Science and Engineering Fairs as a Pathway for Diversifying Engineering Programs

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Abstract

This paper describes the successes and lessons learned from a five-year National Science Foundation supported initiative to increase the quantity and quality of science and engineering fair projects in a region with some of the least, and some of the best, resourced public schools in the country. The overall goals were to (1) understand the impacts of science and engineering fair participation on students' attitudes about pursuing STEM degrees, (2) increase the number and diversity of students participating in the regional science and engineering fair, and (3) increase project quality at the regional fair. During the grant, the number of students completing projects for school fairs grew rapidly, with project teachers mentoring about 2000 students annually. This resulted in the regional fair growing from sixty-three middle and high school students representing nine schools in 2013 to nearly three hundred students representing forty schools in 2018. Moreover, there were significant increases in the diversity of regional fair participants and award winners. For example, in 2013, none of the middle school students who placed in the top three in their category or won special awards were African American. By 2018, African Americans represented 18% of the category award winners and 13% of the special award winners. The number of female award winners also increased. In 2018, women won the majority of senior high school category awards, and junior high school special awards. Evaluation of the program focused on student and teacher self-efficacy and positive experiences as part of the program. Student surveys indicated that participating in the school fair had a net positive effect which was enhanced when students completed projects which were selected to advance to the regional fair. Many of these successful students are now enrolling in engineering and other STEM programs at the university level.

Keywords

Diversity, Science and Engineering Fair, K-12

Introduction

This paper highlights the lessons learned and successes from a five-year effort focused on increasing the quantity and quality of science and engineering fair participation in a region that has some of the most and least well-resourced public schools in the country. Teacher training, online fair management software, and increased extrinsic motivation for participants resulted in the Greater East Alabama Science and Engineering Fair (GEARSEF) growing from sixty-three to nearly three hundred participants and the number of schools participating growing from nine to forty. Many schools that did not previously participate now have in-school fairs that enable a far greater number of students to acquire improved inquiry and communication skills through scientific research. Moreover, the number of women and underrepresented minorities both completing science and engineering fair projects and winning awards has increased dramatically since 2013. These changes were the result of an effort funded by a National Science Foundation (NSF) grant which had the following goals:

1. To establish a network of STEM teachers and area administrators that advocate for students to engage in research experiences and give teachers the tools they need for classroom implementation. To develop a culture of participation in science and engineering fairs in Alabama.
2. To increase the number of students from underrepresented groups in rural Alabama participating in high quality, meaningful science and engineering research projects.
3. To increase positive student attitudes towards STEM through interactions with university research mentors who serve as role models for the students.
4. To build a sustainable relationship between Auburn University and regional public schools.

Science and engineering fairs are a valuable educational activity that are believed to increase students' engagement and learning in science and engineering by emphasizing creativity and inquiry-focused learning.[1-4] However, science and engineering fairs put demands on teachers, parents, and students for time and resources.[5-6] Organizing such an event is especially demanding in the first few years of implementation. As a result, poor and low-achieving schools are less likely to implement such a program for their students, despite the potential benefits.

Methods

This initiative focused on training and supporting teachers to mentor students on high quality science and engineering fair projects. Prior to this project, many schools in the region did not participate in the regional fair and, when they did send students, the projects reflected demonstrations rather than true scientific inquiry. Scientific inquiry projects are both more authentic to scientific practices than a demonstration and are scored more highly at the regional and advanced competitions.

The teachers received a stipend for their participation. Cohorts of approximately fifteen teachers attended a week-long summer training program led by Auburn University faculty and staff as well as teachers who had significant science and engineering fair experience. These workshops (**Figure 1**) included activities on the difference between a research project and a demo, similarities and differences in science and engineering projects judging, generating valid testable questions, statistics, poster preparation, and presenting projects to judges. It also covered logistic aspects such as finding judges for local fairs, involving math and English teachers in projects, laboratory safety, and the project approval system.

After the training, teachers were tasked with identifying a group of five to ten students to mentor and determine how they would implement a science and engineering fair in their classroom, school, or school system. In the fall, teachers were invited to bring their classes to an event called Destination STEM, an open house attended by approximately 2000 6^{th} – 12^{th} grade students. This event was developed on the basis of cohort teachers stating that it was difficult for students to identify project topics because they had very limited views of STEM. This open house consisted of a range of short activities led by faculty, staff, and students from multiple departments. These short experiences provided insight into the range of scientific pursuits that was often expanded into student science and engineering fair projects, particularly at the middle school level.

Teachers and their mentee students were supported by Auburn University faculty, staff, and graduate students who provided access to physical resources and served as a sounding board during project development and poster preparation. The teachers were then brought to GEARSEF to see how a regional fair functioned, even if they did not have students who had progressed to the regional level. The following summer, teachers attended a second workshop to share what they had learned about implementing a fair at their school and work on specific topics of interest such as quantifying differences in images and bacterial plating protocols (specifically, clean lab techniques for schools without sophisticated lab setups).

Figure 1. Photo from Cohort 3 summer professional development.

Data Collected

Teachers were surveyed after each section of each workshop to see which ones they found the most valuable. They were also interviewed about their overall experience with the program. The demographics of the students in each class were recorded along with the demographics of students who conducted projects.

Teachers administered a pre- and post-fair survey of science and fair-related attitudes to students in their 2017-18 science classes. For classes where doing a project was optional, the survey included both students who did and did not complete an S&E project. The evaluation team developed these surveys to assess student attitudes towards science and engineering as well as experiences being involved in science and engineering fairs. These measures of science attitudes were drawn from the Motivation Assessment Project[7] that developed theoretically grounded measures of constructs likely to be impacted by grades 6-12 science interventions. We also asked questions about whether students found science and engineering fair projects to be "transformative experiences"[8] which is expected to reflect deeper engagement with science.

Results

Qualitative interviews and quantitative survey data indicated that teachers found the workshops valuable, particularly those portions that involved hands-on activities. They also found specific aspects of the workshops clarifying. For example, one teacher said, "I don't want my students to be intimidated by engineering projects anymore, and now I feel better equipped to help."

Overall, the program enabled greater teacher self-efficacy in engaging students and science and engineering fair projects. The effort also seems to have created a culture of science and engineering fair participation in the region. In 2013, few schools were engaged in science and engineering fair participation. The number of schools participating grew from nine, predominantly affluent schools, to forty schools, many of which had a high proportion of students on free and reduced lunch (**Figure 2A).** In 2018, it was estimated that over 2000 students had the opportunity to engage in the scientific process and develop their STEM interest, STEM self-efficacy and communication skills at school fairs.

Approximately 10-15% of the participants at school fairs advance to GEARSEF. As shown in **Figure 2B** in 2013, the year prior to award inception there was a total of 63 junior and senior high school projects represented at GEARSEF. In 2018, there were 276. The top three winners in each category progress to the state competition. Moreover, at the high school level, the two Best of Fair winners from GEARSEF and the top three winners at the state competition advance to the International Science and Engineering Fair (ISEF) where they can interact with 1800 high school students from around the world and compete for $5 M in scholarships and prizes.

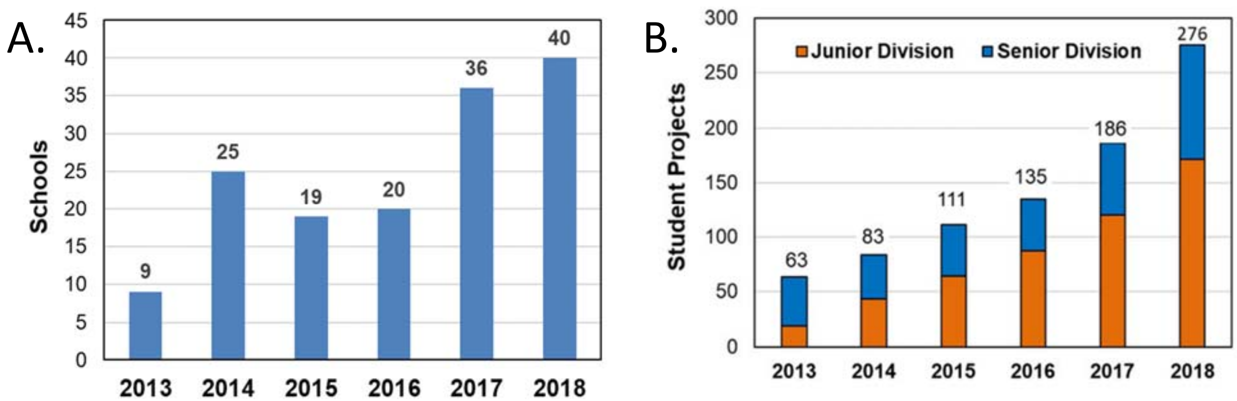

Figure 2. Growth of GEARSEF between 2013 and 2018 A) Number of schools participating, B) Number of junior division (middle school) and senior division (high school) projects

The growth in the number of projects increased the need for judges which resulted in schools, including high needs schools, having more opportunities to interact with local STEM professionals. Also, more faculty, graduate students, and post-docs at Auburn University (the host of GEARSEF) are becoming engaged in STEM outreach through serving as science and engineering fair mentors or judges.

In addition to increasing the diversity of school districts participating in science fair, the project has resulted in greater participation by students traditionally underrepresented in STEM. The data shows that the program has also been successful in diversifying science fair participation in terms of the number of schools participating in fair activities and the gender and ethnicity of the students participating in fairs. For the last two years of the 5-year grant period, all of the classrooms represented girls proportionally and the majority of classrooms had representative numbers of Hispanic and African American students. Moreover, the diversity of students winning special awards and category awards at GEARSEF has increased. For example, in 2013 all the special award winners at the middle school level were white, but in 2019 13% were African American. Also, the percentage of special award winners that identified as female increased from 43% to 52% at the junior level and from 33% to 46% at the senior high level. Although the increased number of participants who identified as other makes detailed analysis difficult, similar trends were seen for category awards. At the junior level, all of the category award winners were Caucasian in 2013. In 2019, 18% were African American. The percentage of female award winners also increased from 43% to 46%. At the senior level, the percentage of African American category award winners increased from 8% to 9%, and the female award winners increased from 46% to 51%.

Student Impacts

The research team was able to match 575 students across 20 teachers who provided both pre- and post-year survey data. **Table 1** presents simple t-tests for each group of students at pre- and post-year survey; a two-way mixed-design ANOVA looking at fair participation and time gave similar results. All of the participation*time interactions were significant, suggesting the patterns in **Table 1** are reliable and that changes from pre- to post- varied by project participation. Students who did not complete a project had significant and medium-sized declines in their science interest, science value, and science self-efficacy. Students who completed a project, but did not advance, showed no changes in attitude over time (which may actually be a good thing if typical students are declining). Students who completed a project that advanced had a significant gain in self-efficacy for science.

We were able to compare the transformative experience value of projects between students whose projects advanced to GEARSEF and those who did not (see **Table 2)**. Prior to the fair, there was no significant differences in the interest, efficacy, or value of these students. However, after the fairs, we found that students who advanced to GEARSEF had greater efficacy, interest, and value for science as well as reporting greater interest in their project and having transformative experiences. Although it is not possible to be certain whether it was the experience of being successful in their project or the topic itself, this is certainly an encouraging finding for the value of science and engineering fairs.

Conclusions

Program records indicated that students from a wide variety of schools, particularly those from underrepresented groups, showed substantial gains in their participation in school and regional fairs. These impacts are especially important given our findings about the positive impacts of fair participation on student attitudes and beliefs about their abilities in science and engineering. We found that participating in the fair avoided the typical declines in science interest and efficacy that we often see in junior high and early high school.[9] We also found that completing a project that advanced was associated with important gains in science and engineering interest, efficacy, and value. These students were also much more likely to report that the experience enhanced their interest in the project topic and created “transformative experiences” where they connected their project to their everyday life. The combination of the broadened participation in GEARSEF along with these positive impacts on individual students suggests that such a program can have profound effects on diversifying the engineering workforce in the long run.

Table 1. Comparison of students' science attitudes before and after the fair (all students)

		Pre		Post		Paired-samples t-test			
Group		M	SD	M	SD	t	df	Sig. (2-tailed)	Cohen's d (SD units)
No project N=186	Interest	2.97	0.61	2.82	0.56	2.69	185	**0.008**	**-0.27**
	Value	3.87	0.81	3.48	0.94	4.57	185	**<0.001**	**-0.44**
	Efficacy	3.57	0.80	3.34	0.83	2.99	185	**0.003**	**-0.29**
Project, did not advance N=330	Interest	2.86	0.57	2.90	0.60	-1.03	329	0.304	0.07
	Value	3.64	0.89	3.62	0.92	0.28	329	0.780	-0.02
	Efficacy	3.68	0.85	3.68	0.85	-0.01	329	0.988	0.00
Project advanced N=49	Interest	2.96	0.54	3.14	0.54	-1.86	48	0.069	0.34
	Value	3.85	0.92	4.13	0.80	-1.81	48	0.077	0.32
	Efficacy	3.68	0.94	4.23	0.57	-3.58	48	**0.001**	**0.71**

Note. Significant effects in bold.

Table 2. Comparison of students who did and did not advance to GEARSEF (all with projects)

Variables	Project, did not advance N=417		Project, advanced N=63		Independent Samples t-test			
	M	SD	M	SD	t	df	Sig. (2-tailed)	Cohen's d (SD units)
Interest	2.91	0.60	3.12	0.53	-2.66	482	**0.008**	**0.38**
Value	3.64	0.90	4.12	0.80	-4.02	482	**<.0001**	**0.57**
Efficacy	3.68	0.83	4.19	0.61	-4.66	482	**<.0001**	**0.70**
Project interest	3.15	1.12	4.12	0.88	-6.62	478	**<.0001**	**0.97**
Transformative experience	2.44	1.01	3.19	0.97	-5.56	478	**<.0001**	**0.76**

Note. Significant effects in bold.

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Paul Cobine, Ph.D. is a Professor in the Department of Biological Sciences at Auburn University. His interests include: understanding of how organisms regulate the concentration and distribution of essential metals using a combination of genetics and biochemistry and developing strategies for engagement of students in STEM fields.