High School Science Fair: Ethnicity Trends in Student Participation and Experience

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Abstract

In this paper, we report ethnicity trends in student participation and experience in high school science and engineering fair (SEFs). SEF participation showed significant ethnic diversity. For survey students, the approximate distribution was Asian-32%; Black-11%; Hispanic-20%; White-33%; Other-3%. Comparing the SEF level at which students competed from school to district to region to state levels, we observed that black students made up only 4.5% of the students who participated in SEF beyond the school level, whereas students from other ethnic groups were more equally represented at all levels. The lower percentage of Black students resulted from a combination of lower overall participation in SEF and lower percentage of those students who did participate to advance to SEFs beyond the school level. Students who advanced to SEFs beyond the school level frequently received help from scientists, coaching for the interview, and were not required to participate in SEF. Black students received the least help from scientists, were least likely to receive coaching for the interview, and were most likely to be required to participate in SEF. They also were most likely to receive no help from parents, teachers, or scientists. Asian and Hispanic students (63.8% and 56.8%) indicated a greater interest in careers in science and engineering (S&E) compared to Black and White students (43.7% & 50.7%). In addition to career interest, the most important experiences that correlated with students who indicated that SEF increased their interests in S&E were getting help from the internet, books and magazines; getting help fine tuning the report; and overcoming obstacles by doing more background research, making a timeline, and perseverance. Black students did not report a positive effect of any of these strategies but experienced time pressure as more of an obstacle than did other students. Our findings identify a wide range of student experiences associated with positive SEF outcomes that could be enhanced for all students but especially Black students. More involvement of scientists in helping students who participate in SEFs would be particularly valuable.

Introduction

Several years ago, we initiated a survey research program to learn student opinions about their experiences in high school science and engineering fairs (SEFs) with the goal of improving SEF practices. In this paper we report our latest findings based on an analysis of new questions regarding student ethnicity and level of SEF competition that we added to the surveys beginning in 2018.

SEFs represent something of an enigma. On one hand, they would seem to be an ideal means for students to experience for themselves the practices of science and engineering [1], now a central goal of Next Generation Science Standards (NGSS) [2]. Moreover, SEFs have become highly visible. In his 2011 State of the Union Address, President Obama remarked, “We need to teach our kids that it’s not just the winner of the Super Bowl who deserves to be celebrated, but the winner of the science fair” [3]. The film *Science Fair* was festival favorite at the 2018 Sundance Film Festival. Winners of the major SEFs can receive college scholarships worth $50,000 or more.

On the other hand, according to the National Center for Education High School Longitudinal Study of 2009/2012 (NCE-HSLS), only about 5% of the 23,500 high school students surveyed participated in a science competitions during high school [4]. Consistent with this finding, only about 5% of the almost 16,000 undergraduate students surveyed in the college Outreach Programs and Science Career Intentions survey (students in introductory freshman, mostly English, classes)

reported participating in SEFs [5]. For many schools, the combination of budget limitations and competition for classroom time will decrease the possibility of promoting and supporting SEFs. Indeed, only 1/3 of the 900 schools surveyed in NCE-HSLS reported that they "hold math or science workshops or competitions" [4]. That number hasn't changed much in the past 10 years judging from our recently reported survey of undergraduates (all on bioscience education trajectories) of whom about 60% attended high schools where participation in SEFs was not available [6].

SEFs began in the U.S. in New York City in the 1930's. The stated goals were "to aid in the development of the scientific leaders of the next generation and at the same time foster a better understanding of science among its laymen" [7]. After the 1939–1940 World's Fair in New York, SEF increasingly was viewed as a means to encourage and help students find their way to science and engineering career paths [8]. Using SEFs to accomplish STEM education for all students became an elusive goal.

When Microsoft Corporation carried out a STEM perceptions study, they found that only about 5% of the students said that they became interested in STEM because of SEFs [9]. Similarly, among students at a Queensland science and engineering university only 7% listed SEF as the reason they became interested in STEM [10]. Consistent with these reports, studies of national U.S. student cohorts suggest that the main effect of participating in high school science competitions is to help retain students who already are interested in STEM rather than attract those previously uninterested [5, 11]. Nonetheless, helping retain students already interested in STEM is an important outcome. Previously, we reported that 75-80% of high school students who participated in SEFs in 11th and 12th grades said that they were interested in a career in the sciences or engineering compared to just under 50% in 9th grade. Moreover, we found that 6 out of every 10 undergraduates students we surveyed (all on bioscience education trajectories) had participated in SEF if they were available at the students' high schools [6].

The question of how SEF outcomes vary in relationship to the type of SEF in which students engage has received little attention. Recent research on middle school SEFs identified three major types: mandatory SEF with high support (curriculum, class time, teacher engagement) (23% of students); mandatory with low support (57% of students); and voluntary with low support (20% of students) [12]. Previously, we reported that 60-70% of students who participated in high school SEFs were required to do so [13]. Students overwhelming disliked a competitive SEF requirement (4:1 or greater). They viewed competitive SEF as emphasizing winning rather than learning. Being required to compete reduced markedly the percentage of students who indicated that SEF increased their interests in the sciences and engineering (S&E) [14]. Since students uninterested in careers in S&E were most likely to participate in SEF in 9th and 10th grades, we suggested that schools should consider offering different SEF opportunities for students in 9th and 10th compared to 11th and 12th grades, e.g., a non-competitive rather than competitive option or incentivized rather than required [6, 15].

Recently, innovative high school programs have been described that combine student participation in SEF with student and teacher curricular support to promote STEM engagement and learning, especially focused on students from under-represented ethnic minorities and low socioeconomic backgrounds [16-18]. Such programs are particularly important given low levels of Black, Hispanic, and some other ethnic minority individuals in STEM fields compared with their proportion in the population. Underrepresentation occurs at the workforce level but begins in the

education pipeline [19-21]. Trying to achieve diversification of the STEM workforce remains a major challenge and requires further development of creative programming at many levels including K-12 STEM education [22].

In this paper, we use our latest surveys to learn about ethnicity trends in student participation and experience in high school SEFs. SEF participation showed significant ethnic diversity. Overall, the data suggest that Black students are not getting the help that they need to be successful in SEFs compared to students in other ethnic groups. Our findings identify a wide range of student experiences associated with positive SEF outcomes that could be enhanced for all students, but especially for Black students. More involvement of scientists in helping students participating in SEFs would be especially valuable. Details are reported herein.

Materials and methods

This study was approved by the UT Southwestern Medical Center IRB (#STU 072014-076). Study design entailed administering to students a voluntary and anonymous online survey using the REDCap survey and data management tool [23]. Survey recipients were high school students who participated in SEFs during the 2018/19 and 2019/20 school years using the Scienteer (www.scienteer.com) online portal adopted by Alabama, Louisiana, Maine, Missouri, Texas, Vermont, and Virginia for SEF registration, parental consent, and project management.

After giving consent for their students to participate in SEF, parents could consent for their students to take part in the SEF survey. However, to prevent any misunderstanding by parents or students about a possible impact of agreeing to participate or actually participating in the survey, access to the surveys was not available to students until after they finished all of their SEF competitions. When they initially signed up for SEF, students were told to log back in to Scienteer after completing the final SEF competition in which they participated. Those who did so were presented with a hyperlink to the SEF survey. Scienteer does not send out reminder emails, and no incentives were offered for remembering to sign back in and participate in the survey.

Survey content was the same as that used previously [13] except modified beginning in 2018 to include questions about student ethnicity and about the level of SEF competition in which students participated (school, district, regional, state). In 2019, a question was added about the location of the student's high school (urban, suburban, rural). The survey can be found in supporting information (S1 Survey).

Survey data were summarized with frequency counts and percentages. Significance of potential relationships between data items was assessed using Chi-square contingency tables for independent groups. Results are presented two ways -- graphically to make overall trends easier to appreciate and in tables to show the actual numbers. A probability value of 0.05 or smaller was accepted as statistically significant but actual p values are shown. No adjustments were made for multiple comparisons.

Results

Overview of survey responses

Table 1 shows the number and ethnicity of almost 40,000 students/year who used the Scienteer website to participate in SEFs during 2018/19 and 2019/20. The table also shows the Scienteer students who completed SEF surveys. Scienteer students answer a question about their ethnicity at the time they register to participate in SEF. They self-identified most often as White (26%) and Hispanic (25%) followed by Asian (15%) and Black (7%). In addition, more than 25% of the students selected the Other category. Students who completed surveys were much less likely to choose the Other category (3%). For the survey students, the average percentages of Asian students (32%) and Black students (11%) were about twice as high as the original Scienteer students, slightly lower for Hispanic students (20%), and slightly higher for White students (33%).

In relationship to U.S. high school data shown in the last row of Table 1 [24], obvious differences in ethnicity between SEF/survey students and the overall high school population were overrepresentation of Asian students and underrepresentation of White students. We treat the Scienteer SEF population as a national group of high school students. However, it should be recognized that these students may not be truly representative of a national sample since they come from only 7 U.S. states, and they only attend high schools where SEFs are available.

Table 1. Number and ethnic distribution of students who signed up for SEF using Scienteer, Scienteer students who participated in the SEF survey, and overall U.S high school students

Data Set (# students)		Asian % (#)	Black % (#)	Hispanic % (#)	White % (#)	Other* % (#)
Scienteer SEF students	2018/19 (36,934)	15.3 (5,662)	6.8 (2,496)	25.2 (9,304)	26.2 (9,690)	26.5 (9,782)
	2019/20 (38,570)	14.6 (5,365)	6.6 (2,504)	24.5 (9,207)	26.1 (10,010)	28.1 (11,484)
Scienteer students who completed surveys	2018/19 (382)	28.8 (110)	13.1 (50)	22.8 (87)	32.2 (123)	1.8 (7)
	2019/20 (938)	35.0 (328)	9.1 (85)	17.4 (163)	33.5 (314)	4.1 (38)
2009 High School NCES X2RACE Ethnicity Profile	2012 (23,503)	3.6 (828)	13.6 (3,128)	22.1 (5,083)	51.9 (11,937)	8.9 (2,047)

*Includes American Indian; Hawaiian Native/Pacific Islander; and various mixed-race combinations.

Overall, 1-2% of all students who signed up for SEFs through Scienteer completed surveys, consistent with our previously reported experience with 2016/17 and 2017/18 Scienteer cohorts [14]. Given that student participation in the surveys involves an indirect, single electronic invitation without incentive or follow-up, the low response rate has not been surprising [25-27]. Most of the submitted surveys (greater than 92%) were complete and non-duplicates. The completed surveys were used for data analyses, and the data sets can be found in supporting information S1 Dataset and S2 Dataset for 2018/19 and 2019/20 school years respectively.

Previously, we found that student survey answers were reproducible from year to year [14]. That trend continued for the 382 students in 2018/19 and 938 students in 2019/20. Supplemental Table 1 (S1 Table) shows results for the entire set of 100+ possible survey questions and answers

regarding student demographics, opinions about SEF, help received, obstacles encountered, and ways of overcoming obstacles. Answers selected by the 2018/19 and 2019/20 cohorts not only were similar to each other, but also were similar to the combined 2016/17 and 2017/18 results.

Fig 1 shows results for selected features from the 2018/19 and 2019/20 surveys that, along with student ethnicity, will be the major focus of this paper. About 2/3 of the students who completed surveys said that they were required to participate in SEF. About half received help doing SEF from parents and/or teachers but less than 10% from scientists. An important point that we realized in analyzing the new SEF surveys, which we had not noticed previously, is that a quarter of the students did not receive help from parents, teachers, or scientists.

In addition to the question about ethnicity, beginning in 2018/19 we also began asking about the level of SEF in which students participated. About half the students participated in SEF at the school level; the remainder went on to higher level SEFs. The lower percentage of students who competed in state level SEF in 2019/20 resulted from changes in SEF opportunities in late spring 2020 because of COVID-19 restrictions. The completion rate for almost all the survey questions was >97% except for the question about level of SEF competition.

Finally, Fig 1 shows that of the students who completed surveys in 2018/19 and 2019/20, slightly more than half said that they were interested in a career in the sciences and engineering; 20% were uninterested; and the remainder unsure. Also, slightly more than half the students said that participating in SEF increased their interest in S&E.

Fig 1: Some key features of SEF experience -- 2018/19 vs. 2019/20 student groups

Students' ethnicity and SEF experience

For subsequent figures, the 2018/19 and 2019/20 student survey results were combined. Fig 2 shows ethnicity demographic data. Most students did SEFs in 9th and 10thgrades. However, the proportion of the Hispanic students doing SEFs in 11th and 12th grades (33%) was higher than for other groups – white (21%), Asian (17%), black (23%). More females than males completed surveys; the difference was more than 2:1 for Black students. Most (80%) of White, Asian and Black students who completed surveys attended suburban schools, whereas the Hispanic student population was more evenly distributed with 50% in suburban schools and just under 40% in urban schools.

Fig 2. Ethnicity and student demographics

Fig 3 shows data about student involvement. The requirement to participate in SEF ranged from 84% for Black students to 58% for Asian students. About half the students in each ethnic group reported help from parents with White students receiving the most help (54%). Also, about half the students in each group received help from teachers. In response to the paired questions, 'did you get the amount of help you wanted from teachers' and 'did you get the kind of help that you wanted from teachers,' around 70% of the students responded "yes" to each question.

Black students received much less help from scientists compared to students in the other ethnic groups, i.e., 2% of the Black students vs. 10% of the Asian and Hispanic students and 7% of

the White students. Also, a higher percentage of Black students (36%) compared to students in the other groups (22-28%) reported receiving no help from parents, teachers, or scientists. For all ethnic groups, students received more help from internet articles than from other sources.

Fig 3. Ethnicity and SEF involvement

Scienteer tracks whether students participate in SEF at only the school level or move on to more advanced SEFs. Table 2 shows that almost 25% of the Scienteer students advanced to SEFs beyond the school level. That number was higher (40%) for students who completed surveys. Both Scienteer and survey data show that Black students made up less than 5% of all students who reached more advanced SEFs. Hispanic and White students were present in advanced SEFs in roughly equal numbers (28%). Asian and Other students were present at 17% and 23% respectively according to Scienteer data but 37% and 1% according to survey data.

Table 2. Distribution by ethnicity of 2018/19 and 2019/20 Scienteer and survey students who competed in higher level SEFs (district, region, or state)

Data Set	Total	Asian	Black	Hispanic	White	Other
# of Scienteer students who advanced to higher level SEFs	18,526*	3,082	823	5,218	5,206	4,197
% of Scienteer students who advanced		16.6	4.4	28.2	28.1	22.7
# of survey students who advanced to higher level SEFs**	441**	165	20	128	122	6
% of survey students who advanced		37.4	4.5	29.0	27.7	1.4
*24.5% of 75,504 students, **39.8% of 1,109 students						

Fig 4 summarizes in more detail data about SEF outcomes based on the surveys. About 80% of the Black students surveyed only competed in SEF at the school level compared to 67% of the White students, 57% of the Asian students, and 41% of the Hispanic students. Comparing different groups, Hispanic students were most likely percentagewise to compete in district, regional and state level SEFs. Fig 4 also shows that Asian and Hispanic students reported a greater interest in careers in science and engineering (64% and 57% respectively) compared to White and Black students (51% and 44%) and were more likely to indicate that participating in SEF increased their interest, 64% for Asian and Hispanic students vs. 46% for White and Black students.

Fig 4. Ethnicity and SEF outcomes

Differences in students' experiences associated with sources of help and level of SEF competition

Another way to analyze the results was by comparing student experience according to from whom the students received help. Fig 5 compares the consequences of receiving help from scientists (which could include teachers and/or parents); parents or teachers but not scientists; and no help from parents, teachers, or scientists. 108 students received help from scientists. More than 80% of

those students participated in SEFs beyond the school level. By comparison, 871 students had help from parents and or teachers but not scientists. About half those students did SEF at the school level and the other half advanced to higher level SEFs. Students having help from scientists also was associated with an increase in the likelihood that students would indicate they were interested in a career in the sciences or engineering and an increase in the likelihood that students would indicate that SEF increased their interest in the sciences or engineering. Help from parents and/or teachers had less impact than help from scientists but more so than no help from scientists, teachers or parents.

Fig 5. Impact of help from scientists, parents and teachers

We also compared differences in student experience according to whether students competed only at the school level or in more advanced SEFs. Fig 6 shows even more clearly than Fig 4 that Black students were the least likely to advance beyond school level SEFs. By comparison, of the Hispanic students who indicated the level of SEF in which they participated, 2/3 went beyond the school level. By the criterion of whether they advanced to SEFs beyond the school level, Hispanic students were more successful in SEF than students in other ethnic groups. Students who advanced to higher level SEFs also were more likely to have an interest in a career in the sciences or engineering; almost twice as likely to indicate that SEF participation increased their interest in S&E; and less likely to have been required to do SEF.

One type of help that students received stood out compared to all others. Students who said that they received coaching for the SEF interview were more than twice as likely to advance beyond the school level compared to students who did not receive coaching.

Fig 6. Level of SEF competition

Factors affecting impact of SEF on student interest in the sciences and engineering

One of the most important goals of SEFs is to increase student interest in S&E. As was shown in Fig 4, Hispanic and Asian students were more likely to indicate that SEF increased their interest in S&E compared to Black and White students. Figs 7, 8 and 10 show the survey data analyzed to determine what experiences by students in each ethnic group correlated with a greater percentage of students who indicated that SEF increased their interest in S&E. Some of these features turned out to be typical of students in all ethnic groups, while others were more selective. Fig 7 concerns overall features. Fig 8 concerns sources of help. Fig 10 concerns types of help received, obstacles faced, and ways to overcome obstacles. Numerical and statistical details for the figures can be found organized by ethnic group in supplemental data (S2-S5 Tables).

Fig 7 shows that students in all ethnic groups who indicated that SEF increased their interests in S&E were more likely be interested in a career in S&E compared to students who indicated that SEF did not increase their interest in S&E. Numerical values for this comparison can be found in row #1 of supplemental Tables S2-5: Asian students, 77.2% vs. 41.4% ($p<.001$); Black students, 63.5% vs. 26.4% ($p<.001$); Hispanic students, 67.9% vs. 37.8% ($p<.001$); White students, 73.2% vs. 31.4% ($p<.001$). Also, students in all ethnic groups who said that SEF increased their interests in S&E were more likely to indicate that they participated in SEF beyond the school level.

On the other hand, if they were required to participate in SEF, then they were more likely to indicate the opposite. Carrying out an individual rather than team project was more positive for Asian and White students. Carrying out SEF more than once was more positive for Hispanic students.

Fig 7. Overall features that influenced impact of SEF on student interest in S&E

Fig 8 is organized similarly to Fig 7. For instance, getting help from parents had a positive impact for Hispanic students who said that SEF increased their interests in S&E. Help for parents did not make a difference for students in the other ethnic groups. Numerical values for this comparison can be found row #6 of supplemental Tables S2-5 -- Asian students, 48.6% vs. 43.8% (p=.338); Black students, 41.3% vs. 43.1% (p=.860); Hispanic students, 47.8% vs. 28.9% (p=.005); and White students, 56.7% vs. 52.1% (p=.411). Also, for students in all groups, getting help from teachers and getting the kind of help wanted had a positive impact on students who indicated that SEF increased their interests in S&E. Help from scientists was positive for students in all the groups but effectively unavailable to Black students as shown earlier (Fig 3 and Fig 5). Hispanic, Asian, and White students but not Black students also indicated a positive impact of some combination of using articles from the internet and books or magazines.

Fig 8. Sources of help that influenced impact of SEF on student interest in S&E

More subtle differences than those shown in Figs 7 and 8 occurred regarding kinds of help students received, obstacles faced, and ways to overcome obstacles. Fig 9 summarizes the most important factors, which showed only small differences between ethnic groups. Black students appeared to receive more help that others gathering background information/logistics and were less likely to do more research to overcome obstacles. White students appeared to receive more help fine tuning their reports. Although experienced similarly overall by students in the different ethnic groups, the factors shown in Fig 9 turned out to be differentially important with respect to the impact of SEF on student interest in S&E.

Fig 9. Ethnicity and SEF help and obstacles

Fig 10 shows that getting help with background information/logistics made more of a difference for Black students compared to other students in relationship to whether students indicated that SEF participation increased their interests in S&E. Numerical values for this comparison can be found in row #12 of supplemental Tables S2-5: Asian students, 29.0% vs. 23.5% (p=.208); Black students, 47.6% vs. 27.8% (p=.021); Hispanic students, 25.5% vs. 34.4% (p=.144); White students, 25.3 vs. 19.1% (p=.121). For students in all ethnic groups, coaching for the interview had a positive impact on the percentage of students who indicated that SEF increased their interests in S&E. Although time pressure was the most frequently indicated obstacle faced, the negative impact appeared to be greater for Black students than others. Getting help fine tuning their reports benefitted students in other groups more than Black students. Getting organized was an obstacle for White students. Hispanic and Asian students (and to a lesser extent White students) indicated a positive impact of overcoming obstacles by doing more background research, making a timeline to follow, and perseverance. None of these ways of overcoming obstacles was statistically significant for Black students.

Figure 10. Kinds of help, obstacles faced, and ways to overcome obstacles that influenced

impact of SEF on student interest in S&E

Discussion

In this paper, we report ethnicity trends in student participation and experience in high school science and engineering fairs. Our findings are based on students who registered and carried out SEF projects through the Scienteer website (almost 80,000 students over two years) and on those students who completed surveys after finishing all of their SEF competitions (1,320 students over two years). We treat the Scienteer SEF population as a national group of high school students. However, it should be recognized that these students may not be truly representative of a national sample since they come from only 7 U.S. states, and they only attend high schools where SEF is available.

SEF participation showed significant ethnic diversity. According to Scienteer registration, the approximate distribution of students was Asian-15%, Black-7%, Hispanic-25%, White-26%, and Other-27%. For survey students, the approximate distribution was Asian-32%, Black-11%, Hispanic-20%, White-33%, and Other-3%. Comparing the survey results to the original Scienteer registration, twice as many students self-identified as Asian, almost twice as many as Black, and very few selected Other. We don't know why the difference in selection of the Other category. One possibility is that during initial Scienteer registration some students preferred to have ethnic anonymity, which was less important to them after completing all of their SEF activities.

The national NCE-HSLS (2009) study determined the percentage of students who indicated that they planned to pursue a STEM major when they reached college [28]. Broken down by ethnic identification, the STEM-interested student groups were Asian (41.9%), Black (15.5%), Hispanic (19.8%), and White (24.8%). Under representation of Black and Hispanic individuals in STEM careers does not result from an initial lack of student interest in STEM but from subsequent differences in persistence and overall graduation rates in STEM degree programs compared to Asian and White students [29, 30].

The pattern of students who participated in SEF resembles the distribution of STEM-interested student groups. An attractive hypothesis is that even though only a small portion of high school students participate, those who do are representative of overall STEM interests amongst high school students. Participating in high school science competitions helps retain students' interest in STEM [5, 11]; SEFs provide an opportunity to practice those interests [6]; and authentic research experiences help high school students understand the nature of science [31]. Therefore, increasing the availability of SEFs to more students would be a valuable objective.

Based on Scienteer and survey data, Black students made up only 4.5% of the students who participated in SEFs beyond the school level, whereas students from other ethnic groups were more equally represented. The lower level could result from two different factors -- on one hand the overall lower level of participation of Black students in SEFs compared to other ethnic groups; and on the other hand, the lower success rate of those black students who did participate to advance beyond the school level. As will be discussed, the data suggest that Black students are not getting the help that they need to be successful in SEFs.

The ratios (percentages) for experiences that appeared to be especially relevant to whether

students advanced to SEFs beyond school only were 3.7:1 for getting help from scientists; 2.2:1 for being coached for the interview; 1.7:1 for not being required to participate in SEF; and 1.6:1 for being interested in a career in S&E. On the other hand, the ratio was 0.42:1 for getting no help from parents, teachers, or scientists. Several of these factors likely contribute to the lower percentage of Black students that advanced. Black students received the least help from scientists; were least likely to get coaching for the interview; most likely to be required to do SEF; were least interested in a career in S&E; and were most likely to get no help from parents, teachers or scientists. Hispanic students were the most likely to advance beyond school level SEFs followed by Asian and White students. A limitation of our analysis is the uncontrolled factor that the number of advancing students will depend not only on student performance, but also on the number of SEF entries that a school or district permits to advance, which typically will be governed by individual school and district policies.

The question regarding level of SEF competition was new to the surveys analyzed in this report. However, the findings are consistent with our previous analysis of a cohort of high school students from a North Texas school district whose students are consistently high achievers in the Dallas Regional Science and Engineering Fair and beyond. We found that 26% of those students received help from scientists; over 80% received coaching for the interview; and less than 10% were required to participate in SEF [32].

One of the most important goals of SEF is to increase student interest in S&E. Asian and Hispanic students indicated that SEF participation increased their interests in S&E (63.6% and 63%), which was higher than Black and White students (46.7% and 45.3%). These differences were similar to those indicated by students about their interests in STEM careers -- Asian and Hispanic students (63.8% and 56.8%) vs. Black and White students (43.7% & 50.7%). Therefore, students already interested in S&E careers might be primed to have a positive SEF experience. Or participation in SEF may consolidate students' interest in STEM careers, consistent with the findings about retention via science competitions cited earlier [5, 11].

Other student experiences that potentially enhanced SEF increasing a student's interest in S&E were competition beyond school level; help from teachers; and coaching for the interview. A requirement to participate was negative. For Asian, Hispanic, and White students, help from scientists (not available to Black students) was positive. Also, help from the internet and/or books and magazines was positive for Asian, Hispanic and White students but made no difference for Black students.

Only Hispanic students indicated that help from parents was positive. Also, only Hispanic students indicated that carrying out SEF more than once was positive. The latter was consistent with the observation that a higher percentage of Hispanic students participated in SEF in 11th and 12th grades. Previously, we reported that high school students who participated in SEF in 11th and 12th grades were more likely to indicate that they were interested in a career in S&E, and more than 50% of undergraduates we surveyed (all on bioscience education trajectories) who participated in SEFs in high school did so more than once [6].

Getting help with background information/logistics was more positive for Black students than others. Time pressure was more of an obstacle for them. Also, Black students did not experience a positive effect of fine tuning the report. Getting organized was more of an obstacle for White students than others. The ways of overcoming obstacles that many students indicated had a

positive effect were doing more background research, making a timeline, and perseverance. Black students did not report a positive effect of any of these ways to overcome obstacles.

These findings identify a wide range of student experiences associated with positive SEF outcomes that could be enhanced for all students, but especially for Black students. More involvement of scientists in helping SEF students would be particularly valuable since 80% of students who received help from scientists said that they were interested in a career in S&E; less than 5% said that they were uninterested; and 83% of the students said that help from scientists increased the positive impact of participating in SEF.

Previous studies by others showed factors contributing to success in SEF included parental support and encouragement [33], social and research resources [34], and access to outside of school facilities [35]. In our work, we observed that students who received help from scientists had an easier time getting their research idea, more access to articles in books and magazines, and less difficulty getting the resources to carry out the projects [13]. SEF guidelines typically emphasize that a SEF project should be the student's; the mentor's job is supportive not directive. Nevertheless, because help from scientists and similar support is available to only a subset of students, some critics have suggested that competitive SEF is fundamentally unfair [36-38]. For this reason, we suggested the possible value of offering students a non-competitive SEF option [15]. For competitive SEF, our findings support the idea that the best way to increase success of all high school students would be by developing programs that result in more help for the students from scientists or student scientists. Some innovative programs along these lines recently have been initiated [16-18, 39].

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Supporting information

S1 Data set. Excel dataset showing all of the survey questions and answers for 2018/19 surveys.

S2 Data set. Excel dataset showing all of the survey questions and answers for 2019/20 surveys.

S1 Survey. Survey questions.

S1 Table. Comparison of survey responses by students from 2018-19 vs. 2019-2020 vs. combined 2016-18 survey years.

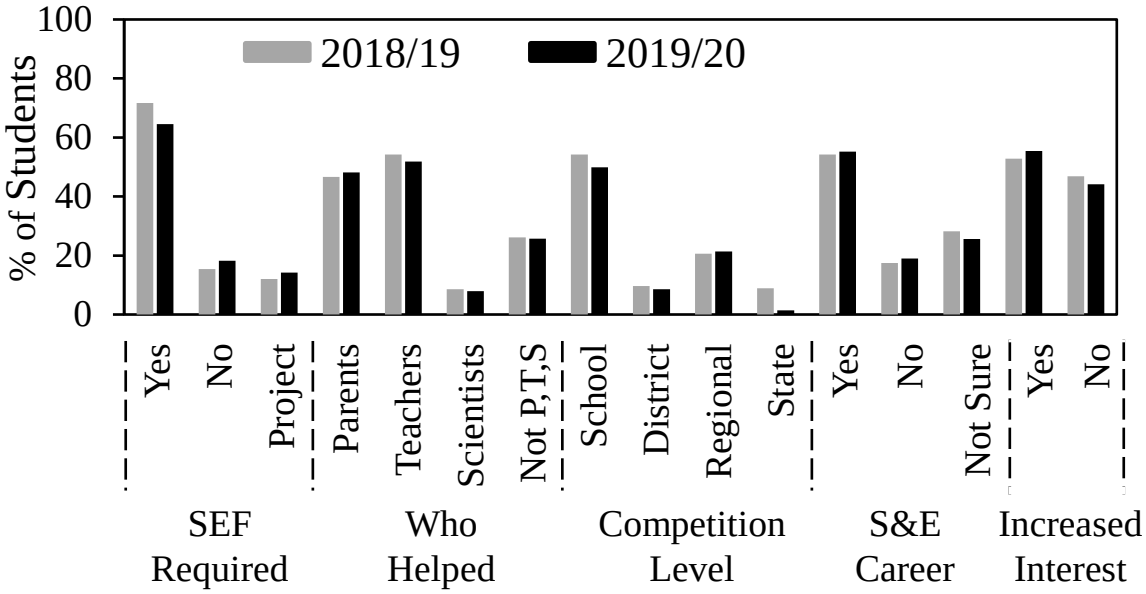
S2 Table. Factors influencing the effect of SEF participation on Asian students' interest in S&E.

S3 Table. Factors influencing the effect of SEF participation on Black students' interest in S&E.

S4 Table. Factors influencing the effect of SEF participation on Hispanic students' interest in S&E.

S5 Table. Factors influencing the effect of SEF participation on White students' interest in S&E.

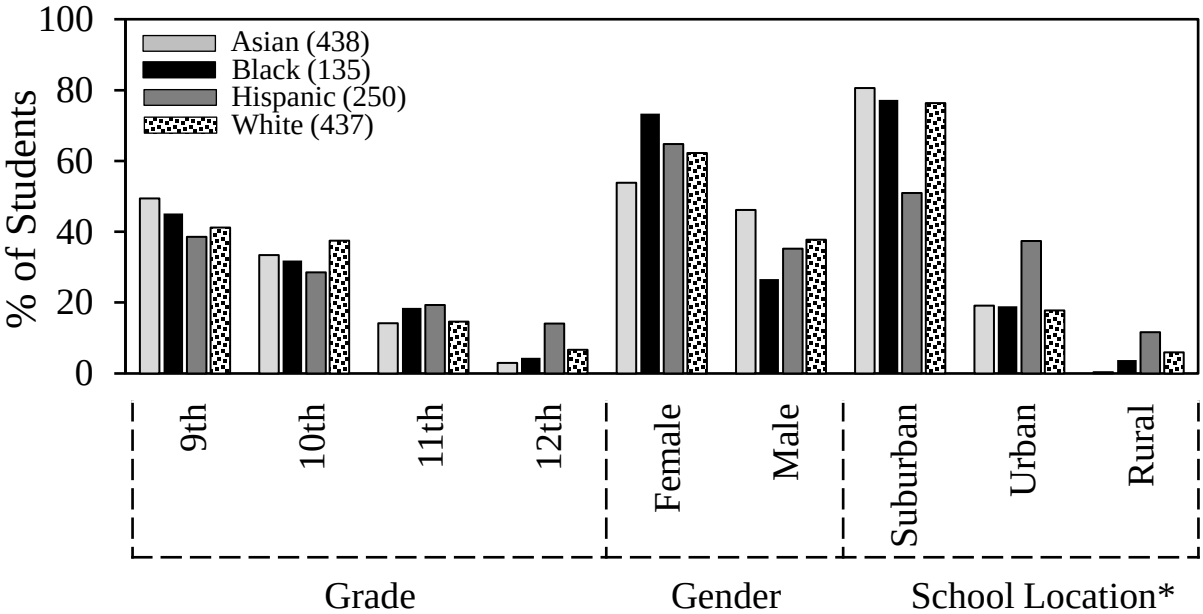
Figure 1. Some key features of SEF experience - 2018/19 vs. 2019/20 student groups



Survey Questions	Answers*	2018/19 382 Students % (#)	2019/2020 938 Students % (#)
SEF required?	Yes	71.7 (274)	64.5 (605)
	No	15.4 (59)	18.2 (171)
	School Project	12.0 (46)	14.3 (134)
Who helped you with your project? (multiple answers possible)	Parents (P)	46.6 (178)	48.2 (452)
	Teachers (T)	54.2 (207)	51.8 (486)
	Scientists (S)	8.6 (33)	8.0 (75)
	Not P, T or S	26.2 (100)	25.7 (241)
Highest level of SEF competition?	School	54.2 (207)	49.9 (468)
	District	9.7 (37)	8.6 (81)
	Regional	20.7 (79)	21.4 (201)
	State	8.9 (34)	1.5 (14)
Interest in a career in the sciences or engineering?	Yes	54.2 (207)	55.2 (518)
	No	17.5 (67)	19.0 (178)
	Not sure	28.3 (108)	25.6 (240)
SEF increased your interest in S&E?	Yes	52.9 (202)	55.4 (520
	No	46.9 (179)	44.1 (414)

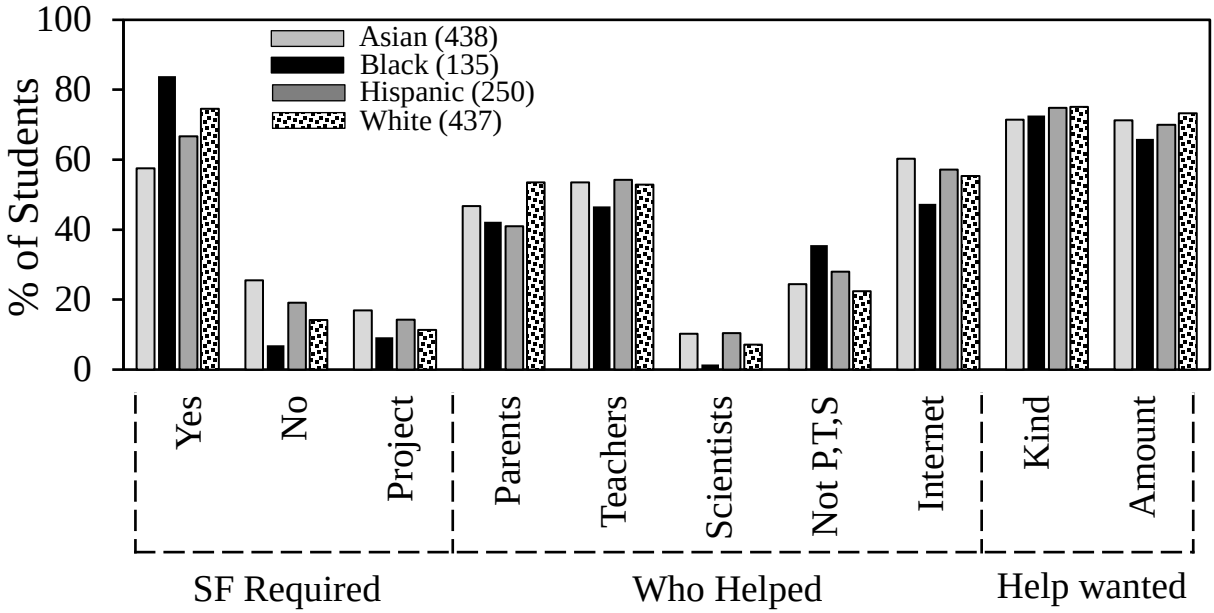
*Answer completion rate >97% except for the question about level of SEF competition = 93.5% in 2018/2019 and 81.4% in 2019/202.

Figure 2. Ethnicity and student demographics



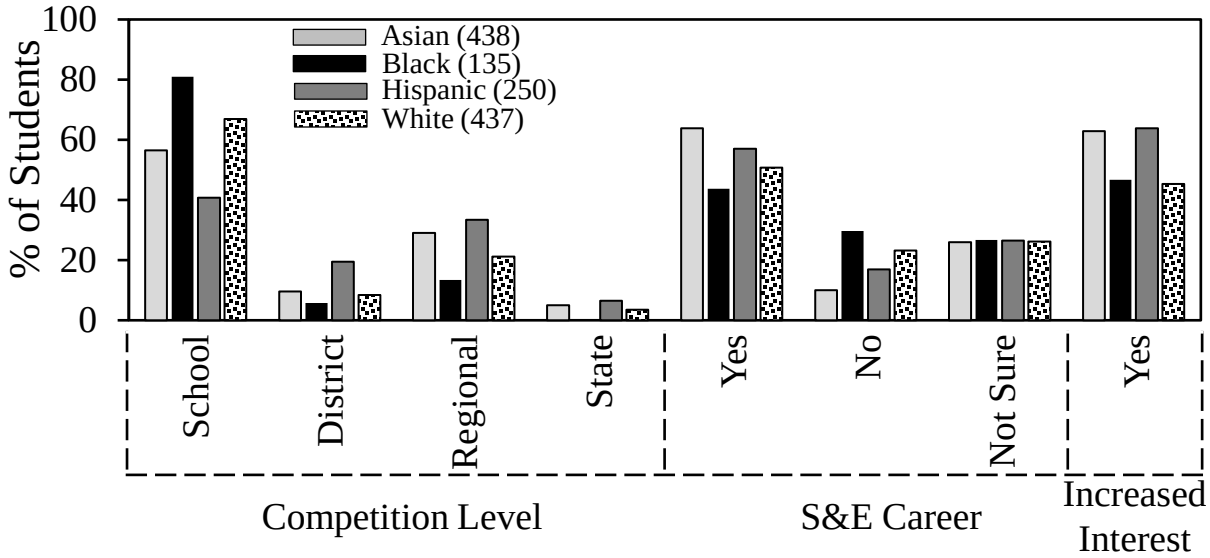
	Answers	Ethnicity				p Value
		Asian % (#)	Black % (#)	Hispanic % (#)	White % (#)	
What grade are you in?	9th	49.4 (216)	45.2 (61)	38.4 (96)	41.2 (180)	<.001
	10th	33.4 (146)	31.9 (43)	28.4 (71)	37.5 (164)	
	11th	14.2 (62)	18.5 (25)	19.2 (48)	14.6 (64)	
	12th	3.0 (13)	4.4 (6)	14.0 (35)	6.6 (29)	
Gender?	Female	53.9 (236)	73.3 (99)	64.8 (162)	62.2 (270)	<.001
	Male	46.1 (202)	26.7 (36)	35.2 (88)	37.8 (164)	
Location of high school? (*2020 only)	Suburban	80.6 (257)	77.2 (61)	51.0 (79)	76.3 (232)	<.001
	Urban	19.1 (61)	19.0 (15)	37.4 (58)	17.8 (54)	
	Rural	0.3 (1)	3.8 (3)	11.6 (18)	5.9 (18)	

Figure 3. Ethnicity and SEF involvement



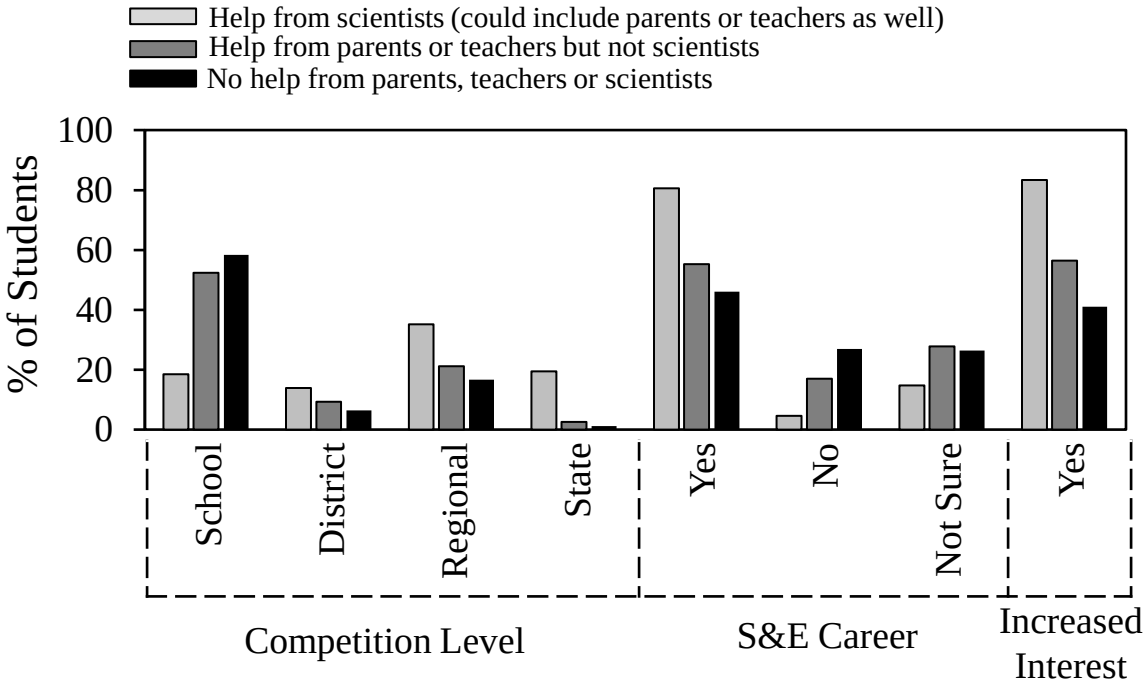
Survey Questions	Answers	Ethnicity				p Value
		Asian % (#)	Black % (#)	Hispanic % (#)	White % (#)	
SEF required?	Yes	57.5 (248)	83.8 (109)	66.7 (164)	74.5 (316)	<.001
	No	25.5 (110)	6.9 (9)	19.1 (47)	14.2 (60)	
	School Project	16.9 (73)	9.2 (12)	14.2 (35)	11.3 (48)	
Who helped you with your SEF project? (more than one answer possible)	Parents	46.8 (205)	42.2 (57)	40.8 (102)	53.5 (234)	.006
	Teachers	53.7 (235)	46.7 (63)	54.0 (135)	52.9 (231)	.507
	Scientists	10.3 (45)	1.5 (2)	10.4 (26)	7.1 (31)	.005
	Not parents, teachers or scientists	24.4 (107)	35.6 (48)	28.0 (70)	22.4 (98)	.015
	Internet Articles	60.3 (264)	47.4 (64)	57.2 (143)	55.4 (242)	.065
Received help wanted from teachers?	Kind	71.5 (313)	72.6 (98)	74.8 (187)	75.1 (328)	.568
	Amount	71.2 (312)	65.9 (89)	70.0 (175)	73.2 (320)	.423

Figure 4. Ethnicity and SEF outcomes



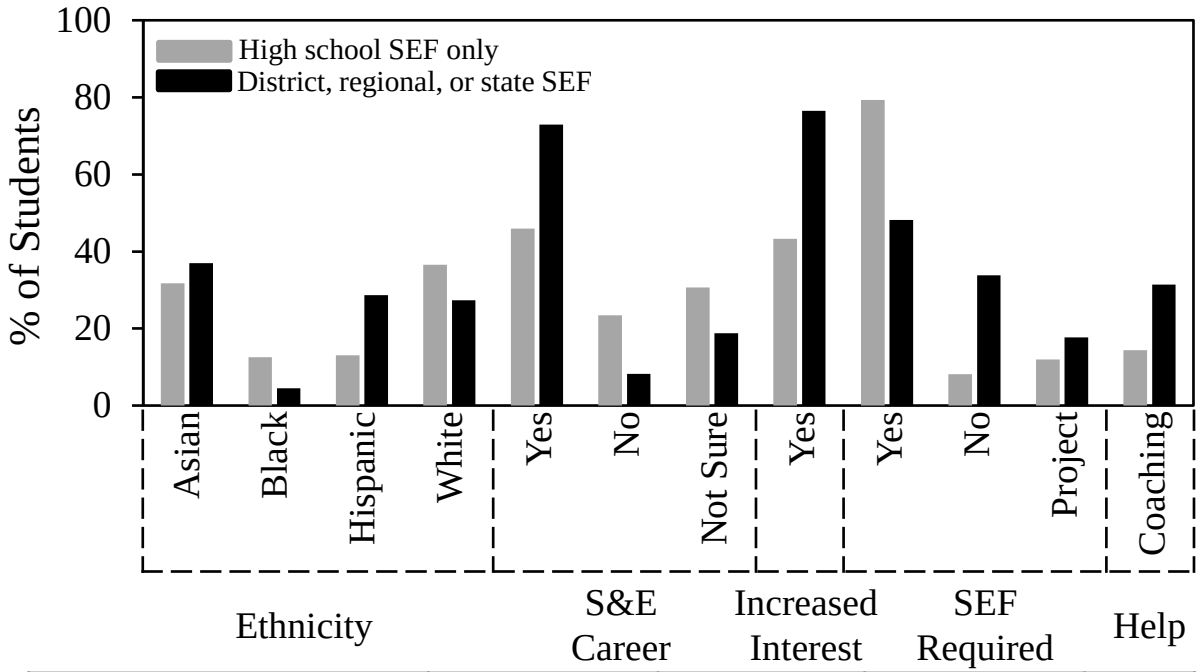
Survey Questions	Answers	Ethnicity				p Value
		Asian % (#)	Black % (#)	Hispanic % (#)	White % (#)	
Highest level of SEF competition?	School	56.5 (214)	81.0 (85)	40.7 (88)	66.9 (247)	<.001
	District	9.5 (36)	5.7 (6)	19.4 (42)	8.4 (31)	
	Regional	29.0 (110)	13.3 (14)	33.3 (72)	21.1 (78)	
	State	5.0 (19)	0.0 (0)	6.5 (14)	3.5 (13)	
Interest in a career in the sciences or engineering?	Yes	63.8 (280)	43.7 (59)	56.8 (142)	50.7 (221)	<.001
	No	10.0 (44)	29.6 (40)	16.8 (42)	23.2 (101)	
	Not sure	26.0 (114)	26.7 (36)	26.4 (66)	26.1 (114)	
SEF increased your interest in S&E?	Yes	62.9 (276)	46.7 (63)	63.6 (159)	45.3 (198)	<.001

Figure 5. Impact of help from scientists, parents and teachers



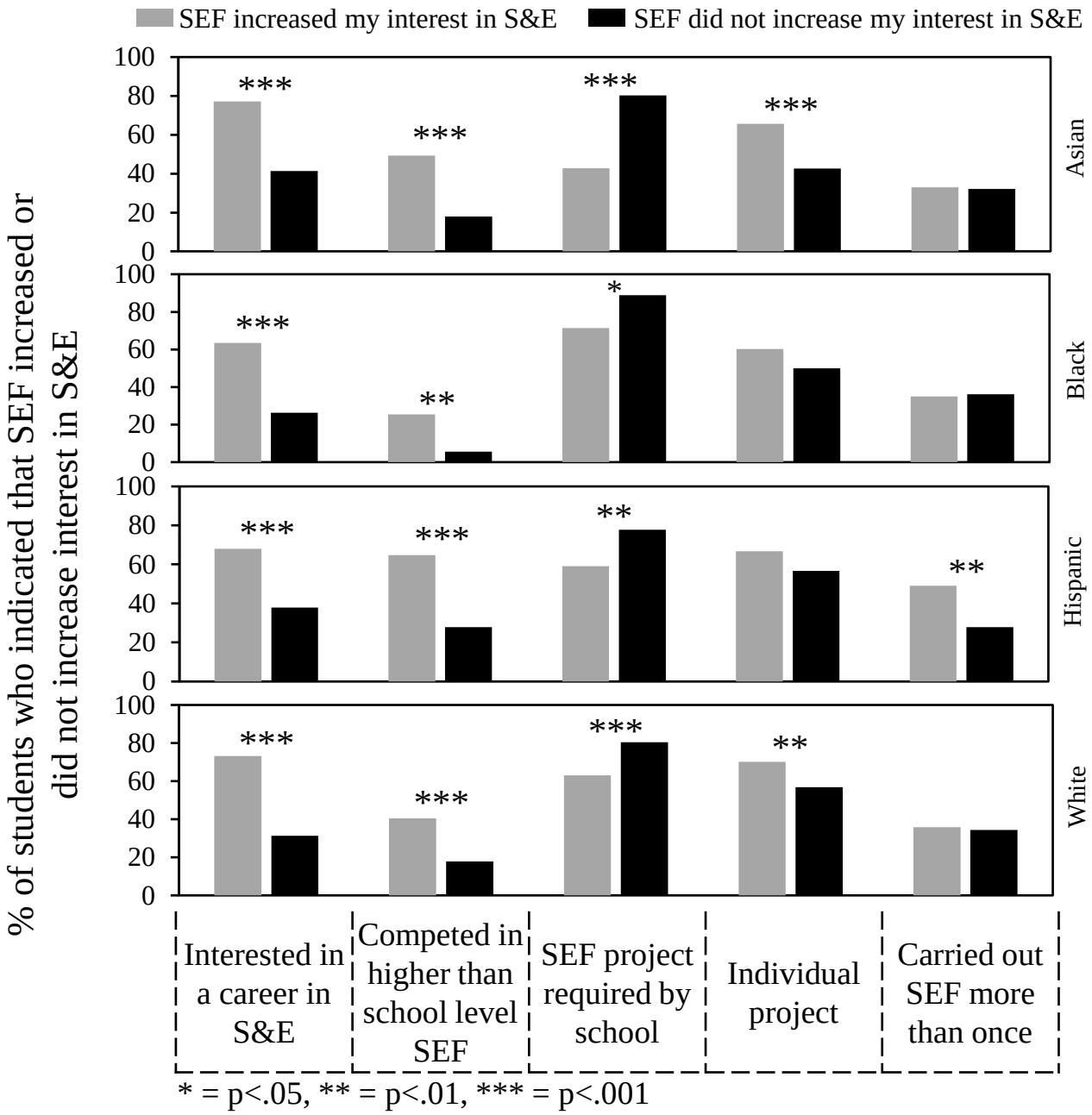
Survey Questions	Answers	Who helped students			p Value
		S (108 stud) % (#)	P,T, not S (871 stud) % (#)	Not P,T,S (341 stud) % (#)	
Highest level of SEF competition?	School	18.5 (20)	52.4 (456)	58.4 (199)	<.001
	District	13.9 (15)	9.3 (81)	6.5 (22)	
	Regional	35.2 (38)	21.2 (185)	16.7 (57)	
	State	19.4 (21)	2.6 (23)	1.2 (4)	
Interested in a career in the sciences or engineering?	Yes	80.6 (87)	55.2 (481)	46.0 (157)	<.001
	No	4.6 (5)	17.0 (148)	27.0 (92)	
	Not sure	14.8 (16)	27.8 (242)	26.4 (90)	
SEF increased your interest in S&E?	Yes	83.3 (90)	56.5 (492)	41.1 (140)	<.001

Figure 6. Level of SEF competition



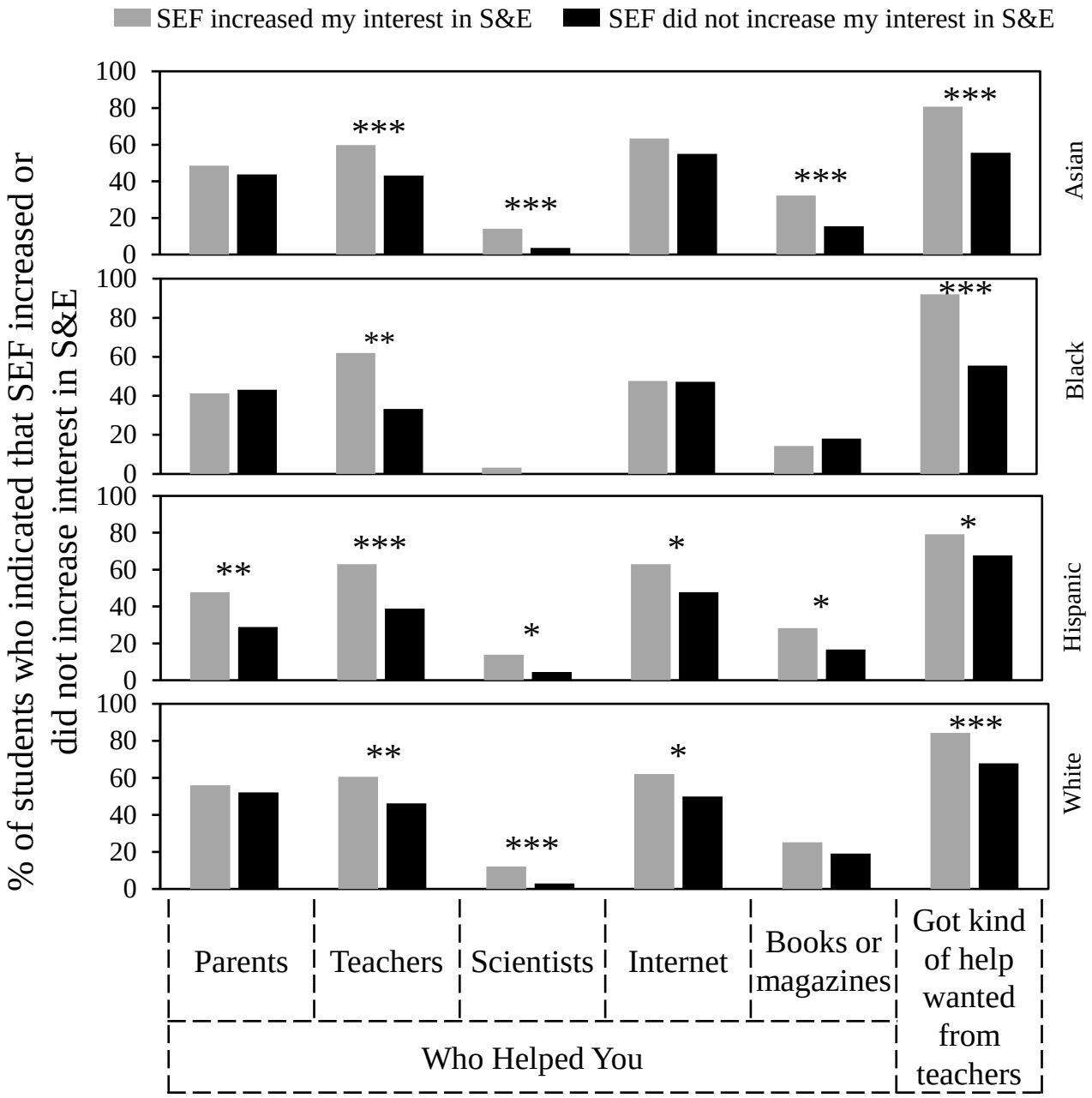
Survey Questions	Answers	School Only % (#)	Dist/Reg/State % (#)	p Value
Ethnicity most identified with?	Asian	31.7 (214)	37.0 (165)	<.001
	Black	12.6 (85)	4.5 (20)	
	Hispanic	13.0 (88)	28.7 (128)	
	White	36.6 (247)	27.4 (122)	
Interest in a career in the sciences or engineering (S&E)?	Yes	45.9 (310)	72.9 (325)	<.001
	No	23.4 (158)	8.3 (37)	
	Not sure	30.7 (207)	18.8 (84)	
SEF increased your interest in S&E?	Yes	43.3 (292)	76.5 (341)	<.001
SEF required?	Yes	79.3 (535)	48.2 (215)	<.001
	No	8.1 (55)	33.9 (151)	
	School Project	12.0 (81)	17.7 (79)	
Received coaching for interview?	Yes	14.4 (97)	31.4 (140)	<.001

Figure 7. Overall features that influenced impact of SEF on student interest in S&E



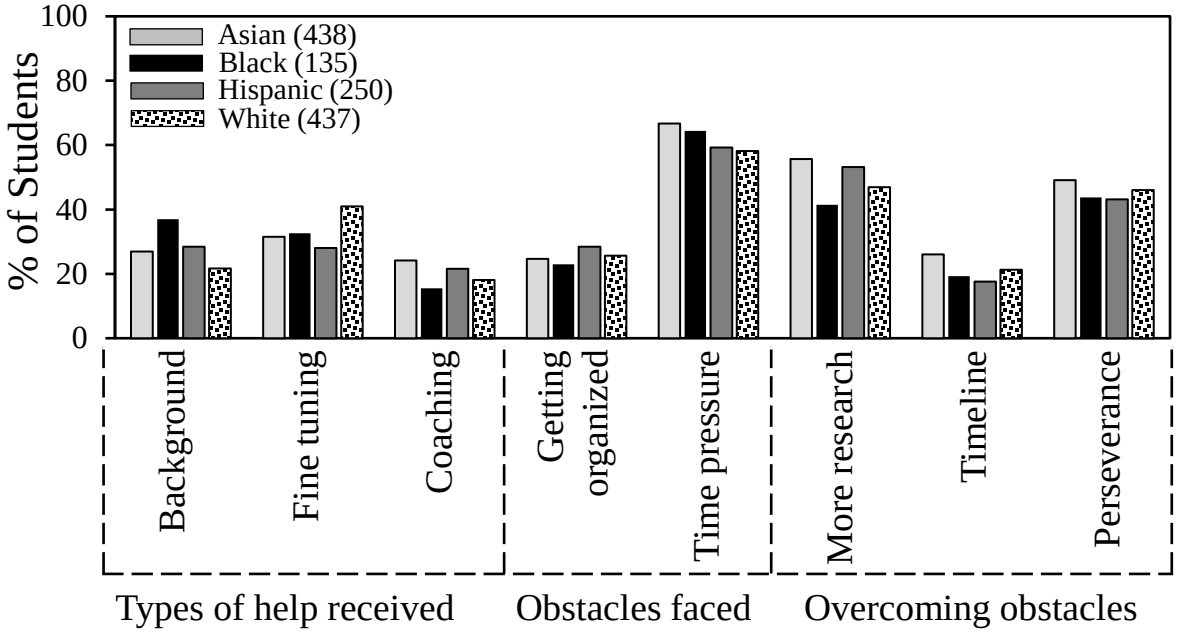
* = p<.05, ** = p<.01, *** = p<.001

Figure 8. Sources of help that influenced impact of SEF on student interest in S&E



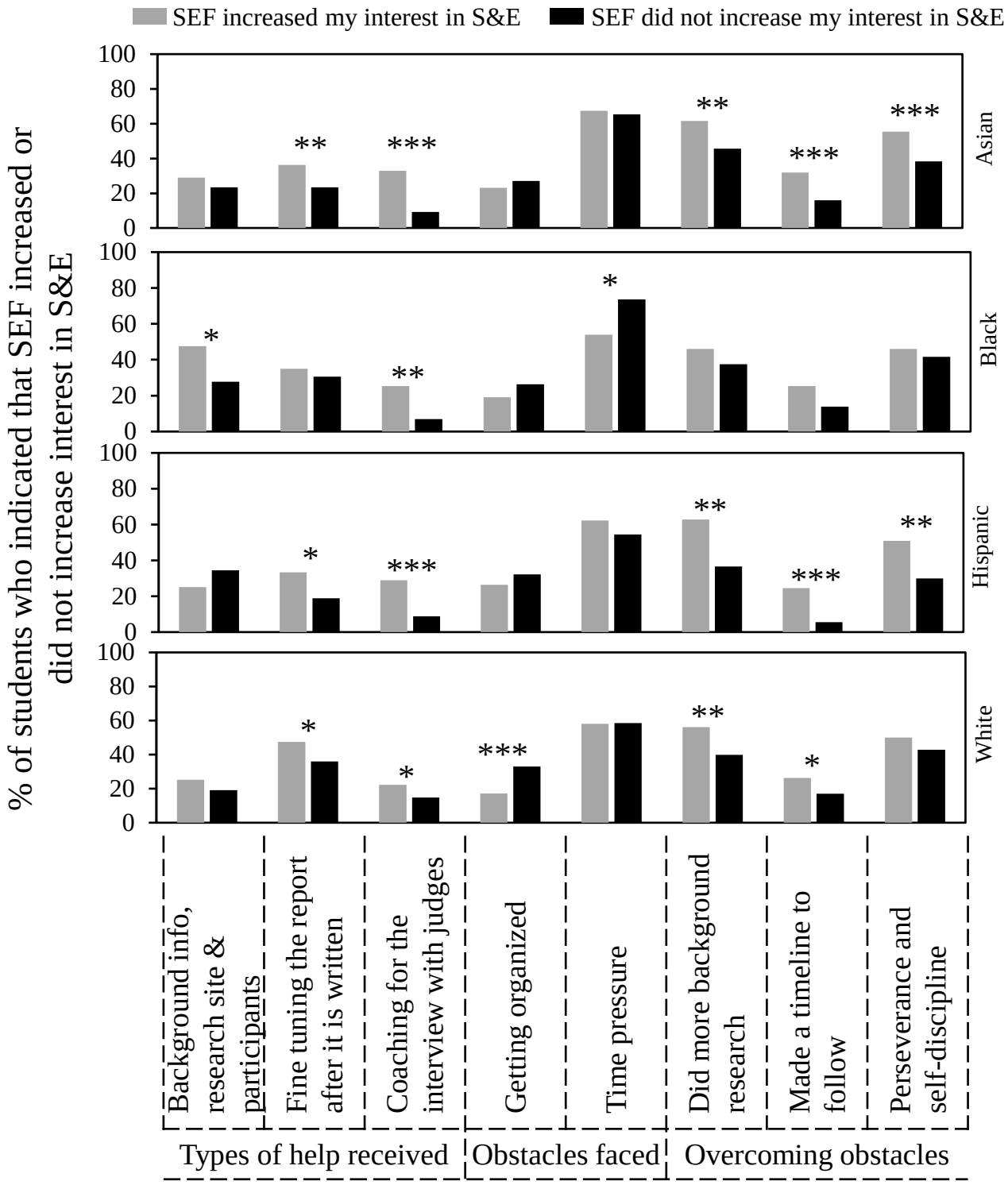
* = p<.05, ** = p<.01, *** = p<.001

Figure 9. Ethnicity and SEF help and obstacles



Survey Questions	Answers	Ethnicity				p Value
		Asian % (#)	Black % (#)	Hispanic % (#)	White % (#)	
Kind of help received	Gathering background info and participants	26.9 (118)	37.0 (50)	28.4 (71)	21.7 (95)	.004
	Fine tuning report	31.5 (138)	32.6 (44)	28.0 (70)	41.0 (179)	.002
	Coaching for Interview	24.2 (106)	15.6 (21)	21.6 (54)	18.1 (79)	.061
Obstacles faced	Getting organized	28.4 (108)	23.0 (31)	24.7 (71)	25.6 (112)	.610
	Time pressure	66.7 (292)	64.4 (87)	59.2 (148)	58.1 (254)	.055
Overcoming obstacles	More background research	55.7 (244)	41.5 (56)	53.2 (133)	46.9 (205)	.007
	Made a timeline	26.0 (114)	19.3 (26)	17.6 (44)	21.3 (93)	.058
	Perseverance and self-discipline	49.1 (215)	43.7 (59)	43.2 (108)	46.0 (201)	.475

Figure 10. Kinds of help, obstacles faced, and ways to overcome obstacles that influenced impact of SEF on student interest in S&E



* = p<.05, ** = p<.01, *** = p<.001

Supplemental Table 1. Comparison of survey responses by students from 2018-19 vs. 2019-2020 vs. combined 2016-18 survey years

Survey Questions	Answers	2018/19 (382 students)	2019/20 (938 students)	2016-18 (363 students)
		% Students		
1. What grade are you in?	9th	44.8	43.6	40.5
	10th	31.9	33.8	32.2
	11th	13.9	16.5	11.3
	12th	8.6	5.8	11.0
1A. Location of high school?	Suburban	-	70.5	-
	Urban	-	20.7	-
	Rural	-	4.8	-
2. Gender?	Female	63.9	59.3	63.4
	Male	34.3	40.2	35.8
2A. Ethnicity most identified with?	Asian	28.8	35.0	-
	Black	13.1	9.1	-
	Hispanic	22.8	17.4	-
	White	32.2	33.5	-
	Other	1.8	4.1	-
3. During high school have you carried out science fair more than once?	Yes	29.6	37.5	31.1
	No	69.4	61.8	67.2
3A. In which science fair competitions did you compete this year?	School	54.2	49.9	-
	District	9.7	8.6	-
	Regional	20.7	21.4	-
	State	8.4	1.5	-
4. Was your science fair project Team or Individual?	Individual	63.1	58.6	70.2
	Team	35.9	37.6	29.2

5. Was the science fair project required by your school?	Yes	71.7	64.5	67.5
	No	14.9	18.2	16.8
	Satisfied School Project	12.0	14.3	15.2
6. Do you think science fair projects should be optional or required? (Need not be for competition.)	Optional	74.1	75.4	74.4
	Required	25.1	23.1	25.6
8. Do you think science fair projects for competition should be optional or required?	Optional	83.8	83.9	78.8
	Required	14.4	13.6	20.9
10. From whom do you think it would be reasonable to receive help?	1. Parents	77.0	77.4	78.0
	2. Siblings	63.1	61.2	61.4
	3. Other family members	57.6	54.3	52.9
	4. Teachers	90.3	90.7	89.8
	5. Other students	64.1	61.6	61.2
	6. Scientists	70.7	67.7	70.0
	7. A paid mentor	33.0	27.5	27.0
	8. Articles on the Internet	78.8	77.1	78.2
	Articles in books or magazines	73.3	70.6	72.5
	Other	3.9	2.3	3.9
11. Who actually helped you?	1. Parents	46.3	48.2	51.0
	2. Siblings	16.5	10.8	14.3
	3. Other family members	4.5	5.4	7.7
	4. Teachers	53.7	51.8	55.4
	5. Other students	30.1	30.7	23.7
	6. Scientists	8.6	8.0	8.0
	7. A paid mentor	0.5	0.4	1.1

	8. Articles on the Internet	52.6	57.5	57.9
	Articles in books or magazines	23.3	22.7	24.0
	Other	5.8	3.4	5.2
12. Kind of help reasonable to expect from others?	1. Being given the main idea	18.3	18.9	21.2
	2. Development of the idea	39.0	45.6	40.5
	3. Gathering background research information, or finding a research site or participants	46.1	45.0	49.3
	4. Performing the experiments	43.2	46.2	43.5
	5. Writing the report	12.6	14.7	13.5
	6. Fine tuning the report after it is written	58.9	62.4	52.3
	7. Designing the poster board and presentation	33.5	35.9	33.1
	8. Producing charts or graphs	23.0	24.4	19.3
	9. Coaching for the interview with judges	63.1	59.1	58.4
	10. Copying the project from someone else	1.6	2.7	1.4
	Other	2.4	2.1	3.3
13. What kind of help did you actually receive?	1. Being given the main idea	8.9	9.4	13.8
	2. Development of the idea	25.7	26.8	26.2
	3. Gathering background research information, or finding a research site or participants	27.2	25.8	25.9
	4. Performing the experiments	29.3	28.6	24.5
	5. Writing the report	6.8	9.5	8.5
	6. Fine tuning the report after it is written	35.9	33.2	32.2
	7. Designing the poster board and presentation	19.9	22.3	19.0
	8. Producing charts or graphs	11.8	13.9	7.7
	9. Coaching for the interview with judges	19.4	20.9	22.0
	10. Copying the project from someone else	0.3	0.7	1.1
	Other	6.5	6.1	8.8

14. Did you get the kind of help you wanted from teachers?	Yes	69.9	74.3	72.2
	No	28.0	24.6	26.7
16. Did you get the amount of help you wanted from teachers?	Yes	65.4	73.1	74.1
	No	31.9	25.2	24.5
17. Were the results of your project as expected?	Yes	63.6	65.6	63.1
	No	34.8	32.8	35.5
18. What obstacles did you face?	1. Coming up with the main idea	47.9	45.6	44.6
	2. Getting motivated to do the project	46.1	43.1	35.5
	3. Becoming disappointed with the project	29.1	25.5	21.8
	4. Limited resources	39.8	38.1	36.1
	5. Limited knowledge	29.1	30.9	30.6
	6. Limited skills	23.6	24.5	22.0
	7. Limited cooperation	15.4	12.7	11.6
	8. Getting organized	23.3	26.8	21.2
	9. Time pressure	59.2	62.6	57.3
	10. Not enough money	21.5	16.7	18.7
	11. Results not as expected	24.6	22.8	20.7
	Other	4.2	3.7	4.4
19. How did you overcome the obstacles?	1. Used someone else's main idea	1.8	1.3	2.8
	2. Picked a familiar / interesting topic	34.0	30.8	29.8
	3. Did more background research	49.7	50.4	48.5
	4. Stopped working on the project for a while	17.5	15.8	16.0
	5. Made a timeline to follow	19.9	22.3	20.7
	6. Perseverance and self-discipline	41.6	48.1	44.4
	7. Had someone else to keep me on track	16.0	16.2	13.8
	8. Had someone else do the math	1.3	1.6	1.1

	9. Changed the research plan	14.7	18.7	11.6
	10. Collected more data	23.6	24.6	22.0
	11. Had someone else collect the data	1.0	2.1	0.6
	12. Used someone else's data	0.3	0.5	1.4
	13. Made up the data	5.0	4.1	4.1
	14. Changed the hypothesis to fit the data	4.7	3.8	4.4
	15. Changed the data to fit the hypothesis	3.1	1.5	2.2
	Other	6.0	4.5	8.0
20. Are you interested in a career in the sciences or engineering?	Yes	53.9	55.2	57.6
	No	17.5	19.0	15.2
	Not Sure	28.0	25.6	27.3
21. Did your science fair experience increase your interest in the sciences or engineering?	Yes	52.4	55.4	58.7
	No	46.9	44.1	40.8

Supplemental Table 2. Factors influencing the effect of SEF participation on Asian students' interest in S&E

Survey Questions	**Answers**	**SEF increased my interest in S&E**		
		Yes % (#) (276 students)	**No % (#) (162 students)**	**P value**
Interested in a career in S&E	Yes	77.2 (213)	41.4 (67)	<.001
Level of SEF competition?	District, Region or State	49.3 (136)	17.9 (29)	<.001
SEF required?	Yes	42.8 (118)	80.2 (130)	<.001
Project Team or Individual?	Individual	65.6 (181)	42.6 (69)	<.001
Participation?	Did SEF > once	33.0 (91)	32.1 (52)	.851
Who helped with your SEF project? (more than one answer is possible)	Parents	48.6 (134)	43.8 (71)	.338
	Teachers	59.8 (165)	43.2 (70)	<.001
	Scientists	14.1 (39)	3.7 (6)	<.001
	Articles on the internet	63.4 (175)	54.9 (89)	.080
	Articles in books or magazines	32.2 (89)	15.4 (25)	<.001
Received kind of help needed from teachers?	Yes	80.8 (223)	55.6 (90)	<.001
Types of help received?	Gathering background info, research site and participants	29.0 (80)	23.5 (38)	.208
	Fine tuning the report	36.2 (100)	23.5 (38)	.005
	Coaching for the interview	33.0 (91)	9.3 (15)	<.001
Obstacles faced?	Getting organized	23.2 (64)	27.2 (44)	.352
	Time Pressure	67.4 (186)	65.4 (106)	.675
Ways to overcome obstacles?	More background research	61.6 (170)	45.7 (74)	.001
	Made a timeline	31.9 (88)	16.0 (26)	<.001
	Perseverance	55.4 (153)	38.3 (62)	<.001

Supplemental Table 3. Factors influencing the effect of SEF participation on black students' interest in S&E

Survey Questions	Answers	SEF increased my interest in S&E		
		Yes % (#) (63 students)	No % (#) (72 students)	P value
Interested in a career in S&E	Yes	63.5 (40)	26.4 (19)	<.001
Level of SEF competition?	District, Region or State	25.4 (16)	5.6 (4)	.001
SEF required?	Yes	71.4 (45)	88.9 (64)	.015
Project Team or Individual?	Individual	60.3 (38)	50.0 (36)	.298
Participation?	Did SEF > once	34.9 (22)	36.1 (26)	.885
Who helped with your SEF project? (more than one answer is possible)	Parents	41.3 (26)	43.1 (31)	.860
	Teachers	61.9 (39)	33.3 (24)	.001
	Scientists	3.2 (2)	0 (0)	.215
	Articles on the internet	47.6 (30)	47.2 (34)	.963
	Articles in books or magazines	14.3 (9)	18.1 (13)	.554
Received kind of help needed from teachers?	Yes	92.1 (58)	55.6 (40)	<.001
Types of help received?	Gathering background info, research site and participants	47.6 (30)	27.8 (20)	.021
	Fine tuning the report	34.9 (22)	30.6 (22)	.589
	Coaching for the interview	25.4 (16)	6.9 (5)	.004
Obstacles faced?	Getting organized	19.0 (12)	26.4 (19)	.211
	Time Pressure	54.0 (34)	73.6 (53)	.020
Ways to overcome obstacles?	More background research	46.0 (29)	37.5 (27)	.381
	Made a timeline	25.4 (16)	13.9 (10)	.125
	Perseverance	46.0 (29)	41.7 (30)	.610

Supplemental Table 4. Factors influencing the effect of SEF participation on Hispanic students' interest in S&E

Survey Questions	Answers	SEF increased my interest in S&E		
		Yes % (#) (159 students)	No % (#) (90 students)	P value
Interested in a career in S&E	Yes	67.9 (108)	37.8 (34)	<.001
Level of SEF competition?	District, Region or State	64.8 (103)	27.8 (25)	<.001
SEF required?	Yes	59.1 (94)	77.8 (70)	.003
Project Team or Individual?	Individual	66.7 (106)	56.7 (51)	.133
Participation?	Did SEF > once	49.1 (78)	27.8 (25)	.001
Who helped with your SEF project? (more than one answer is possible	Parents	47.8 (76)	28.9 (26)	.005
	Teachers	62.9 (100)	38.9 (35)	<.001
	Scientists	13.8 (22)	4.4 (4)	.029
	Articles on the internet	62.9 (100)	47.8 (43)	.024
	Articles in books or magazines	28.3 (45)	16.7 (15)	.045
Received kind of help needed from teachers?	Yes	79.2 (126)	67.8 (61)	.049
Types of help received?	Gathering background info, research site and participants	25.2 (40)	34.4 (31)	.144
	Fine tuning the report	33.3 (53)	18.9 (17)	.019
	Coaching for the interview	28.9 (46)	8.9 (8)	<.001
Obstacles faced?	Getting organized	26.4 (42)	32.2 (29)	.330
	Time Pressure	62.3 (99)	54.4 (49)	.227
Ways to overcome obstacles?	More background research	62.9 (100)	36.7 (33)	<.001
	Made a timeline	24.5 (39)	5.6 (5)	<.001
	Perseverance	5.9 (81)	3.0 (27)	.001

Supplemental Table 5. Factors influencing the effect of SEF participation on white students' interest in S&E

Survey Questions	Answers	SEF increased my interest in S&E		
		Yes % (#) (198 students)	No % (#) (236 students)	P value
Interested in a career in S&E	Yes	73.2 (145)	31.4 (74)	<.001
Level of SEF competition?	District, Region or State	40.4 (80)	17.8 (42)	<.001
SEF required?	Yes	63.1 (125)	80.5 (190)	<.001
Project Team or Individual?	Individual	70.2 (139)	56.8 (134)	.005
Participation?	Did SEF > once	35.9 (71)	34.3 (81)	.738
Who helped with your SEF project? (more than one answer is possible)	Parents	56.1 (111)	52.1 (123)	.411
	Teachers	60.6 (120)	46.2 (109)	.003
	Scientists	12.1 (24)	3.0 (7)	<.001
	Articles on the internet	62.1 (123)	50.0 (118)	.012
	Articles in books or magazines	25.3 (50)	19.1 (45)	.121
Received kind of help needed from teachers?	Yes	84.3 (167)	67.8 (160)	<.001
Types of help received?	Gathering background info, research site and participants	25.3 (50)	19.1 (45)	.121
	Fine tuning the report	47.5 (94)	36.0 (85)	.019
	Coaching for the interview	22.2 (44)	14.8 (35)	.047
Obstacles faced?	Getting organized	17.2 (34)	33.1 (78)	<.001
	Time Pressure	58.1 (115)	58.5 (138)	.934
Ways to overcome obstacles?	More background research	56.1 (111)	39.8 (94)	.001
	Made a timeline	26.3 (52)	16.9 (40)	.019
	Perseverance	50.0 (99)	42.8 (101)	.134