of Science-Related Attitudes). TOSRA measures seven different science-related attitudes (Fraser, 1981):

- Social Implications of Science (S)
- Normality of Scientists (N)
- Attitude to Scientific Inquiry (I)
- Adoption of Scientific Attitudes (A)
- Enjoyment of Science Lessons (E)
- Leisure Interest in Science (L)
- Career Interest in Science (C)

A modified version of TOSRA was implemented at both the beginning and completion of the program. The modifications involved changing the words ""science"" and "scientific" to "engineering," and "scientist" to "engineer". A similar use of TOSRA may be found in Clewett and Tran (2003), which also cited references documenting TOSRA's effectiveness in evaluating these attitudes. TOSRA for engineers consists of seventy statements, ten for each of the attitude categories. The five possible responses (Strongly Agree, Agree, Not Sure, Disagree, Strongly Disagree) are scored 1, 2, 3, 4, 5 (respectively) or 5, 4, 3, 2, 1 (respectively) depending on the statement. The end result is that the lowest score (1) indicated the most negative attitude towards engineering and the highest score (5) indicated the most positive attitude towards engineering. The lowest and highest score totals a student could have

Assessment	Statistic	S	N	I	A	E	L	C
Pre	Mean	38.5	36.2	40.1	39.1	37.6	33.1	35.3
	Standard Deviation	3.9	3.2	4.4	4.3	6.1	6.2	6.4
Post	Mean	40.2	37.6	39.5	39.6	38.7	34.3	37.2
	Standard Deviation	4.9	4.3	5.0	4.7	6.5	7.3	5.8
(Post Mean) – (Pre Mean)		1.7	1.4	-0.6	0.5	1.1	1.2	1.9

Table 4: TOSRA for engineers results

on any one attitude category were ten and fifty, respectively.

Results for X-TEEMS are in Table 4. The most improved mean pre to post was attitude category C. This may be due to the success of the discussion panel consisting of career engineers and scientists, as explained later in relation to Table 6. Other attitude categories with improved means pre to post were, from most to least improved, S, N, L, E, and A. The only attitude category whose mean did not improve pre to post due to the X-TEEMS experience was I, "Attitude to Scientific (Engineering) Inquiry". This may be due to the students' frustrations with the design project during the program, as explained later in relation to Table 6. The standard deviations increased pre to post for all but attitude category C. This implied the X-TEEMS program had a more varying affect on student attitudes toward engineering. It was desirable for the program to affect students similarly, so it seemed to have issues appealing to a wider range of interest and ability levels in students.

Paired t-tests were also performed on the post-assessment mean score minus the pre-assessment mean score for each of TOSRA for engineers' 70 statements. Sixteen of the 70 statements showed a statistically significant improved mean score (at a 0.05 significance level) from pre-assessment to post-assessment (all of the statistically significant differences belonged to improved mean scores). Five of these 16 statements belonged to attitude category S, two to N, none to I, one to A, three to E, three to L, and two to C. Overall, 51 of the 70 statements had improved mean scores from pre- to post-assessment. Nine of these belonged to attitude category S, eight to N, three to I, six to A, eight to E, seven to L, and ten to C. One statement had the same mean score post-assessment as in the pre-assessment. The mean of the differences from the improved means was 0.17. The mean of the differences from the negative means was 0.08. This indicated that changes in students' attitudes were greater when the change was an improvement than when the change was not an improvement.

A different assessment of the X-TEEMS program resulted in 98% of the students expressing satisfaction with it at a "Very Great Extent" or "Great Extent" level. Satisfaction was expressed at these same levels by 100% of the parents. When asked if they would recommend the X-TEEMS program to a friend, 95% of the students and 100% of the parents indicated they would at a "Strongly Agree" or "Agree" level.

Another pre-/post-program student survey used a 5-point Likert scale (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree) to

Survey Statement	Pre-Survey Percentages		Post-Survey Percentages	
	Strongly Agree	Agree	Strongly Agree	Agree
1. I plan to go to college when I finish high school	82	15	91	9
2. My parents/guardians are encouraging me to go to college	90	10	95	5
3. My friends plan on going to college	31	38	50	24
4. I enjoy school	45	50	49	44
5. My teacher(s)/counselor(s) care if I go to college	66	29	64	34
6. I have a specific career goal(s)	47	33	57	24
7. I am interested in a career in engineering	15	25	31	26

Table 5: Results from another student pre-/post-program survey

Survey Statement	Post-Survey Percentages	
	Very Great Extent	Great Extent
1. The student team competitions helped me to understand more about what it is like to be an engineer	46	45
2. Working on a project presentation helped me to understand more about what it is like to be an engineer	43	36
3. The field trips helped me to understand more about what it is like to be an engineer	43	41
4. The industry site visits helped me to understand more about what it is like to be an engineer	47	38
5. The discussions with professional engineers and scientists helped me to understand more about what it is like to be an engineer	71	22

Table 6: Results from a final student post-program satisfaction survey

measure the students' attitudes toward future college and career goals. Results for "Strongly Agree" and "Agree" are in Table 5. All but statement 5 showed an increase in "Strongly Agree" responses.

A final student post-program survey also used a 5point Likert scale (Very Great Extent, Great Extent, Some Extent, Not At All, Not Applicable) to gauge attitudes related to the satisfaction level of the activities and overall program experience. Results from the student post-program satisfaction survey for "Very Great Extent" and "Great Extent" are shown in Table 6. The positive attitude of students towards hands-on activities and competitions was in-line with research and the results of similar summer programs (see Abdel-Salam et al., 2009, ASEE, 2009, and Martinez & Hibbs, 2003). The highest percentage for "Very Great Extent" belonged to statement 5. A group of young, diverse, and dynamic engineers were selected to serve on the discussion panel. The panelists interacted and engaged the students rather than providing a lecture on engineering. The discussions included personal stories and practical applications that related to the students.

The development and presentation of a design project had the lowest approval rating among the students. This may have been due in part to the compressed time line for identifying and selecting a project. With limited knowledge and experience, many students may have had difficulty conceptualizing the product or experimental ideas. The project was subsequently designed and fabricated during the fall semester at the students' schools. Based upon the excitement and level of engagement that was evidenced during the demonstration and presentation of the finalized project at the summer site of the program, the category rating may have been different if the survey was conducted after the design project was completed.

A parent post-program satisfaction survey similar to the student post-program satisfac-

Survey Statement	Post-Survey Percentages	
	Very Great Extent	Great Extent
1. The student team competitions helped my child understand more about what it is like to be an engineer	74	26
2. Working on a project presentation helped my child understand more about what it is like to be an engineer	63	26
3. The field trips helped my child understand more about what it is like to be an engineer	67	26
4. The industry site visits helped my child understand more about what it is like to be an engineer	59	33
5. The discussions with professional engineers and scientists helped my child understand more about what it is like to be an engineer	81	15

Table 7: Results from the parent post-program satisfaction survey

tion survey (see Table 6) with the statements reworded appropriately was administered. Results are in Table 7. One purpose of the parent survey was to facilitate a conversation between students and their parents regarding the students' experiences in the program. Since parents did not participate in the program, responses were based upon observations and discussions between students and their parents. As with the students, statement 5 received the highest percentage of responses at the "Very Great Extent" level.

Conclusions

A two-week summer program called X-TEEMS was designed to promote interest and learning in the STEM fields. The program featured a week-long emphasis on engineering and a second week focused on other STEM disciplines. The program engaged participants through collaborative hands-on learning activities, industry tours, and interactions with career engineers. It culminated with a design project that was developed and demonstrated during the school year.

A total of 62 students and 20 teachers from ten rural and financially disadvantaged school districts participated in XTEEMS. The ethnicity and parents' highest level of education in the study sample was comparable to the national statistics for rural areas. However, the percentage of female students in the program was two and half times higher than the national average for Bachelor of Science degrees in engineering awarded to females in the United States.

Student and parent surveys were administered pre- and post-program to determine its effectiveness in influencing students' attitudes toward engineering. Overall, 98% of the students and 100% of the parents expressed satisfaction with the X-TEEMS program at a "Very Great Extent" or "Great Extent" level. The most popular and influential activities, as rated by the students and parents, were the collaborative hands-on activities and interactions with the career engineers.

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Matthew E. Elam, Ph.D., is an Associate Professor of Industrial Engineering at Texas A&M University-Commerce. He has taught courses, authored publications, performed funded research, and consulted with industry in several statistics related areas, engineering education, mathematics, and other subject areas. He has presented his research and served as session chairs at conferences. He has served as a reviewer for several journals and conference proceedings, and on the editorial board of one journal. He is a member of the Institute of Industrial Engineers and the American Society for Quality (ASQ), and is an ASQ Certified Quality Engineer.

Brent Donham is a Department Head and Associate Professor at Texas A&M University-Commerce. He received his B.S. in Electrical Engineering from New Mexico State University, his M.S. in Electrical Engineering from Stanford University, and his Ed.D. in Educational Administration from Texas A&M University-Commerce. He has been and continues to be actively involved in engineering education initiatives at the secondary and post-secondary levels. He has led the development and implementation of four new engineering / engineering technology programs. He has 12 years of industry experience, primarily in the field of microelectronics, in addition to over 14 years of teaching experience in higher education.

Ms. Stephanie R. Solomon is a student at Texas A&M University-Commerce (TAMU-C) working to get her Bachelor of Science Degree in Industrial Engineering with a Second Major in Mathematics. She is an initial member and vice president of the TAMU-C Alpha Pi Mu Chapter. She is also a member of Alpha Chi, National Society of Collegiate Scholars, and the Institute of Industrial Engineers. She served on the Student Advisory Board for the TAMU-C College of Business and Technology. She has worked two summer camps on the TAMU-C campus: X-TEEMS in 2009 and M2T2 in 2010.