

## Challenges and Benefits of Introducing a Science and Engineering Fair in High-Needs Schools (Work in Progress)

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## **Challenges and Benefits of Introducing a Science and Engineering Fair in High-Needs Schools (Work in Progress)**

Science and Engineering (S&E) 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.<sup>1,2</sup> However, S&E Fairs put demands on teachers, parents, and students for time and resources.<sup>3,4</sup> 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<sup>1,3,4</sup>. Our study is based on data from teachers from mostly low-achieving schools who engaged in a program focused on introducing S&E Fairs at their schools. Our research questions included:

- (1) Do teachers perceive S&E Fairs as effective educational tools?
- (2) What professional development activities are effective in encouraging S&E Fair implementation?
- (2) What benefits do teachers perceive from introducing S&E Fairs to their school?
- (3) What challenges do teachers face in introducing S&E Fairs to their school?

### ***Past research on science fairs***

There is a gap in the literature on the impact of S&E fairs on student achievement, particularly knowledge of scientific methods and research design.<sup>6</sup> Yasar and Baker conducted one of the few studies to directly assess changes in student science achievement as a result of S&E fair participation, but their study failed to detect any increase in knowledge from participation.<sup>7</sup> Finding effects of this type of intervention can be challenging, because teachers often allow students to self-select into participation.<sup>2</sup> Self-selection makes comparisons to non-participants problematic and likely biased. Although we do not have student achievement data at this time for this project, the goal of our project is to encourage teachers to implement fair projects for all students, so that self-selection is not a factor. We can then more validly compare the effects to comparison classrooms.

Even though there is no direct evidence of a positive effect of science fairs on student achievement, many proponents of S&E fairs strongly believe they are effective in teaching important scientific investigation skills to students. Proponents also argue that S&E fairs enhance students' interest in science and science careers.<sup>3,6</sup> And there is some evidence to support this belief based on students self-reported increases in knowledge and attitudes in a British science fair program.<sup>8</sup> There are a number of studies that confirm these perceptions of S&E fairs. For example, Grote<sup>9</sup> found that his sample of K-12 teachers believed that S&E fairs and independent science projects were appropriate activities for older students. This sample unanimously agreed that such projects teach important skills in scientific methods and over 70% agreed that projects are valuable, increase science interest, and that the competition aspect has educational value. A similar study<sup>4</sup> of pre-service teachers focused on the pre-service teachers' own experiences in S&E fairs as K-12 students. When asked about the benefits of S&E fair projects, the most popular reason by far was that it encouraged creativity. Respondents also felt it promoted interest in science and gave students an opportunity to explore their interests and conduct independent

research. The most common reason these respondents gave for not enjoying S&E fair projects included disliking the judging and competitive aspect of S&E fairs. Given the interest in these potential outcomes, we are gathering data on student attitudes so that we can detect these important outcomes.

For the purposes of this Work in Progress paper, our focus is on teachers' perceptions of the program, which is intended to promote high quality S&E fair projects in rural and underachieving schools, and their perceptions of S&E fairs as effective pedagogical tools for science. Future reports from the program will include student outcomes.

### ***The STEM-IQ Program***

This data was collected as part of a project called STEM-IQ that focuses on introducing S&E Fairs to high-needs and low-achieving schools as a means for improving science interest and achievement. Teachers participate in professional development to give them the organizational knowledge and inquiry-related pedagogical skills to mentor students on fair projects and organize an S&E fair in their school or in their community. Future years of the program will include additional schools, increasing our sample of teachers. Most of these schools are located in the Alabama Black Belt, an agricultural region that is historically poor and has a large African American population.

In the first year of the program, teachers participated in a fall workshop on the basics of mentoring student projects as well as a spring workshop where they attended a regional fair and discussed issues with helping students create meaningful S&E projects. At the end of the first year, teachers participated in a weeklong summer academy. Teachers received over 30 hours of professional development related to organizing an S&E fair as well as in implementing inquiry methods to support high quality S&E projects that follow authentic science and engineering practices. Four science and engineering faculty, supported by other instructional and outreach staff, provided the PD experiences. The faculty also served as mentors to teachers and directly to students completing S&E fair projects, when requested.

Teachers were recruited in "vertical teams", which included two to three middle school teachers, two to three high school teachers, and one administrator from the same school district. This arrangement promoted within-school and cross-school support system for student mentoring and S&E fair development.

### **Methods**

Our data collection methods included quantitative surveys related to perceptions of S&E Fairs as well as focus groups to gather qualitative evidence from teachers about the challenges they experienced in the first two years of implementing an S&E fair. The project's evaluator compiled survey measures of teachers' attitudes and evaluation of program activities. These surveys were partly based on previous evaluations (particularly a Math-Science Partnership [MSP]) and assess buy-in to the program and intent to implement program activities. We also conducted literature reviews of science-fair-related research and adapted measures of teachers' perceptions of the value of S&E fairs.<sup>4,9</sup>

Data was collected from 20 teachers involved in the program over the course of the first year. The first workshop occurred in October 2014, with 17 teachers from four school systems in attendance. All teachers completed a pre-test of S&E fair attitudes and perceptions of the program and expected benefits. After the workshop, a post-test consisting of some repeated measures and an evaluation of that day's events was administered. A similar post-event survey was administered at the spring workshop and the summer weeklong academy. The spring workshop also included a focus group interview with the 13 teachers present. Table 1 outlines the surveys administered, including which scales were administered pre- and post-workshop.

**Table 1: Survey Scales for Teachers**

| Survey scales                                | Example items   | Timing   | # items | Cronbach's $\alpha$ |
|--|---|----------|---------|---------------------|
| Background and teaching assignment           | Number of years teaching, content areas, grades taught  | Pre-test | 12      | NA                  |
| Prior experience with S&E fairs              | Did you participate in a science and engineering fair when you were in grades K-12?   | Pre      | 3       | NA                  |
| Science fair perceptions                     | (I believe...) Science fairs promote interest and enthusiasm about science.   | Pre      | 16      | .82                 |
| Buy-in for the program                       | The school workdays during the school year for the <i>STEM-IQ</i> will be worth the time it takes to attend.                | Pre/Post | 4       | .65/.62             |
| Expectations for collaboration               | The university faculty mentors will be helpful to me.   | Pre/Post | 5       | .58/.90             |
| Intent to mentor students                    | I will mentor at least two students on a science/engineering fair project this year.  | Pre/Post | 1       | NA                  |
| Expected benefits for students               | I think completing Science and Engineering Fair <i>Projects</i> will help me increase my students' competence in science.   | Pre/Post | 8       | .89/.94             |
| Content knowledge related to research skills | Which of the following correlation coefficients indicates the strongest relationship? (a) -1.0 (b) 0.3 (c) 0.8 (d) Not sure | Pre/Post | 20      | NA                  |
| Evaluation of workshop activities            | The content presented will be useful in organizing a science and engineering fair.  | Post     | 15      | NA                  |

## Results

Program teachers taught different combinations of grades 6-11. These teachers had an average of 12.4 years ( $SD = 8.7$ ) of teaching experience and 9.0 years ( $SD = 8.3$ ) of service at their current school. Of this sample, 12 teachers had a master's degree, 1 had a doctorate, and 1 had graduate credits beyond bachelor's degree. In terms of demographics, 13 of the 17 teachers were female, 7 teachers were African American, and 10 were white.

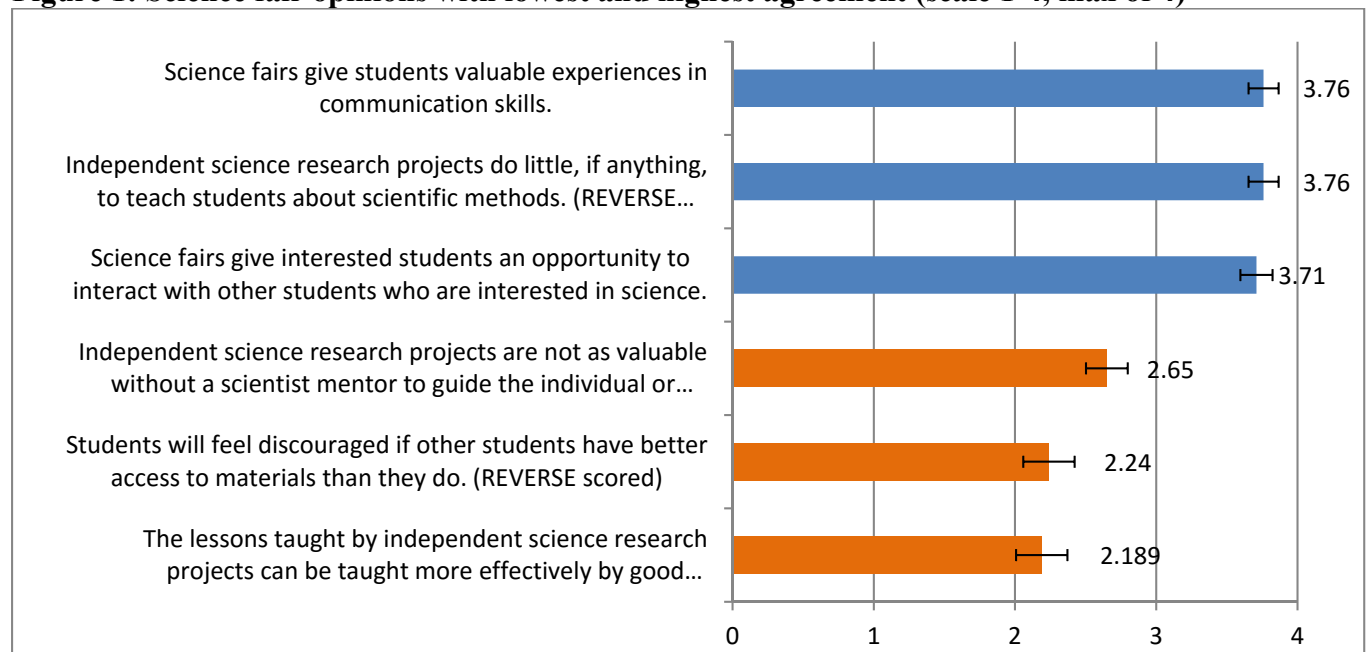
When asked about the typical performance level of their students, 3 teachers reported that their students were part or mostly below grade-level, 11 reported having a balance of students above and below grade-level, and just 1 reported having mostly at or above grade-level students.

### *Teacher experiences with and attitudes towards S&E fairs*

Of the 17 teachers who attended the initial workshop, 11 had participated in S&E fairs as students, while 6 never had the opportunity to participate in a S&E fair. Ten teachers reported that they had organized a S&E fair as a teacher before the program began. They were evenly distributed in whether their previous experience involved (1) small, informal science fairs, (2) school-wide science fairs without formal rules, and (3) school-wide science fairs with formal rules (such as the Intel competition rules).

When asked about their attitudes towards S&E fairs on a rating scale of 1 (strongly disagree) to 4 (strongly agree), teachers generally had strong positive attitudes ( $M=3.31$ ,  $SD = 0.28$ ) towards S&E fairs. Of the 16 survey items, the 6 items with the highest and lowest agreement are shown in Figure 1. Among the lowest average scores: Teachers varied in their opinion about whether S&E fairs taught lessons that could be more effectively taught by regular instruction. They also varied in whether they believed that students would be discouraged if they didn't have access to the same resources as others or if the projects would be more successful with a scientist mentor. Among the highest average scores and most consistent positive ratings: Teachers consistently agreed that S&E fairs give students opportunities to interact with others who are interested in science, that S&E fairs teach students scientific methods, and that S&E fairs give students chances to use communication skills.

**Figure 1: Science fair opinions with lowest and highest agreement (scale 1-4, max of 4)**



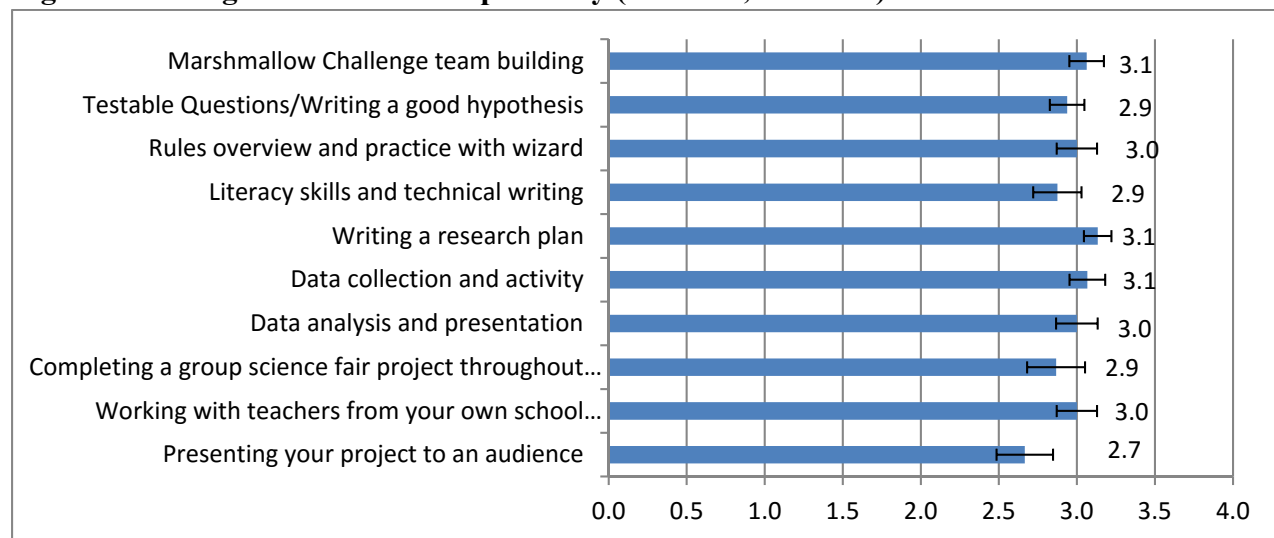
### *Effective PD experiences*

In July 2015, the first summer workshop was held to provide participating teachers with extensive professional development related to mentoring science and engineering fair projects. Events included hands-on activities, lectures on critical topics for science and engineering

projects (writing a testable hypothesis, data analysis, see Figure 2), and creating their own project with a poster and presentation.

At the end of each day, teachers completed an evaluation survey for that day's workshop sessions. Those results are aggregated in Figure 2. The teachers had a positive workshop experience and rated all aspects of the workshop positively. The participants' ratings were most positive for sessions on writing research plans, overviews of the rules of S&E fairs, and data collection. Teachers were also very positive about the hands on activities, including a team building exercise that kicked off the week (the Marshmallow Challenge<sup>10</sup>) and producing their own S&E fair projects. One thing teachers were less enthusiastic about was presenting their posters to the other workshop participants. When the teachers were asked what topics they needed more help with, many mentioned needing more coverage of data analysis methods, forming testable questions, and supporting students' technical writing for the projects.

**Figure 2: Ratings of each workshop activity (scale 1-4, max of 4)**



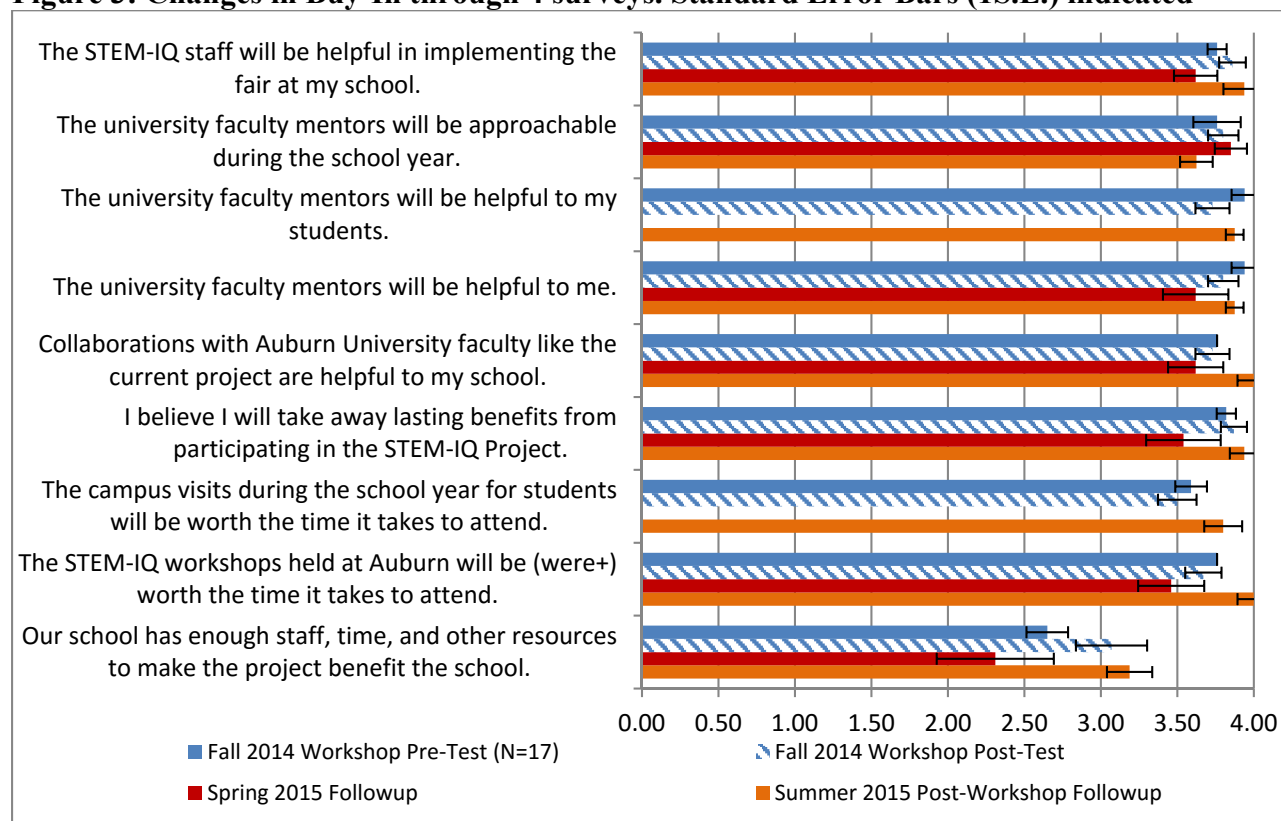
### ***Changes in buy-in and expected benefits of program***

Teachers responded to a series of items regarding their beliefs about the program (i.e., buy-in) at four times during the first year of the program: before and after the first fall workshop, after the spring workshop, and after the summer academy. Buy-in items were rated on a scale of 1 (strongly disagree) to 4 (strong agree). See Figure 3. Teachers have had consistently positive beliefs about the program, with particularly strong beliefs that they will take away lasting benefits from the program and that program staff and faculty are valuable resources to the teachers and their students. Teachers show the most concern about their schools having enough resources for the project and for S&E fairs in general. These concerns seemed to diminish with extended participation in the program.

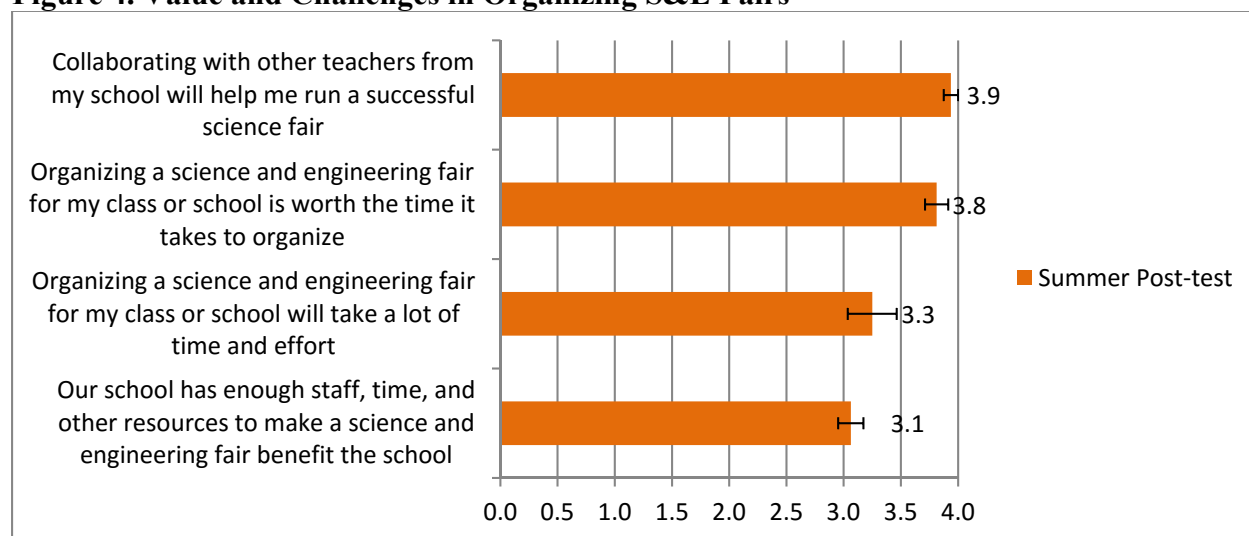
At the summer workshop, teachers were asked about their buy-in for S&E fairs themselves. There was strong agreement that organizing the fair would be worth the time and effort and also that collaborating with other teachers is key to running a successful fair. See

Figure 4. Again, teachers were concerned about their school having the resources to run a fair that benefits students.

**Figure 3: Changes in Buy-In through 4 surveys. Standard Error Bars (1S.E.) indicated**



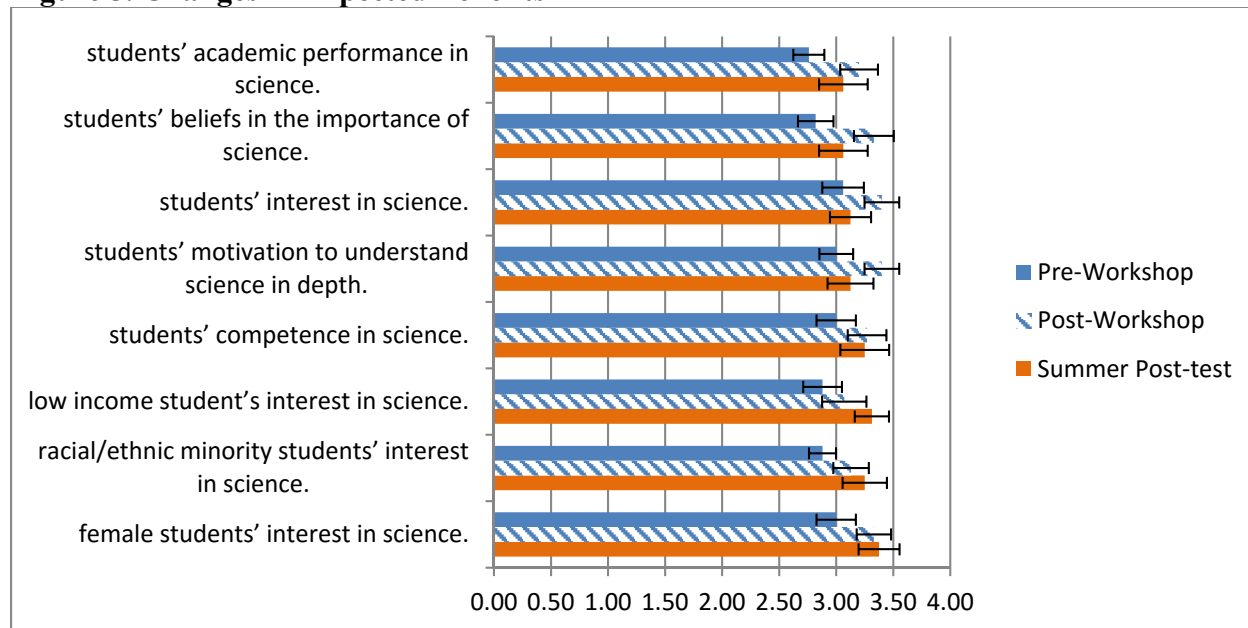
**Figure 4. Value and Challenges in Organizing S&E Fairs**



Teachers also completed ratings of the extent to which they felt S&E fairs would have a positive impact on their students. See Figure 5. The first workshop significantly increased teachers' beliefs about the positive impacts on their students, including among low income,

minority, and female students. These expected benefits diminished somewhat, but not significantly, by the next summer's workshop. The expected benefits for traditionally underrepresented students seemed to increase with additional participation in the program.

**Figure 5. Changes in Expected Benefits**



### ***Challenges in Implementing S&E Fairs***

Based on a goal-setting exercise at the summer workshop, we discovered that teachers have clear goals for participating in science and engineering fairs. These goals are to help their students gain important scientific skills (aligned with state standards), promote curiosity and creativity, and to give students a chance to visit a college campus and see real scientists at work to promote college interest. Schools that were more rural were especially enthusiastic about the opportunities their students had to visit the university and meet faculty.

During a focus group interview, we found that teachers were generally satisfied with the first year of the project and were excited about the opportunities that S&E fairs provided for student engagement in science projects. When asked what support they needed in the future, the teachers suggested several things including (1) formal opportunities to connect with faculty for assistance on student projects, (2) field trips to the university to see science and engineering in action (spark interest), (3) faculty visits to schools to engage in hands-on activities with students that may inspire projects. Teachers also made suggestions for better informal communication paths with the program and with each other—many teachers had useful resources that they wanted to share with other teachers working on the project. Edmodo was the chosen venue by the program, but was seen as less convenient to teachers than a Google Drive folder or something similar.

When asked what issues teachers had in organizing their own S&E fairs, teachers reported a big “learning curve” in running their first fair, which was easier to manage when they had collaborating teachers to help. Collaborating teachers could mean either other science



teachers to co-organize the fair or English teachers who collaborated on fair projects so that students received feedback on their research papers from both the Science and English Language Arts (ELA) teacher. Teachers reported that working with ELA faculty to support students in writing technical papers (suggested but not required for the regional fair) helped promote the quality of student projects and meet multiple state objectives for learning.

Other issues that teachers had in organizing their first fair included finding judges for the school fair, especially judges with any science background (experience with research of some kind was preferred for judges). Teachers shared strategies including reaching out to local business and community colleges. Some teachers also do an initial review of posters before having them judged so that external judges only reviewed the most promising projects.

### ***Mentoring Outcomes***

In the first year of participation, the program team felt that it was feasible to ask each teacher to mentor 2 students and not require them to organize a local fair. We expected this to result in 34 mentored students participating in the 2014-2015 program. This goal was met: in the spring, project teachers (N=17) reported between 0 to 58 students (Med. = 9) participating in S&E fairs at their school. Teachers reported mentoring between 0 to 47 students (most ranged from 2-4, Med. = 3). Excluding the teacher who reported 47 mentees, this leads to a total number of 51 students who were mentored this year. Although this result was encouraging, the students mentored did not reflect school diversity to the extent that the program had hoped.

Table 2 shows the characteristics of students in the class, who completed fair projects, and who were mentored. Underrepresented racial/ethnic minority groups were underrepresented among students completing projects and being mentored. This underrepresentation needs to be addressed in workshop information in the coming year to ensure teachers are consciously promoting diversity in students who participate and who are mentored. Teachers reported similar numbers of girls in all categories. In the GEARSEF focus group, teachers described many different processes of mentoring and selecting mentees. Mostly teachers reported mentoring students who showed initiative and existing interest, which may overlook students who could develop interest if motivated to complete a project. As a result of these findings, the program plans to increase their efforts to help teachers promote interest in completing projects among traditionally underrepresented groups.

**Table 2: Median percentage of students by demographic characteristics**

|                              | Median % in class | Median % in fair | Median % mentored |
|------------------------------|-------------------|------------------|-------------------|
| African American or Hispanic | 65                | 38               | 33                |
| Female                       | 49                | 53               | 51                |

During the focus group interviews, when discussing their experience mentoring students, teachers reported the most difficulty with helping students narrow down and select a promising topic. Students and teachers struggled with distinguishing between a demonstration (e.g., the classic baking soda and vinegar volcano) and a true scientific investigation that would advance from a regional fair to a state competition. Many online S&E fair resources focus on demonstrations, which do not make for successful S&E fair projects.

Students also struggled to find topics of interest. The teachers suggested university-based activities and online videos that students can watch to get new ideas. New resources were especially needed to promote ideas outside of the usual focus of classes (basic biology and physics studies). Finally, teachers also reported gaining many ideas and resources from attending the regional fair as part of this project. They reported that it gave them a sense of what was possible when they saw the high performing students at the regional fair.

## **Discussion**

In their surveys, teachers reported beliefs that S&E Fairs can benefit all students, including those with limited resources or who don't already show enthusiasm for science. However, they also were generally not supportive of S&E Fairs as a classroom activity for all students—they indicated that S&E Fairs were better as optional, outside projects rather than an activity that requires in-class time. Teachers also tended to make projects optional and focus mentoring on those already self-motivated or interested in completing a project. This is problematic, especially given that the students who completed projects in the first year tended to be white or Asian (at a proportion greater than the classroom makeup). In the future, the program will address diversity and promoting interest among students not currently interested in science.

After completing projects with their students, teachers reported strong beliefs that their students learned important things and became more interested in science as a result of their S&E Fair projects. They also expressed belief that S&E Fairs would especially benefit their female, low-income, and minority students' interest and achievement in science. This suggests that teachers will be open to investing more time and classroom resources in organizing fairs in the future.

Teachers found the extended format of the summer academy to be beneficial in organizing a S&E fair. Although they emphatically did not enjoy presenting their projects to the group, they did find it valuable to complete the projects during the workshop. During the workshop, teachers felt they learned a lot about these topics: data analysis, technical writing, and testable questions. But, they want even more support in learning about these same topics. These topics will be given more coverage during the second year of the project, when they will participate in a second summer academy.

From the focus groups, the challenges faced by teachers included recruiting enough judges for the fair, finding space for the fair, and following the guidelines required to advance to the regional and state fairs. Teachers also reported challenges in helping students find original and effective project topics and promoting engagement among students who would benefit from the projects, but who were not already interested in science. Working with faculty may address some of these issues, especially for rural schools that typically do not have close ties and access to university faculty and facilities.

Many teachers reported that working in supportive teams was critical to successful fairs at their school. An unexpected finding was the important role that English teachers played in success. Teachers reported that collaborating with the English department to develop research statements helped both science and English faculty address important curriculum standards and

increased the quality of the S&E projects. Implications for establishing similar training programs for teachers will be discussed.

Overall, we found that this program was very successful in its first year in providing teachers with the resources they needed to mentor students in completing S&E fairs. We found that extensive PD opportunities are needed to help teachers organize S&E fairs and to successfully mentor students engaging in authentic scientific investigations. Even with a weeklong workshop, teachers still expressed a need for more training on inquiry methods and data analysis to be effective mentors. The workshop was most successful with its hands-on activities that model the skills needed by the teachers as project mentors. The vertical teams, with multiple grade levels from the same district, also supports the sustainability of S&E fair programs because there are many teachers working together to plan successful school fairs.

The university collaboration is also a vital ingredient to the program, providing teachers with knowledgeable resources as they mentor students. These faculty members are also resources to students. Through the faculty, students have access to information about cutting edge scientific research, which may spark their own science and engineering interests. As the program evolves, more opportunities to connect with rural schools and provide novel science and engineering experiences will develop.

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