



Impacts of Outreach on Entering College Students Interests in STEM

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Fundamental Research: Impacts of Outreach on Entering College Students Interests in STEM (Fundamental)

Introduction

The need to train qualified science, technology, engineering, and mathematics (STEM) professionals is recognized as paramount in the United States. STEM fields currently impact the majority of activities that comprise modern life. The demand for more and better trained STEM professionals continues to increase without a clear boundary. To fully participate in today's society, all students, regardless of race, gender or economic status, require a strong understanding of the STEM fields.¹ Yet, it is well recognized that there exists an achievement gap in STEM between minority and majority student populations. Underrepresented groups or groups that have been traditionally underserved in STEM, comprise 26% of the general US population but only account for 10% of the science and engineering workforce.² This disparity is a social justice issue, as some members of our society are being excluded from the most fulfilling and profitable careers of the modern age. Additionally, the talents and diverse ideas that these students offer are being lost or underutilized in informing the growth of STEM fields.³

In order to encourage students to eventually pursue STEM careers, early exposure is likely to be critical. Many colleges and universities are developing and implementing outreach programs that are designed to stimulate more students to develop an interest and understanding in STEM before they enter college. It is currently unknown for many of these programs as to whether they positively impact students' desires to pursue STEM as a major or as a career. A more traditional and highly successful approach to attracting students to STEM has been participation in a research experience for undergraduates.^{4,5} These programs, however, occur after students have entered college and do not have the potential of attracting students to STEM before college.

A common and accepted method for gauging students' attitudes in STEM and with respect to outreach programs is through self-report in the form of attitude surveys.⁶⁻⁸ The surveys used in this investigation were internally developed and designed to specifically address the impact of programs that were offered through the participating university, Texas Tech University. Two surveys were developed and implemented at pivotal points in the students' education: i) at the start of their freshman year or as soon as they transferred in to the university (Admissions Survey), and ii) at the time of graduation (Graduate Survey).⁹ The purpose of the Admissions Survey was to examine the impact that STEM outreach programs, which the students completed before college, had on students' college entrance and declared college major. The purpose of the Graduate Survey was to determine which students participated in K-12 Outreach programs or research experiences for undergraduates while in college and the impact of these programs on their career decisions.

The research questions that guide this investigation are:

1. Do outreach programs offered at the high school level impact students' decisions to enter STEM programs when they enter college?

2. Do outreach programs completed at the high school level have a different impact on the attitudes of minority and majority students with respect to STEM?
3. Do outreach programs completed during college to support K-12 have as significant of an impact on students' attitudes toward a future career in STEM as do participation in a research experience for undergraduate programs?

Methods

The first two sections that follow describe the participating university and the student population that responded to each survey. The second section describes the Admissions Survey and the Graduate Survey.

University

As of the fall 2013, Texas Tech University had an undergraduate student enrollment of approximately 27,000 with 93% of the student body consisting of state residents. On average undergraduates are predominantly traditional college students (e.g. recent high school graduates) with the average student age of 21 with only 10% of students 25 or older. Demographically the student body is 44% female and predominantly non-Hispanic white (63%). Hispanic students comprise 21% and African American students comprise 6% of the student population.

Subjects

Incoming freshman and transfer students completed the Admissions Survey in the Fall of 2011, 2012, and 2013. Table 1 provides the demographic information for students who reported participating in one or more of the specific STEM Outreach Programs offered at the university of interest while they were still completing their K-12 education. The primary demographic distinction made within this manuscript is between "minority" and "non-minority" students. For the purposes of this analysis Black or African American, American Indian or Alaskan, Native Hawaiian or Pacific Islander, Hispanic or Latino and more than one race are classified as "minority" because these groups are underrepresented in STEM. Similarly, non-Hispanic White and Asian students are both over-represented within STEM fields and as such are classified as "non-minority". This definition is consistent with that which is used by the National Science Foundation.

Graduate surveys were e-mailed to students who were completing STEM degrees in 2011, 2012 and 2014. This data could not be summarized based on gender or ethnicity because of a low response rate. Table 2 separates the responding students into two groups: i) those that participated in STEM Outreach before entering college, and ii) those that completed an undergraduate research experience while in college.

	2011	2012	2013
Sample Size	78	86	178
Gender			
Male	37 (47%)	31 (36%)	101 (57%)
Female	41 (53%)	55 (64%)	77 (43%)
Ethnicity			
Minority	25 (32%)	32 (37%)	80 (45%)
Non-Minority	53 (68%)	54 (63%)	98 (55%)

Table 1 - Demographic information and sample size for the incoming student survey responses.

	2011	2012	2014
Participated in a STEM Outreach Program before entry	11	20	15
Participated in Undergraduate Research during attendance	17	23	56

Table 2 – Graduation survey sample size by specific program by year. Here all STEM Outreach Programs have been combined and compared to undergraduate research.

Instruments

The admissions survey, which was administered to entering freshman and transfer students at the start of the years 2011, 2012 and 2013, is contained in Appendix A. This instrument was designed to identify students who participated in the institution’s K-12 outreach activities prior to entering colleges. Students who participated in these activities were further asked to evaluate their effectiveness and provide basic demographic information. The graduate survey, which was administered to graduating students from the STEM fields in the years 2011, 2012 and 2014, is contained in Appendix B. Students who completed the graduate survey were asked to identify outreach activities that they participated in as undergraduate students at the university. This list included K-12 outreach programs and undergraduate research experiences. Graduating seniors both evaluated their experiences and provided basic demographic information.

Description of Outreach Programs

The K-12 outreach STEM programs implemented as part of this investigation included after-school enrichment, a weekend of STEM, and summer programs. Each has been offered at a high school level with many programs containing either a plurality or majority of students from underrepresented groups. These programs vary in length from one day to seven weeks. Student participation ranges from 10 to 100 students per program. Most programs are partially funded by local foundations and federal grants; institutional support is also provided in the form of campus classrooms, laboratories, and voluntary faculty efforts. The goals of the program, which include increasing the diversity of participating students, have not changed over the course of implementation. However, the recruitment strategies and program activities have evolved during the course of this project. Our best practices for inspiring minority students in STEM were believed to be:

- Hands-on experiences completing real science and engineering projects;
- Working in peer based teams for the solution of projects;
- On-going support and encouragement from the instructor;
- Real world examples; and
- Role models in the form of successful professionals.

This investigation begins to examine the effectiveness of these approaches. Our entering freshman and transfer students participated in these programs as learners, before they entered college. Our graduating seniors participated in these programs as K-12 mentors or volunteers during their undergraduate education.

Results

Freshman and Transfer Students

Table 3 summarizes the reported impact that participation in K-12 outreach programs sponsored by the university had on participating students' interests in STEM. This table is further subdivided based on minority and non-minority status. The most notable trend is the steady increase in STEM interest among minority students who participated in STEM outreach programs sponsored by the given university. In 2011, a lower proportion of minority students reported that participation in STEM outreach programs positively impacted their attitudes in STEM when compared to non-minorities. By 2013, the opposite was true. During this period, the university efforts to create outreach programs that appealed to minorities had matured. These results indicate that these efforts were meeting some success.

Ethnicity	2011	2012	2013
Overall Sample Size	78	86	178
Minority			
Sample Size	25	32	80
Improved STEM Interest	52%	62%	81%
Non-Minority			
Sample Size	53	54	98
Improved STEM Interest	63%	75%	73%

Table 3 - Incoming Student STEM interest by year and minority designation.

To guide further inquiry into the effectiveness of specific program elements, students were asked to rank the perceived effectiveness of various program elements. Table 4 displays the percentage of students that ranked survey-identified program elements as "most effective for improving student learning" (Q4). Using the 3-year average for these program elements, "working with other students," "hands on activities," and "real world applications," received the highest ratings. These three elements of the STEM outreach programs were recognized by students as motivational factors that attracted them to STEM majors. By the conclusion of this investigation, minority students rated all of identified elements higher than did non-minority students, an encouraging outcome from the perspective of seeking to recruit minorities. "Presentation from professionals," a common element of most outreach programs, was rated the lowest in terms of impact. Students, in general, appear to place the least value on presentations from STEM professionals. However, one should bear in mind that the surveys were geared towards tracking STEM interest and so the data gathered from this study is not able to discern statistical similarity for these trends and should instead be used to inform further study into program element effectiveness.

Graduating Seniors

Table 5 provides numerical representations for the responses to questions 3-5 on the graduating senior survey. These questions ask if the students agreed that their participation as mentors in either a STEM outreach program or as participants in an undergraduate research program had a positive impact on their career choice (Q3), undergraduate education (Q4), and employment preparation (Q5). The responses to these questions range from "Strongly Disagree" which is assigned a value of 1 up through "Strongly Agree" which is given a value of 5. On this scale, an average value above 3 indicates that more students "Agreed" or "Strongly Agreed." Figure 1 provides a visual comparison of the student perceived benefit of student outreach to undergraduate research programs on their own interests. Unfortunately, there were not enough minority respondents to make comparisons between minority and non-minority participants, as

was the survey's original intent. Interestingly, though, a surprising result emerged: students give similar weight to the positive impact that participating in student outreach programs had on their career choice (Q3), undergraduate education (Q4), and employment preparation (Q5) as undergraduate research. Undergraduate research, in general, involves working on material that is related to one's field of study and is perceived by many faculty as one of the best ways to prepare a student studying STEM for future employment.

		2011	2012	2013	3 year Avg
Working with other students	Minority	48%	62%	71%	60%
	Non-Minority	60%	42%	55%	52%
Working with Teachers	Minority	48%	38%	35%	40%
	Non-Minority	43%	48%	30%	40%
Real world applications	Minority	32%	41%	64%	46%
	Non-Minority	36%	46%	50%	44%
Presentations from professionals	Minority	16%	41%	24%	27%
	Non-Minority	13%	52%	12%	26%
Hands-on activities	Minority	60%	41%	58%	53%
	Non-Minority	45%	52%	48%	48%

Table 4 - Percentage of students who rated a specific program element as "most effective for improving student learning".

Regrettably, this trend was not discovered until after the surveys were constructed and administered, and so the surveys were not designed to discern how well undergraduate research and outreach participation compare to a control population. Therefore, it is important to bear in mind that the data gathered from this survey is not able to discern statistical similarity. These results should be seen primarily as inspiration for further research to tease out how strongly participation in STEM outreach benefits undergraduate STEM students themselves.

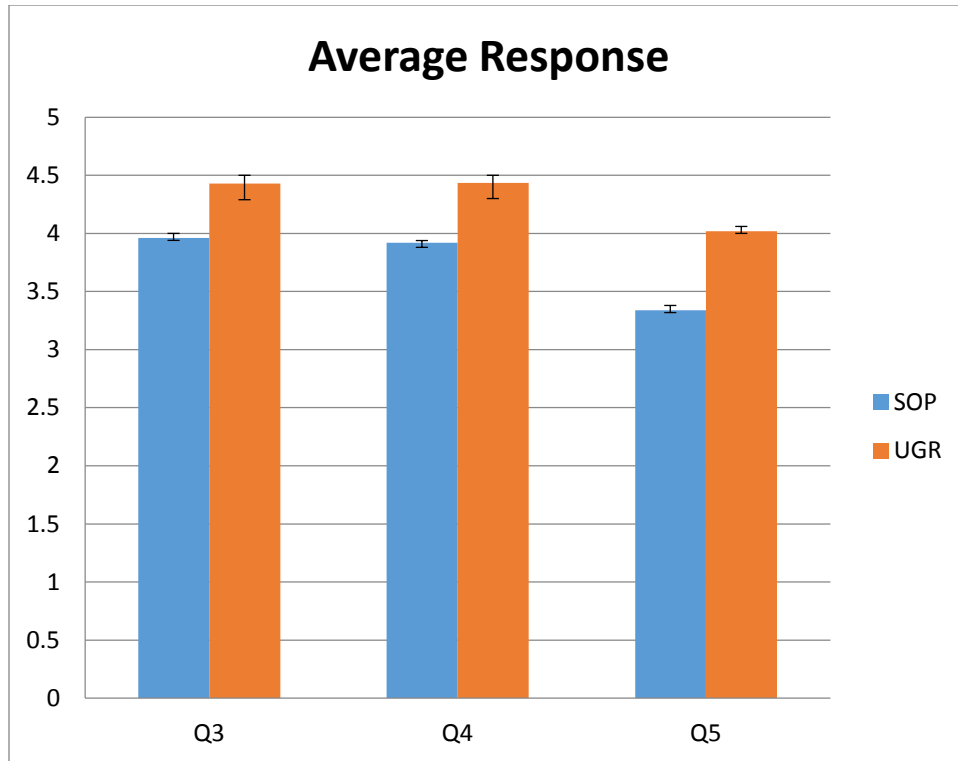


Figure 1 - The above figure shows the average of the values given in Table 5 across all 3 years sampled with the error bars representing the range of average responses.

Year	Program Type	Question		
		Q3	Q4	Q5
2011	Student Outreach	3.9	3.9	3.3
	Undergraduate Research	4.5	4.5	4.0
2012	Student Outreach	4.0	3.9	3.3
	Undergraduate Research	4.5	4.5	4.0
2014	Student Outreach	3.9	3.9	3.4
	Undergraduate Research	4.3	4.3	4.1

Table 5 - The above table gives the average student response for questions 3-6 on the graduation survey (see Appendix B). The response options were assigned a numeric value with "Strongly Disagree" being equal to 1 up through "Strongly Agree" which is set equal to 5.

Conclusion

Based on this work, it appears that K-12 outreach programs can have a positive impact on students' decisions to pursue STEM when they enter college. Both minority and non-minority populations indicated that participation in such programs effectively improved their interest in STEM. Over the course of this project, minority evaluation of the impact of these programs improved further, exceeding the value given by non-minority students. This suggests that targeted programs that seek to implement strategies (e.g. hands-on activities) known to influence minority populations do have an impact, at least in terms of the attitudes that these students convey with respect to STEM.

A surprising finding at the graduating senior level of this investigation is that students placed as much value on participation in K-12 outreach activities in terms of their STEM interest as they did on research experiences for undergraduates. This particular finding, if used correctly, could have widespread impact on the appeal of STEM to various student populations. Participation in K-12 outreach programs increases the STEM interests of undergraduates who are assisting in implementing those programs; these same programs attract high school students to STEM. This creates a win-win situation for both student populations.

Results from this study motivate further work on which specific program elements have the most significant impact. In K-12 programs, students valued working with other students, hands on activities, and real world applications. They placed less value on visits from practicing professionals within the field. This may be promising news for the K-12 classroom, in that this requires the re-definition of what students do in the classroom, not the acquisition of additional speakers. Locating willing STEM speakers can be challenging; securing motivational speakers can be close to impossible.

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Appendix A

1. When you were a high school student, which of the following programs designed to improve K-12 students' interests in mathematics/science, did you participate in (check all that apply):
 - Mathematical Associations of America (MAA) funded math clubs
 - Summer Math Academy
 - Super Saturdays
 - Science It's a Girl Thing
 - Shake Hands with Your Future
 - Applied Robotics: The NXT Step (LEGO)
 - University Interscholastic League Academic Competitions
 - TexPREP
 - Texas Tech Distance Education Programs
 - South Plains Science and Engineering Fair
 - Other _____
 - Does not apply

2. Referring to question 1, did the program(s) improve your interest in mathematics or science?
 - Yes
 - No
 - Does not apply

3. Referring to question 1, did you participate as an instructor or an instructor's assistant in any of the programs?
 - Yes
 - No
 - Does not apply

4. Referring to question 1, which of the following program activities were the most effective in improving your learning (check all that apply):
 - Working with other students your age
 - Working with other teachers or graduate students
 - Real world applications
 - Presentations from graduate students or professionals
 - Hand-on math activities
 - Does not apply

5. Referring to question 1, did any of the K-12 programs influence your decision to attend Texas Tech University?

- Yes
- No

6. Did you enter Texas Tech as a new student or as a transfer student from another institution?

- New Student
- Transfer Student

7. Gender: Male/Female

8. Ethnicity: Black or African American, American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, White, Hispanic or Latino, More than one race reported

9. Degree Seeking Major: Agricultural & Applied Economics, Agricultural Education, Agriculture, Animal Science, Crop Science, Environmental Crop & Soil Sciences, Food Science, Horticultural & Turfgrass Sciences, Horticultural & Turfgrass Sciences-Distance Program, Horticultural, Natural Resources Management, Conservation Science Track, Fisheries Biology Track, Ranch Management Track, Range Conservation Track, Wildlife Biology Track, Plant & Soil Science, Plant Protection, Range Science, Soil Science, Wildlife Aquatic & Wildlands Science & Management, Wildlife Science, Architecture, Atmospheric Science, Biochemistry, Biology, Cell & Molecular Biology, Chemistry, Economics, Environmental Toxicology, Exercise & Sport Sciences, Geography, Geosciences, Health, International Economics, Mathematics, Microbiology, Physics, Applied Physics, Psychology, Psychology- Clinical Psychology, Psychology- Counseling Psychology, Psychology- Experimental Psychology, Sociology, Statistics, Zoology, Management Information Systems, Multidisciplinary Science, Bioengineering, Chemical Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Engineering, Engineering Technology, Environmental Engineering, Industrial Engineering, Manufacturing Systems & Engineering, Mechanical Engineering, Petroleum Engineering, Software Engineering, Systems & Engineering Management, Honors Arts & Letters, Natural History & Humanities, Nutrition, Nutritional Sciences, Nutritional Sciences & Dietetics, Other

Appendix B

Graduation Survey

1. When you were a student at <Blind> University, did you participate in any of the STEM Education and Outreach Programs (check all that apply):
 - Noyce Scholars
 - South Plains Math Scholars
 - Mathematical Associations of America (MAA)
 - Plains Bridges to the Baccalaureate
 - PRISM
 - Science It's a Girl Thing
 - TexPREP
 - Super Saturdays
 - Applied Robotics the NXT Step (LEGO)
 - Shake Hands with Your Future
 - Undergraduate research
 - Service learning
 - K-12 math clubs
 - Does not apply

2. Referring to question 1, did any of the STEM Education and Outreach Programs at Texas Tech University influence your decision on attending as an undergrad student?
 - Yes
 - No

3. Using a scale 1 to 5 (1-strongly disagree to 5-strongly agree), indicate the extent to which the projects you participated in had a positive influence on your career choice.
 - Noyce Scholars
 - South Plains Math Scholars
 - Mathematical Associations of America (MAA)
 - Plains Bridges to the Baccalaureate
 - PRISM
 - Science It's a Girl Thing
 - TexPREP
 - Super Saturdays
 - Applied Robotics the NXT Step (LEGO)
 - Shake Hands with Your Future
 - Undergraduate research
 - Service learning

- K-12 math clubs
 - Does not apply
4. Using a scale 1 to 5 (1-strongly disagree to 5-strongly agree), indicate the extent to which the projects you participated in had a positive influence on your learning.
- Noyce Scholars
 - South Plains Math Scholars
 - Mathematical Associations of America (MAA)
 - Plains Bridges to the Baccalaureate
 - PRISM
 - Science It's a Girl Thing
 - TexPREP
 - Super Saturdays
 - Applied Robotics the NXT Step (LEGO)
 - Shake Hands with Your Future
 - Undergraduate research
 - Service learning
 - K-12 math clubs
 - Does not apply
5. Using a scale 1 to 5 (1-strongly disagree to 5-strongly agree), indicate the extent to which the projects you participated in had a positive influence on your preparation for employment.
- Noyce Scholars
 - South Plains Math Scholars
 - Mathematical Associations of America (MAA)
 - Plains Bridges to the Baccalaureate
 - PRISM
 - Science It's a Girl Thing
 - TexPREP
 - Super Saturdays
 - Applied Robotics the NXT Step (LEGO)
 - Shake Hands with Your Future
 - Undergraduate research
 - Service learning
 - K-12 math clubs
 - Does not apply
6. Using a scale 1 to 5, (1-strongly disagree to 5-strongly agree), indicate the extent to which the projects you participated in had a positive impact on K-12 students.

- Noyce Scholars
- South Plains Math Scholars
- Mathematical Associations of America (MAA)
- Plains Bridges to the Baccalaureate
- PRISM
- Science It's a Girl Thing
- TexPREP
- Super Saturdays
- Applied Robotics the NXT Step (LEGO)
- Shake Hands with Your Future
- Undergraduate research
- Service learning
- K-12 math clubs
- Does not apply

7. Gender: Male/Female

8. Ethnicity: Black or African American, American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, White, Hispanic or Latino, More than one race reported

9. Degree Seeking Major: Agricultural & Applied Economics, Agricultural Education, Agriculture, Animal Science, Crop Science, Environmental Crop & Soil Sciences, Food Science, Horticultural & Turfgrass Sciences, Horticultural & Turfgrass Sciences-Distance Program, Horticultural, Natural Resources Management, Conservation Science Track, Fisheries Biology Track, Ranch Management Track, Range Conservation Track, Wildlife Biology Track, Plant & Soil Science, Plant Protection, Range Science, Soil Science, Wildlife Aquatic & Wildlands Science & Management, Wildlife Science, Architecture, Atmospheric Science, Biochemistry, Biology, Cell & Molecular Biology, Chemistry, Economics, Environmental Toxicology, Exercise & Sport Sciences, Geography, Geosciences, Health, International Economics, Mathematics, Microbiology, Physics, Applied Physics, Psychology, Psychology- Clinical Psychology, Psychology-Counseling Psychology, Psychology- Experimental Psychology, Sociology, Statistics, Zoology, Management Information Systems, Multidisciplinary Science, Bioengineering, Chemical Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Engineering, Engineering Technology, Environmental Engineering, Industrial Engineering, Manufacturing Systems & Engineering, Mechanical Engineering, Petroleum Engineering, Software Engineering, Systems & Engineering Management, Honors Arts & Letters, Natural History & Humanities, Nutrition, Nutritional Sciences, Nutritional Sciences & Dietetics, Other