HIGH SCHOOL SCIENCE FAIR: POSITIVE AND NEGATIVE OUTCOMES

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Short Title: High School Science Fair – Positive and Negative Outcomes

Abstract

The goal of our ongoing research is to identify strengths and weaknesses of high school level science fair and improvements that might enhance student learning outcomes. During 2017 and 2018, a national cohort of more than 300 high school students from Texas and several other states completed anonymous and voluntary surveys containing quantitative and open-ended text questions about their science fair experiences. We learned that ~60% of the students said they were interested in a career in the sciences or engineering. Also, ~60% overall said that participating in science fair increased their interest. Students who said science fair increased their interest were more motivated, more likely to have had help from teachers, and more likely to have received coaching. About two-thirds of the students were required to participate in science fair, and that requirement decreased markedly the frequency of students who said that science fair increased their interest in science or engineering. In the worst case, ~10% of the students who said that they were required to participate in science fair and uninterested in science engaged in research misconduct (i.e., plagiarism and making up their results). Students' positive comments about competitive science fair focused on the competition incentive, whereas their positive comments about non-competitive science fair focused on learning about the scientific process and learning in general. We discuss the findings in the context of NSTA guidance that science fair participation should be voluntary.

Keywords: science fair, science education, next generation science standards, practice of science

Introduction

Next Generation Science Standards (NGSS) describes practice of science as one of three key dimensions of science education (1). How best to introduce this experience into the science curriculum lacks widespread consensus. One possibility is science fair. Science fair brings together many of the elements of practice -- problem selection, experimental design and implementation, data analysis, and communication of research findings – and by doing so offers students a potential opportunity to experience for themselves these practices combined (2-6).

Attitudes towards science fair diverge markedly. On one hand, science fair receives a lot of public visibility. President Obama stated in his 2011 State of the Union Address, *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* (7). The film *Science Fair* won the 2018 Sundance Film Festival *festival favorite award*. And a recently published book *The Class* (Penguin Random House, 2018) chronicles a year in a classroom where science fair is the center of science education. On the other, the series of science education-related committee publications by the U.S. National Academies leading up to and following NGSS essentially ignores science fair, which last was mentioned in a footnote in the 2011 National Research Council report Successful K-12 STEM Education: Identifying Effective Approaches…" (8). Moreover, notwithstanding the long history and wide implementation of science and engineering fairs as part of informal and formal science education in the United States, only a few published reports examine how science fair participation affects student engagement with science.

Several years ago, we began a systematic and ongoing study of students' high school science

fair experiences. Our subjects, who were invited to fill out anonymous and voluntary surveys, consisted of a regional group of high school students who had competed in the Dallas Regional Science and Engineering Fair (DRSEF) and post high school students in biomedical STEM educational trajectories doing research at UT Southwestern Medical Center. We characterized student experiences by asking them to identify sources of help received, types of help received, obstacles encountered, and ways of overcoming obstacles. We found important similarities between the experiences of the high school and post high school students and also learned that only ~25% of the post-high school students had participated in science fair (9). Of particular relevance to the current report, we learned that students overwhelmingly (4:1) opposed the idea of being required to compete in science fair but were more nuanced in their views of non-competitive science fair (10).

In this paper, we confirm and extend our previous findings. We added new survey questions aimed at learning about student interest in a career in sciences or engineering and also whether science fair participation increased that interest. We surveyed a much more diverse high school student group than previously, namely, a national group of students who registered and got parental consent to participate in science fair during 2017 and 2018 using the Scienteer (www.scienteer.com) online portal. The Scienteer online portal now is used by Texas and some other states to manage science fair registration, parental consent, and project management. Unlike the regional group of high school students we surveyed previously -- mostly from a suburban North Texas school district that encourages but does not require students to carry out science fair projects -- we found that about 2/3 of the students in the 2017/2018 surveys were required to participate in science fair. Consequently, it was possible to determine the impact of requiring science fair on students' science fair experiences.

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 (9, 10) using the REDCap survey and data management tool (11). Survey content was adapted from earlier research by Montreal psychologists (12) and included questions about student demographics, type of science fair participation, help expected and received, obstacles encountered and solutions implemented to overcome obstacles, interest in science, and impact of science fair participation on interest in science. The survey can be found in supporting information (S1_Survey).

High school students were invited to participate in the science fair survey through the Scienteer (www.scienteer.com) online portal used in Texas and some other states for student science fair registration, parental consent, and project management. After giving consent for their students to participate in science fair, parents could consent for their students to take part in the science fair survey. To prevent any misunderstanding by parents or students about a possible impact of agreeing to participate or actually participating in the survey, access to surveys was not available to students until after they finished all of their science fair activities. Students were instructed to log in to Scienteer after completing each science fair activity in which they participated. Those who did so after their last fair were presented with an alert and hyperlink to the science fair survey. No incentives were offered for participation, and Scienteer does not send out reminder emails.

Table 1 summarizes the student survey responses. Of the students who clicked on the hyperlink, 20-25% completed the surveys. We don't know if some students logged back into

Scienteer but did not click on the hyperlink so the maximum response rate would have been ~20%. Most of the submitted surveys (>90%) were complete and non-duplicates. These surveys were used for data analysis. Given that participation in the survey involved an indirect, single electronic invitation without incentive or follow-up, a low response rate would not have been surprising (13-15). The complete survey data sets for students who participated during 2017 and 2018 school years can be found in supporting information (S1_Dataset and S2_Dataset).

Table 1. Student survey responses

Survey Responses	2017	2018
Parents consented	10,382	20,058
Students clicked on survey hyperlink	1,089	769
Survey records uploaded including incomplete and duplicate submissions	255	150
Complete surveys included in analysis	223	140

Quantitative data were analyzed by frequency counts and percentages. Data were sorted to compare different answer selections. Significance of potential relationships between data items was assessed using relevant statistical methods, e.g., Chi-square contingency tables for independent groups. Results shown in the figures are presented graphically to make overall trends easier to appreciate and in tables beneath the graphs to show the actual numbers. A probability value of 0.05 or smaller was accepted as statistically significant but actual p values are indicated.

Qualitative text analysis for the open-ended text questions was accomplished using an approach modeled on NVivo (16, 17) as described previously (10). Two members of the research team (FG and SD) independently coded comments from 314 students (86.5%) about non-competitive science fair and from 301 students (82.9%) about competitive science fair regarding why science fair should be optional or required. These comments were categorized into a matrix of shared student reasons (nodes). The independently coded matrices were revised and harmonized into 16 *Reason Why* categories that contained 445 student reasons about non-competitive science fair and 378 student reasons about competitive science fair. Longer student comments frequently expressed more than one idea, in which case the comments were coded into more than one *Reason Why* category, and which is why the number of reasons exceeds the total number of student comments. The complete set of student answers to the *Reason Why* question and corresponding reason category assignments can be found in supporting information (S3_Dataset).

Results

Survey Demographics

Students who completed surveys represented slightly more than 0.5% of all students who signed up for science fair through Scienteer). In 2018 that amounted to 24,516 students across six states (Alabama, Maine, Missouri, Texas, Vermont, and Virginia) with the majority (13,978) from Texas. Fig 1 shows that most of the students who participated in the survey (~75%) were in 9th and 10th grades. More girls than boys completed surveys. About one in three students had carried out science fair more than once. Three out of four student projects were individual. Of particular significance,

65-70% of the students who participated in science fair reported that they were required to do so even though National Science Teaching Association (NSTA) guidance advises that student participation in science competitions should be voluntary (18).

Insert Fig 1: Student demographics. (In figure legend it will state -- Most but not all students answered every demographic question, which is why the total number of students and percentages were less than 100% of all the students.)

In what follows, we first present the data regarding sources of help students received, types of help received, obstacles encountered, and ways of overcoming obstacles. Subsequently, the focus is on the impact of science fair – features that increase student interest in science and the consequences of requiring science fair participation. For the initial figures (Figs 1-6), we kept separate the 2017 and 2018 national student data to make it possible to observe the similarity of student responses from year to year notwithstanding some small differences in particular selections.

Student Experiences in High School Science Fair– Help and Obstacles

Fig 2 shows student answers to the question concerning from whom they obtained help. 50-60% selected parents, teachers, and articles on the internet as the main sources. Less than one in four students reported receiving help from any other source, including scientists.

Insert Fig 2: Sources of help

Fig 3 shows the types of help that students actually received. No more than 35% of the students received any particular type of help. The type of help received most frequently was fine-tuning the report, followed by developing the idea, background information, performing experiments, and coaching for the interview. Even though only about a third of students received any particular type of help, overall a large majority of students reported receiving the kind and amount of help that they wanted from teachers.

Insert Fig 3: Types of help received

Fig 4 shows student answers to questions about obstacles encountered while doing science fair. Time pressure was experienced most frequently, e.g., by ~60% of the students, followed by coming up with the main idea by almost 50% of the students. Getting motivated to do the project and limited resources were the next most frequently selected.

Insert Fig 4: Obstacles faced in science fair

Fig 5 shows student answers to questions about how they overcame obstacles they encountered. Doing more background research and perseverance were selected most often as the means to overcome obstacles and were reported by 40-50% of the students. The other choice selected by ~30% of the students was to pick a familiar topic.

Previously, we reported that none of the students in the regional group answered that they had used someone else's data or made up their data (9). In marked contrast, five of the students in the 2017/2018 national group indicated that they used someone else's data and 15 said they made up their data.

Insert Fig 5: Means to overcome obstacles faced in science fair

The results in Figs 1-5 show that student responses were very similar from one year to the next. In Table 2, we compare the 2017/2018 national student data (averaged) with our previously published regional DRSEF student data (9). The most frequently selected choices between the national and regional groups were almost identical in every category. One major difference was that the number one type of help reported by the regional DRSEF students (85%) was coaching for the interview, which corresponded to the 5th most frequent choice of the 2107/2018 national students (21%). This difference, and another regarding use of articles in books and magazines (65% of regional DRSEF students vs. 24% of 2017/2018 national students), may reflect the highly supportive attitude towards science fair participation and practices adopted by the North Texas suburban school district where most of the regional DRSEF students surveyed attended. Finally, Table 2 summarizes that 68% of the 2017/2018 students were required to participate in science fair compared to 8% of the regional DRSEF students.

Table 2. Comparison of Scienteer and DRSEF student survey results

Survey Item		Student Group			
		2017/2018 # (%) of 363 students	Item rank	DRSEF # (%) of 64 students	Item rank
Sources of help received (9 options)	Articles on internet	210 (57.9)	1	35 (53.8)	3
	Teachers	201 (55.4)	2	45 (69.2)	1
	Parents	185 (51.0)	3	27 (41.5)	4
	Articles in Books or Magazines	87 (24.0)	4	42 (64.6)	2
Types of help received (10 options)	Fine-tuning report	117 (32.2)	1	31 (47.7)	2
	Developing idea	95 (26.2)	2	19 (29.2)	4
	Background information & finding research site and participants	94 (25.9)	3	24 (36.9)	3
	Coaching for the Interview	80 (22.0)	5	55 (84.6)	1
What obstacles did you encounter? (11 options)	Time pressure	162 (44.6)	1	42 (64.6)	1
	Coming up with the idea	208 (57.3)	2	41 (63.1)	2
How did you overcome obstacles? (15 options)	More background research.	176 (48.5)	1	47 (72.3)	1
	Perseverance and self-	161 (44.4)	2	45 (69.2)	2

	discipline.				
Required to do science fair		245 (67.5)		5 (7.7)	

Effect of Science Fair on Student Interest in a Career in the Sciences or Engineering and the Consequences of Requiring Science Fair Participation

An important (perhaps the most important) positive outcome of science fair would be for students to become more interested in science. Fig 6 presents an overview of student interest in science and the impact and value of science fair. Almost 60% of the students said they were interested in a career in the sciences or engineering; 15% said they were not; and the remainder were unsure. Almost 60% of the students said that science fair increased their interest in a career in the sciences or engineering. Nevertheless, only 1 in 5 students favored requiring science fair competition and that number was only marginally higher for requiring participation in non-competitive science fair.

Insert Fig 6: Student interest in science, impact of science fair, and science fair requirement

Fig 7 shows significant differences between students who said that science fair did vs. did not increase their interest in science. In general, students who reported that science fair increased their interest in science were less likely to have been required to do science fair and more likely to say they were interested in science. More of these students said they received help from teachers and coaching for the interview. Getting motivated was less of an obstacle. In response to obstacles, they did more background research, and they self-reported more perseverance and self-discipline. Finally, these students were more positive about requiring both non-competitive and competitive science fair but only the former data reached statistical significance. (Students' reasons why will be presented in later figures.)

Insert Fig 7: Differences depending on whether students said that science fair increased their interest in science.

Fig 8 shows more clearly the negative impact of requiring science fair. Regardless whether or not students were interested in science, requiring them to participate in science fair decreased the number who said that participating in science fair increased their interest.

Insert Fig 8: Impact of requiring science fair on students saying that participating in science fair increased their interest in science.

Besides decreasing the positive impact, Fig 9 shows other differences if students were required to do science fair. In general, these students had more trouble getting motivated; were less likely to receive coaching; and less likely to use articles in books or magazines. Also, these students were less likely to say that they were interested in a career in the sciences or engineering.

Insert Fig 9: Differences depending on whether students said that they were required vs. not required to participate in science fair.

In contrast to becoming more interested in science, the most negative outcome of science fair would be students committing research misconduct, i.e., using someone else's data or making up their data. As was shown in Fig 5, five of the 2017/2018 national students indicated that they

used someone else's data and 15 said they made up their data. Fig 10 shows the impact of requiring science fair combined with interest in science on research misconduct. Students who were required to participate in science fair were more likely to use someone else's data or make up their data. ~10% of the students who also said they were required to participate in science fair and not interested in science did one or the other.

Insert Fig 10: Research misconduct by students depending on science fair requirement and interest in science.

Student Reasons -- Qualitative findings

Given the voluntary and anonymous format of our surveys, interviewing students was not a possibility. However, the open-ended text questions asking students to state reasons why science fair should be optional or required provided a rich source of insights regarding student attitudes. That more than 80% of the students wrote thoughtful answers was one indication that the students took the surveys seriously.

Table 3 shows the students' comments about whether science fair should be required or optional organized into 16 *Reason Why* categories (7 positive and 9 negative) including examples. Longer comments frequently expressed more than one idea, in which case the comments were coded into more than one *Reason Why* category. For instance, the student comment, *Science Fairs encourage students to learn new things in science in specific areas that interest them, which might lead to a future career in the science department*, was placed into both the "Introduction to scientific knowledge" and "Career interests" categories.

Table 3. Student reasons about science fair requirements organized according to positive (P) and negative (N) reasons with examples*.

P/N	Reason Category	Examples -- When a single comment is used to express more than one idea, the text relevant to the idea in bold type.
P	Intro to the scientific process	It helps enhance the student's knowledge of conducting an experiment, the scientific method, and a subject outside of school.
P	Communication or presentation skills	It builds up one's ability to present one's scientific findings or observations.
P	Intro to scientific knowledge	Science Fairs encourage students to **learn new things in science in specific areas that interest them**, which might lead to a future career in the science department.
P	Career interests	Science Fairs encourage students to learn new things in science in specific areas that interest them, which **might lead to a future career in the science department.**
P	Competition incentive	Competition is a motivation for many students who want to be known as the best.
P	General learning	It is a good opportunity for students to build their education level and thinking.
P	Other positive	Some people do not want to spend a lot of time working on a project that they don't want to do, but I myself had a lot of fun doing it.

N	Not everyone interested in science	Because not everyone has a passion for science
N	Too much stress/pressure	I feel that many kids are stressed with other assignments... one more project is the last thing they need
N	No enjoyment and negative attitude	Because people shouldn't be **forced to do something they don't want to do**. Also people might not have the time or resources to do a science project.
N	Negative behaviors and consequences	There are many people who put forth no effort in their projects and make up data.
N	No time/money	Because people shouldn't be forced to do something they don't want to do. Also people **might not have the time or resources** to do a science project.
N	No value	Doing a basic project, like most people do, is more harmful then helpful, and serves no purpose other than wasting time
N	Don't like to compete	Some people just like to research and not compete
N	Don't like to make public presentations	Not all students may be comfortable speaking in front of people.
N	Other negative	They're [sic] certain way of having things done isn't the way everybody normally works.

*314 (86.5%) and 301 (83.0%) survey responders provided answers to “Reason why?” questions regarding non-competitive and competitive science fair respectively.

Fig 11 shows the frequency with which the different reasons were mentioned. The order of reasons in Figs 11-13 is the same as in Table 3. Negative reasons outnumbered positive ones for both non-competitive (314 vs. 131) and competitive (277 vs. 101) science fair, but the reason categories differed. For non-competitive science fair, the most frequently mentioned negative reasons were “No enjoyment/negative attitude” (~22% of the students) and “No time/money” (~17% of the students); whereas for competitive science fair, the most frequently mentioned negative reason was “Don’t like to compete” (~22% of the students). The most frequently mentioned positive reasons for non-competitive science fair were “Introduction to the scientific process” and “General learning” (each ~8% of the students) vs. “Competition incentive” (~14% of the students) for competitive science fair.

Insert Fig 11. Student reasons about requiring science fair.

Fig 12 divides the results in Fig 11 according to students’ quantitative responses to the question whether or not science fair should be required (Fig 6). The 21-26% of students who said that science fair should be required accounted for 98% of the positive reasons regarding non-competitive science fair and 95% of the positive reasons regarding competitive science fair. Therefore, the students’ open-ended comments compared favorably to their quantitative answers, providing a valuable indication of internal survey consistency.

Insert Fig 12. Student reasons depending on whether students said science fair should be required or optional.

Fig 13 divides the results in Fig 11 according to students' quantitative responses to the question whether participating in science fair increased their interest in science (Fig 7). Students who said that science fair increased their interest in science were more likely to write positive comments in every category, especially introduction to process of science and general learning. Also, these students were more likely to select "competition incentive" for competitive science fair. Although the students who said science fair increased their interest in science complained less about "Too much stress/pressure" and "No time/money," they were just as negative about "No enjoyment/negative attitude" and "Don't like to compete."

Insert Fig 13: Student reasons depending on whether or not students say science fair increased their interest in science

Discussion

The goal of our ongoing research is to identify strengths and weaknesses of high school level science fair and improvements that might enhance learning outcomes. Previously, we described the results of anonymous and voluntary surveys carried out with a regional group of high school students who had competed in the Dallas Regional Science and Engineering Fair (DRSEF) and post high school students on STEM education tracks doing research at UT Southwestern Medical Center (9, 10). In the current paper, we confirm and extend the previous findings. We added new survey questions aimed at learning about student interest in a career in sciences or engineering and also whether science fair participation increased that interest. We surveyed a national high school student group, namely, students who signed up for science fair in 2017 and 2018 using the online portal *Scienteer,* which Texas and several other states now use for science fair registration.

More than 300 students completed surveys during 2017 and 2018, representing about 0.5% of students that participated in high school science fair via Scienteer. We found that students' answers to questions about sources of help received, types of help received, obstacles encountered, and ways of overcoming obstacles were similar between the 2017 and 2018 national cohorts (Figs 1-5). Also, their experiences were similar to previously published answers by the regional DRSEF student group (9) (Table 2). Articles on the internet, teachers, and parents were the main sources of help; time pressure and coming up with the idea were the main obstacles; more background research and perseverance were the main ways to overcome obstacles; fine-tuning the report and developing the idea were important types of help received.

A potential limitation of our study is the small size of the study population relative to the total number of students participating in science fair. However, we suggest that the similarity of results from year to year and the overall similarity between the 2017/2018 national cohort and the results with the regional DRSEF students described previously (9) support our previous conclusion that science fair experiences are common to students notwithstanding the diversity of science fair formats. That more than 80% of the 2017/2018 national students wrote thoughtful answers to the open-ended text questions was one indication that the students took the surveys seriously. And the finding that >95% of the positive comments about either type of science fair were given by the 20-25% of students who said that science fair should be required (Fig 12) provided additional validation of the survey responses.

Some differences noted between the 2017/2018 national and regional DRSEF cohorts likely reflect the highly supportive attitude towards science fair participation of the North Texas suburban school district where most of the regional DRSEF students attended. For instance, ~85% of DRSEF students reported receiving coaching for the interview vs. 21% of 2017/2018 students. Also, 65% of the DRSEF students had access to articles in books and magazines vs. 24% of the 2017/2018 students. Therefore, local school district support clearly can have an impact on some aspects of student science fair experience.

The specific emphasis on science fair by the high school where most of the regional DRSEF students attended might also account for some important differences between these students and the national group in their answers to open-ended text comments. For instance, the national group of students mentioned *general learning* as a positive value of science fair (7.9% & 4.2%) even more than *intro to scientific process* (7.9% & 0.7%); few of the regional DRSEF students mentioned general learning (10). Also, the national group mentioned too much stress/pressure (5.4% & 4.8%) and no value (6.1% & 3.2%) as negative reasons, neither of which was emphasized by the regional DRSEF students (10). And the negative comment *don't like to make public presentations* (0.2% & 4.8%) made by the 2017/2018 students but not previously might reflect directly the lower number of 2017/2018 students who reported receiving coaching for the interview.

Overall, the findings with the 2017/2018 national group of students are consistent with idea that the students' focus switches from competition to learning when thinking about competitive vs. non-competitive science fair. For instance, regarding competitive science fair, the top negative reasons given by students were *don't like to compete* (22%) and *no enjoyment/overall negative attitude* (13%); the top positive reason was *competition incentive* (14%). By contrast, the most common negative reasons about non-competitive science fair were *no enjoyment/overall negative attitude* (22%) and *no time/money* (17%); the top positive reasons were *general learning* (7.9%) and *intro to scientific process* (7.9%). Such differences led us to emphasize previously (10) the potential value of developing non-competitive science fair in which judges assess on a sliding scale student progress towards mastery of the different practices of science (19-22). The latter approach would be consistent with student motivation and goal orientation theory, i.e., mastery (competition with oneself with emphasis on understanding and improving skills and knowledge) vs. performance (competing with others with emphasis on demonstrating high ability and grades) (23-25).

Increasing student interest in science represents one of the most important potential positive outcomes of science fair. Previous research by others had shown that participating in science competitions helped to maintain high school student interest in pursuing science education and science careers albeit to a small extent (26-30). Similarly, about 60% of the students we surveyed said that participating in science fair increased their interest in science or engineering careers (Fig 6). However, that number was much higher if the students had chosen to participate in science fair rather than been required to do so (Fig 7). Indeed, requiring science fair participation decreased the positive impact of science fair regardless whether the students said they were interested in science (Fig 8).

Other key features of science fair experience mentioned by students who said science fair increased their interest in science or engineering included being more likely to get help from teachers and to receive coaching for the interview. Also, getting motivated was less of an obstacle for these students. Indeed, science fair was a more positive experience overall as reflected by the student comments (Fig 13). By contrast, students who were required to participate in science fair

had more difficulty getting motivated, were less likely to receive coaching, and less likely to use articles in books or magazines (Fig 9). In the worst case, ~10% of the students who said that they were required to do science fair and not interested in science engaged in research misconduct (Fig 10).

Previously, we reported that none of the regional DRSEF students made up their data (9). However, only 8% of those students were required to participate in science fair in contrast to 68% of the 2017/2018 national group described in the current paper. On the other, 24% (5 of 21) of the students who participated in the 2000 Bell Montreal regional science fair were found to make up their data, and 100% of the students surveyed in that study were required to participate (12). Taken together, these findings emphasize that requiring students to participate in science fair can have a negative outcome. A perhaps related finding is that professional scientists who perceive the institutional environment as unfair are more likely to engage in research misconduct (31). Some previous research has analyzed student motivations and the benefits of participating in science fair, but an explicit attempt to learn the impact of requiring science fair participation was not the focus (32-34).

In conclusion, our results lend strong empirical to the National Science Teaching Association guidance that *student and staff participation in science competitions should be voluntary* (18). Previously, we found that students dislike the idea of being required to participate in science fair (10). Now, we show that being required to participate can have the practical consequence of decreasing the overall positive impact of science fair. The observation that 68% of the 2017/2018 national group of high school students surveyed were required to participate in science fair suggests that NSTA guidance currently is widely ignored.

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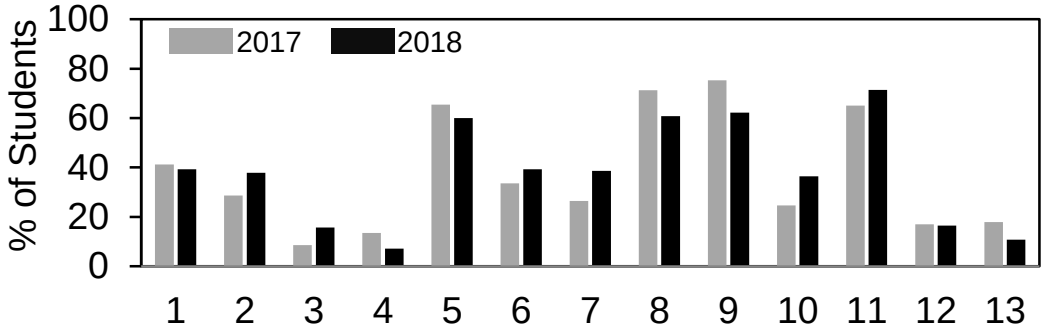
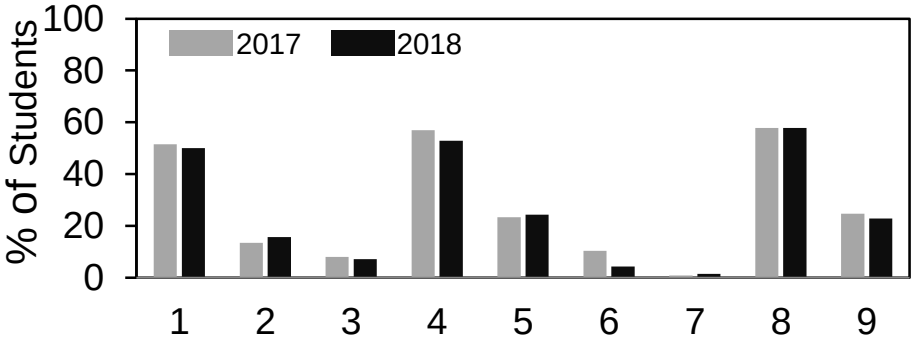
Figure 1. Student demographics



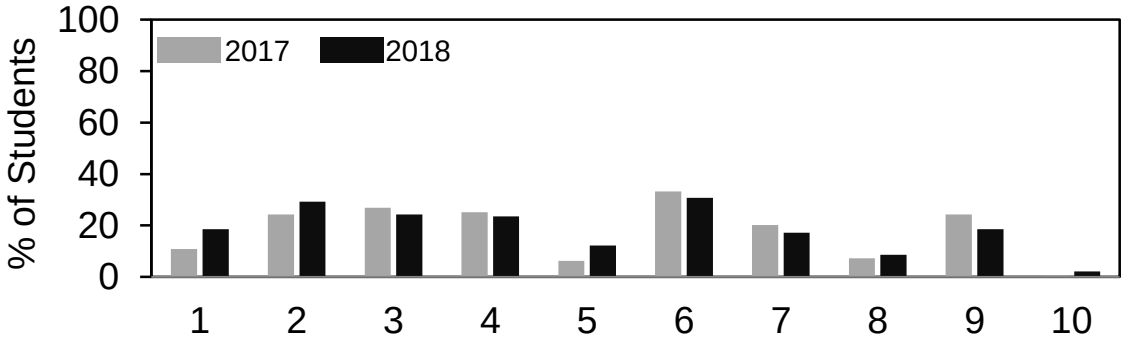
#	Survey Year		2017 (223 students)	2018 (140 students)
	Demographic Questions		**# (%)**	**# (%)**
1	Grade	9th	92 (41.3)	55 (39.3)
2		10th	64 (28.7)	53 (37.9)
3		11th	19 (8.5)	22 (15.7)
4		12th	30 (13.5)	10 (7.1)
5	Gender	Female	146 (65.5)	84 (60.0)
6		Male	75 (33.6)	55 (39.3)
7	Carried out science fair more than once	Yes	59 (26.5)	54 (38.6)
8		No	159 (71.3)	85 (60.7)
9	Team or individual project	Individual	168 (75.3)	87 (62.1)
10		Team	55 (24.7)	51 (36.4)
11	Required to do science fair?	Yes	145 (65.0)	100 (71.4)
12		No	38 (17.0)	23 (16.4)
13		No but fulfilled project requirement	40 (17.9)	15 (10.7)

Figure 2. Sources of help students received in science fair.



#	Different sources of help received	2017 (223 students)	2018 (140 students)
		# (%) receiving help from	
1	Parents	115 (51.6)	70 (50.0)
2	Siblings	30 (13.5)	22 (15.7)
3	Other family members	18 (8.1)	10 (7.1)
4	Teachers	127 (57.0)	74 (52.9)
5	Other students	52 (23.3)	34 (24.3)
6	Scientists	23 (10.3)	6 (4.3)
7	A paid mentor	2 (0.9)	2 (1.4)
8	Articles on the Internet	129 (57.8)	81 (57.9)
9	Articles in books or magazines	55 (24.7)	32 (22.9)

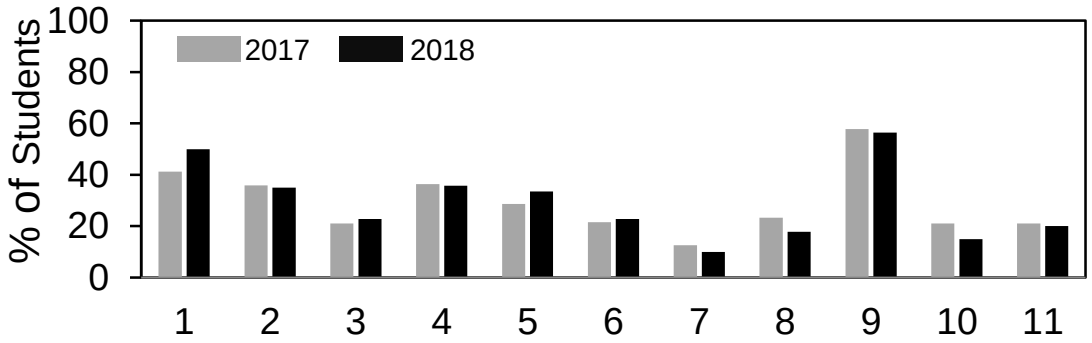
Figure 3. Types of help students received in science fair.



#	Different types of help received	2017 (223 students)	2018 (140 students)
		# (%) receiving type of help	
1	Being given the main idea	24 (10.8)	26 (18.6)
2	Development of the idea	54 (24.2)	41 (29.3)
3	Background information & finding research site and participants	60 (26.9)	34 (24.3)
4	Performing experiments	56 (25.1)	33 (23.6)
5	Writing the report	14 (6.3)	17 (12.1)
6	Fine tuning the report	74 (33.2)	43 (30.7)
7	Designing the poster board	45 (20.2)	24 (17.1)
8	Produce charts or graphs	16 (7.2)	12 (8.6)
9	Coaching for the interview with judges	54 (24.2)	26 (18.6)
10	Copying the project from someone else	1 (0.4)	3 (2.1)

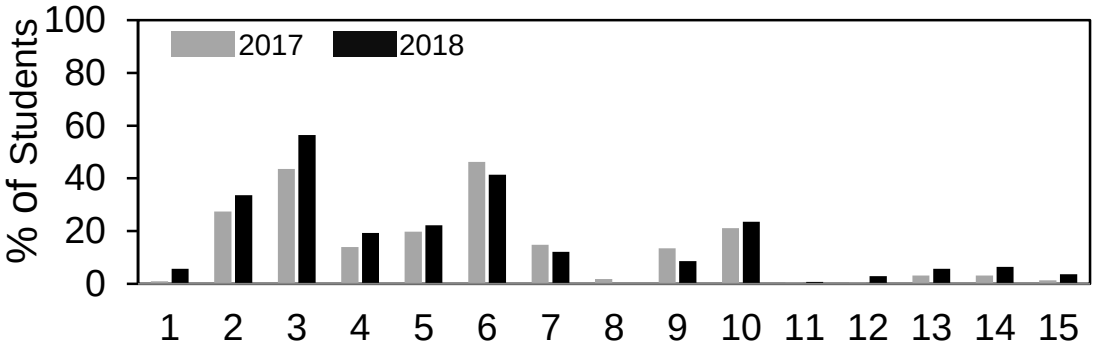
Received the kind of help wanted from teachers	168 (75.3)	94 (67.1)
Received amount of help wanted from teachers	175 (78.5)	94 (67.1)

Figure 4: Obstacles students encountered in science fair.



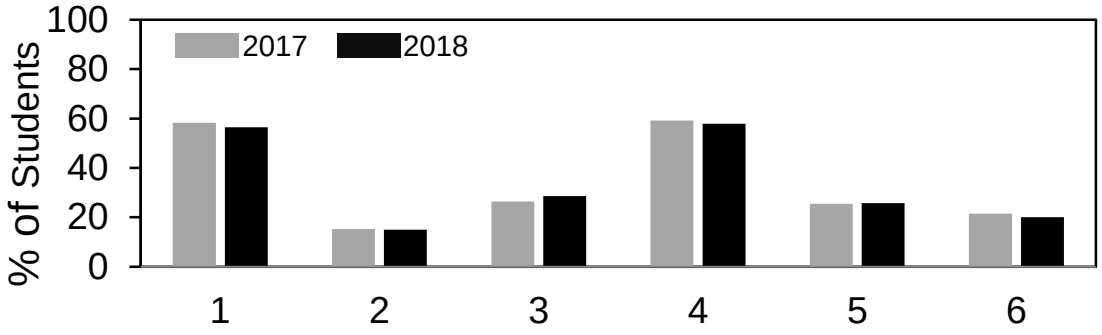
#	Obstacles encountered in science fair	2017 (223 students)		2018 (140 students)	
		# (%) obstacle encountered			
1	Coming up with the main idea.	92	(41.3)	70	(50.0)
2	Getting motivated to do the project.	80	(35.9)	49	(35.0)
3	Becoming disappointed with the project.	47	(21.1)	32	(22.9)
4	Limited resources.	81	(36.3)	50	(35.7)
5	Limited knowledge.	64	(28.7)	47	(33.6)
6	Limited skills.	48	(21.5)	32	(22.9)
7	Limited cooperation.	28	(12.6)	14	(10.0)
8	Getting organized.	52	(23.3)	25	(17.9)
9	Time pressure.	129	(57.8)	79	(56.4)
10	Not enough money.	47	(21.1)	21	(15.0)
11	Results not as expected.	47	(21.1)	28	(20.0)

Figure 5: How students overcame obstacles in science fair.



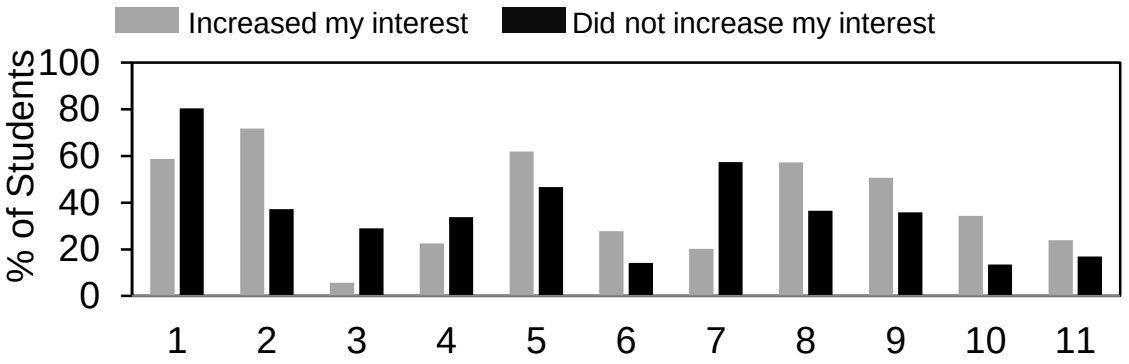
#	Means to overcome obstacles	2017 (223 students)		2018 (140 students)	
		# (%) using means to overcome obstacles			
1	Used someone else's main idea.	2	(0.9)	8	(5.7)
2	Picked a familiar/interesting topic.	61	(27.4)	47	(33.6)
3	Did more background research.	97	(43.5)	79	(56.4)
4	Stopped working on the project for a while.	31	(13.9)	27	(19.3)
5	Made a timeline to follow.	44	(19.7)	31	(22.1)
6	Perseverance and self-discipline.	103	(46.2)	58	(41.4)
7	Had someone else to keep me on track.	33	(14.8)	17	(12.1)
8	Had someone else do the math.	4	(1.8)	0	(0.0)
9	Changed the research plan.	30	(13.5)	12	(8.6)
10	Collected more data.	47	(21.1)	33	(23.6)
11	Had someone else collect the data.	1	(0.4)	1	(0.7)
12	Used someone elses data.	1	(0.4)	4	(2.9)
13	Made up the data.	7	(3.1)	8	(5.7)
14	Changed the hypothesis to fit the data.	7	(3.1)	9	(6.4)
15	Changed the data to fit the hypothesis.	3	(1.3)	5	(3.6)

Figure 6. Student interest in science and impact of science fair on interest in science.



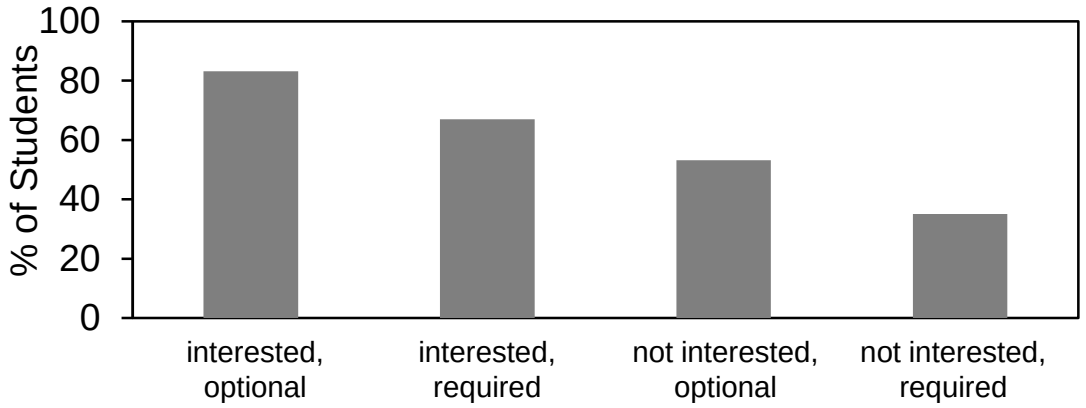
#	Survey Item		2017 (223 students)	2018 (140 students)
			# (%) who reported	
1	Interest in a career in the sciences or engineering?	Yes	130 (58.3)	79 (56.4)
2		No	34 (15.2)	21 (15.0)
3		Unsure	59 (26.5)	40 (28.6)
4	Science fair experience increased my interest in sciences or engineering.		132 (59.2)	81 (57.9)
5	Science fair (not for competition) should be required.		57 (25.6)	36 (25.7)
6	Science fair (competitive) should be required.		48 (21.5)	28 (20.0)

Figure 7. Differences depending on whether students said science fair increased their interest in science



#	Survey Item		Students who say science fair increased their interest in the sciences and engineering		p value
			Yes (213)	No (148)	
			# (%) who reported		
1	Required to do science fair		125 (58.7)	119 (80.4)	<.001
2	Interest in a career in sciences or engineering?	Yes	153 (71.8)	55 (37.2)	<.001
3		No	12 (5.6)	43 (29.1)	<.001
4		Unsure	48 (22.5)	50 (33.8)	0.020
5	Received help from teachers		132 (62.0)	69 (46.6)	0.004
6	Received coaching for the interview		59 (27.7)	21 (14.2)	0.002
7	Getting motivated was an obstacle		43 (20.2)	85 (57.4)	<.001
8	Overcoming Obstacles	Did more background research	122 (57.3)	54 (36.5)	<.001
9		Perseverance and self-discipline	108 (50.7)	53 (35.8)	0.005
10	Science fair (not for competition) should be required		73 (34.3)	20 (13.5)	<.001
11	Science fair for competition should be required		51 (23.9)	25 (16.9)	n.s.

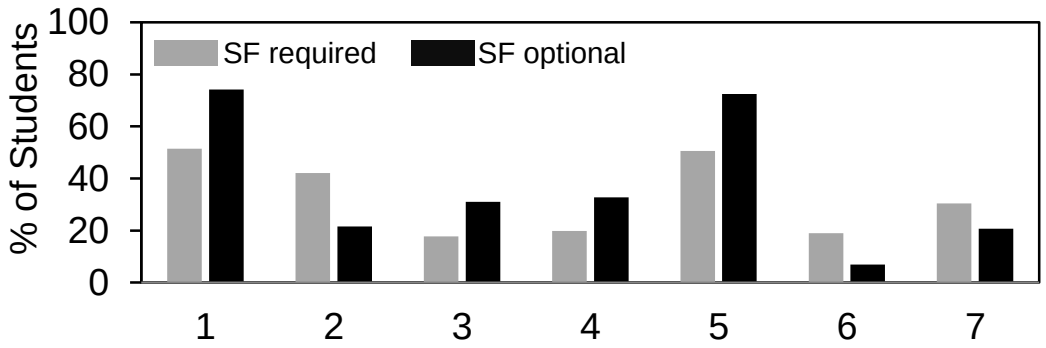
Figure 8. Students who say science fair increased their interest in science depending on science interest and science fair requirement.



Interested in Science	Science Fair Participation	All Students # (%)		Students who say science fair increased their interest -- # (%)	
Yes	Optional	83	(23.1)	69	(83.1)
Yes	Required	124	(34.5)	83	(66.9)
No	Optional	32	(8.9)	17	(53.1)
No	Required	120	(33.4)	42	(35.0)
All Students		359	(100)	211	(58.8)

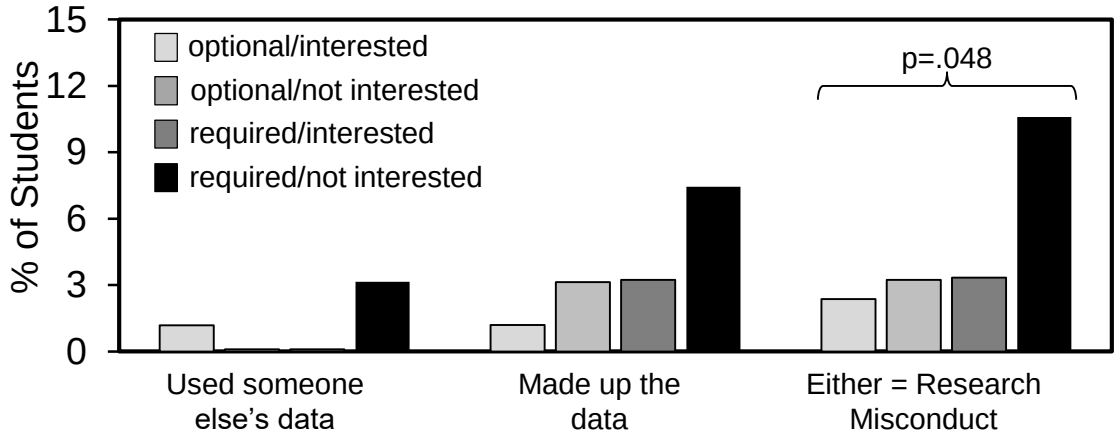
Chi Square p<.001

Figure 9. Differences in science fair experiences depending on whether students were required to do science fair.



#	Survey Item		Students required to do science fair		p value
			Yes (247)	No (116)	
			# (%) who reported		
1	Science fair experience increased my interest in the sciences or engineering.		127 (51.4)	86 (74.1)	<.001
	Getting motivated was an obstacles.		104 (42.1)	25 (21.6)	<.001
2	Received coaching for the interview.		44 (17.8)	36 (31.0)	0.005
3	Received help from articles in books or magazines.		49 (19.8)	38 (32.8)	0.007
5	Interest in a career in the sciences or engineering?	Yes	125 (50.6)	84 (72.4)	<.001
6		No	47 (19.0)	8 (6.9)	0.003
7		Unsure	75 (30.4)	24 (20.7)	n.s.

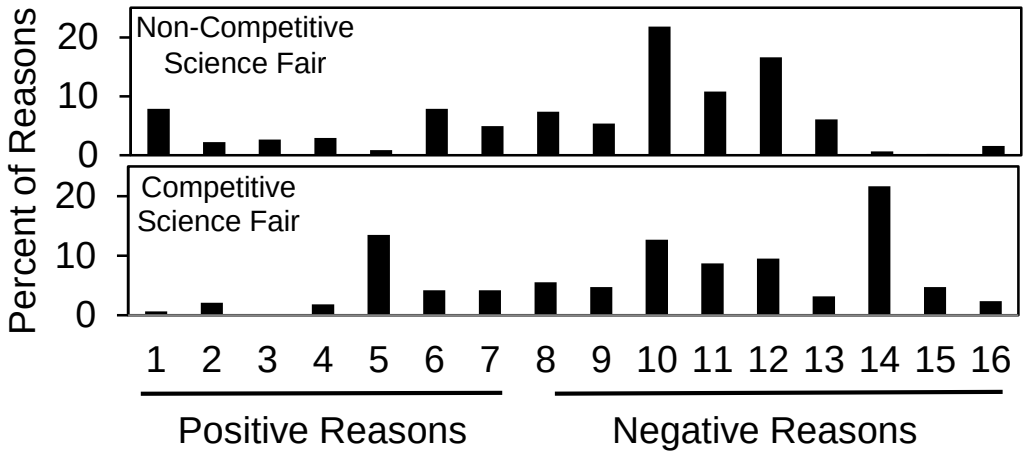
Figure 10. Research misconduct by students depending on science fair requirement and interest in science.



Student group			Students who reported		
Science Fair Participation	Interested in Science	# Students	Used Someone Else's Data	Made Up the Data	Either = Research Misconduct
			# (%)	# (%)	# (%)
Optional	Yes	84	1 (1.2)	1 (1.2)	2 (2.4)
Optional	No	32	0 (0.1)	1 (3.1)	1 (3.1)
Required	Yes	125	0 (0.1)	4 (3.2)	4 (3.2)
Required	No	122	4* (3.3)	9* (7.4)	12* (9.8)
All Students		363	5 (1.4)	15 (4.1)	19 (5.2)

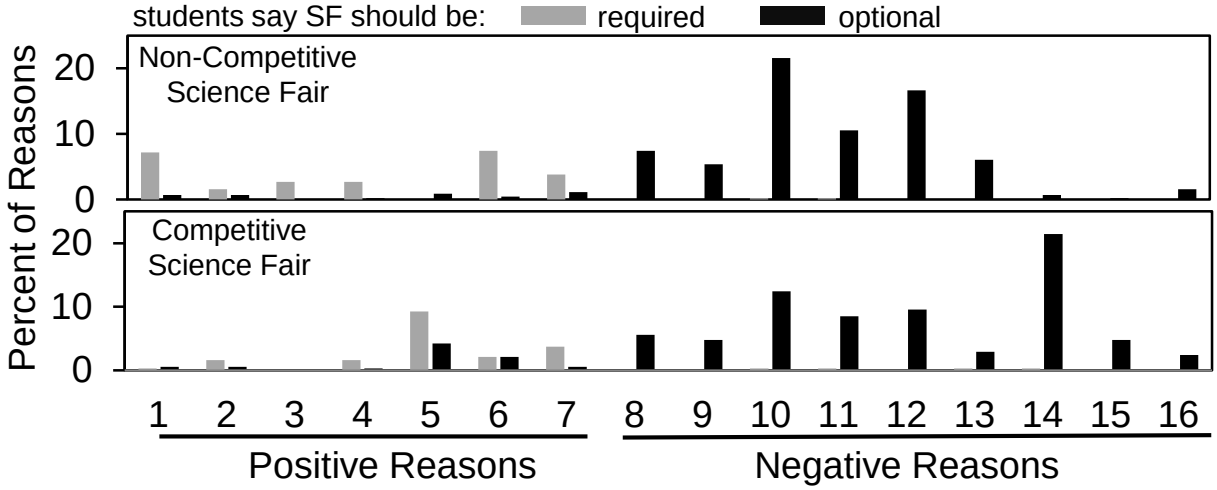
* one student marked both "used someone else's data" and "made up the data"

Figure 11. Student reasons about requiring science fair.



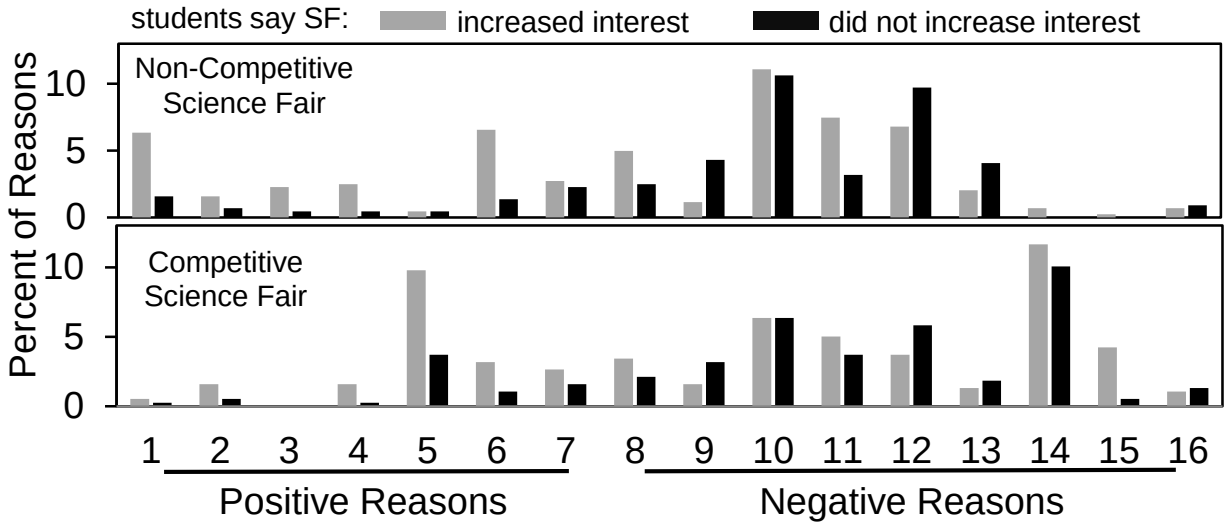
Type of Science Fair		Non-Competitive	Competitive
		445 reasons	378 reasons
#	Reason Categories Mentioned	# (%)	# (%)
1	Intro to the scientific process	35 (7.9)	3 (0.7)
2	Communication or presentation skills	10 (2.2)	8 (2.1)
3	Intro to scientific knowledge	12 (2.7)	0 (0)
4	Career interests	13 (2.9)	7 (1.9)
5	Competition incentive	4 (0.9)	51 (13.5)
6	General learning	35 (7.9)	16 (4.2)
7	Other positive	22 (4.9)	16 (4.2)
Total Positive		**131 (29.4)**	**101 (26.7)**
8	Not everyone interested in science	33 (7.4)	21 (5.6)
9	Too much stress/pressure	24 (5.4)	18 (4.8)
10	No enjoyment and negative attitude	97 (21.8)	48 (12.7)
11	Negative behaviors and consequences	48 (10.8)	33 (8.7)
12	No time/money	74 (16.6)	36 (9.5)
13	No value	27 (6.1)	12 (3.2)
14	Don't like to compete	3 (0.7)	82 (21.7)
15	Don't like to make public presentations	1 (0.2)	18 (4.8)
16	Other negative	7 (1.6)	9 (2.4)
Total Negative		**314 (70.6)**	**277 (73.3)**

Figure 12. Student reasons depending on whether students said science fair should be required or optional.



Type of Science Fair		Non-Competitive		Competitive	
Students Say Science Fair Should Be…		Required	Optional	Required	Optional
Reason categories mentioned		# (%)	# (%)	# (%)	# (%)
1	Intro to the scientific process	32 (7.2)	3 (0.7)	1 (0.3)	2 (0.5)
2	Communication or presentation skills	7 (1.6)	3 (0.7)	6 (1.6)	2 (0.5)
3	Intro to scientific knowledge	12 (2.7)	0 (0.0)	0 (0.0)	0 (0.0)
4	Career interests	12 (2.7)	1 (0.2)	6 (1.6)	1 (0.3)
5	Competition incentive	0 (0.0)	4 (0.9)	35 (9.3)	16 (4.2)
6	General learning	33 (7.4)	2 (0.4)	8 (2.1)	8 (2.1)
7	Other positive	17 3.8)	5 (1.1)	14 (3.7)	2 (0.5)
Total Positive		113 (25.4)	18 (4.0)	70 (18.5)	31 (8.2)
8	Not everyone interested in science	0 (0.0)	33 (7.4)	0 (0.0)	21 (5.6)
9	Too much stress/pressure	0 (0.0)	24 (5.4)	0 (0.0)	18 (4.8)
10	No enjoyment and negative attitude	1 (0.2)	96 (21.6)	1 (0.3)	47 (12.4)
11	Negative behaviors and consequences	1 (0.2)	47 (10.6)	1 (0.3)	32 (8.5)
12	No time/money	0 (0.0)	74 (16.6)	0 (0.0)	36 (9.5)
13	No value	0 (0.0)	27 (6.1)	1 (0.3)	11 (2.9)
14	Don't like to compete	0 (0.0)	3 (0.7)	1 (0.3)	81 (21.4)
15	Don't like to make public presentations	0 (0.0)	1 (0.2)	0 (0.0)	18 (4.8)
16	Other negative	0 (0.0)	7 (1.6)	0 (0.0)	9 (2.4)
Total Negative		2 (0.4)	312 (70.1)	4 (1.1)	273 (72.2)

Figure 13. Student reasons depending on whether or not students say science fair increased their interest in science



Type of Science Fair		Non-Competitive		Competitive	
Impact of Science Fair on Students' Interest in Science		Increased	No Inc	Increased	No Inc
Reason categories mentioned		# (%)	# (%)	# (%)	# (%)
1	Intro to the scientific process	28 (6.3)	7 (1.6)	2 (0.5)	1 (0.3)
2	Communication or presentation skills	7 (1.6)	3 (0.7)	6 (1.6)	2 (0.5)
3	Intro to scientific knowledge	10 (2.3)	2 (0.5)	0 (0.0)	0 (0.0)
4	Career interests	11 (2.5)	2 (0.5)	6 (1.6)	1 (0.3)
5	Competition incentive	2 (0.5)	2 (0.5)	37 (9.8)	14 (3.7)
6	General learning	29 (6.6)	6 (1.4)	12 (3.2)	4 (1.1)
7	Other positive	12 (2.7)	10 (2.3)	10 (2.6)	6 (1.6)
Total Positive		99 (22.4)	32 (7.2)	73 (19.3)	28 (7.4)
8	Not everyone interested in science	22 (5.0)	11 (2.5)	13 (3.4)	8 (2.1)
9	Too much stress/pressure	5 (1.1)	19 (4.3)	6 (1.6)	12 (3.2)
10	No enjoyment and negative attitude	49 (11.1)	47 (10.6)	24 (6.3)	24 (6.3)
11	Negative behaviors and consequences	33 (7.5)	14 (3.2)	19 (5.0)	14 (3.7)
12	No time/money	30 (6.8)	43 (9.7)	14 (3.7)	22 (5.8)
13	No value	9 (2.0)	18 (4.1)	5 (1.3)	7 (1.9)
14	Don't like to compete	3 (0.7)	0 (0.0)	44 (11.6)	38 (10.1)
15	Don't like to make public presentations	1 (0.2)	0 (0.0)	16 (4.2)	2 (0.5)
16	Other negative	3 (0.7)	4 (0.9)	4 (1.1)	5 (1.3)
Total Negative		155 (35.1)	156 (35.3)	145 (38.4)	132 (34.9)