Approaches for conducting middle school science fairs: A landscape study

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Abstract

Although science fairs have been an institution of science education for decades in schools across the United States, little is understood about how students' science fair experiences vary and how these variations relate to student learning. Research on this topic is particularly imperative as new science standards increase emphasis on the teaching of science and engineering practices. Science fairs represent a potential opportunity to engage students in these practices, but may not be effective in supporting the learning of all students. As a first step in a programmatic research agenda, this study employs a nationally representative survey of middle schools to describe the most commonly conducted, broad approaches to middle school science fairs. Using a framework based on teacher support for inquiry, three types of science fairs emerged: mandatory fairs with high levels of teacher support for students' project work, mandatory fairs with low levels of teacher support, and voluntary fairs. Mandatory fairs with limited teacher support were more common in schools with a high proportion of African American students and high poverty, but were also more likely to emphasize goals related to learning. Implications for the effectiveness and equity of science fairs are discussed.

1 INTRODUCTION

For over 60 years, annual science fairs have been held in schools, regions, and over 47 states in the U.S., culminating in national and international events, and reaching students as young as nine years old (McComas, 2011). Science-fair supporters claim that they advance students' problem-solving skills, encourage critical thinking, increase understanding of the scientific research process, and enhance educational and career interest in STEM (Schachter, 2011). These claims are particularly germane in light of the vision for science education articulated by the Framework for K–12 Science Education (National Research Council [NRC], 2012) and the Next Generation Science Standards (NGSS Lead States, 2013). These documents articulate a three-dimensional vision for U.S. science education that places heightened emphasis on the science and engineering practices (SEPs) associated with doing scientific and engineering work. The authors of the Framework describe eight SEPs, including asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, and engaging in argument from evidence; all skills that could be developed in the context of participation in a science fair. They cite three reasons why students must *do* science, or directly engage with and develop practices of science and engineering. First, only by doing science will students understand how scientific knowledge is created and appreciate the varied ways in which it is accumulated over time. Second, by doing science, students have firsthand access to the cross-cutting concepts and disciplinary core ideas of science and engineering. And third, doing science can inspire students' interest in science and motivate them to continue to pursue science and engineering learning and careers.

For many middle school students, science fairs may not only be a good opportunity to engage in SEPs; they may be one of the only opportunities they have to do so. Banilower et al. (2013) found that only "23% of middle school classes engage students in project-based learning at least once a week, and only 54% have students represent and/or analyze data using tables, charts, or graphs" (p. 78). In an earlier report, Banilower,

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Smith, Weiss, & Pasley (2006) found "that only 14 percent of all lessons in a national sample exhibited intellectual rigor, and that questioning was among the weakest elements of instruction" (p. 6). With regard to communication skills, it is rare to see discourse in the science classroom as a means of exploring student ideas and for fostering explanation and sense-making (Windschitl, 2009). Other studies of teachers' pedagogical practices reveal that while teachers perceive their instruction to be based on students' interest and encouraging investigation, most provided more prescribed experiences with few opportunities for argumentation or deep thinking about questions, methodology, or conclusions (Jeanpierre, 2006). Furthermore, opportunities to engage with engineering have been limited in public school classrooms. Although engineering education may foster students' interest in science, few curriculum materials and professional development programs contain engineering components, and it is estimated that fewer than 6 million of the nation's 56 million students have encountered engineering education (NRC, 2009).

Nevertheless, science fairs have their critics as well, and these critics point out noteworthy weaknesses related to both effectiveness and equity. First, some have questioned the effectiveness of science fairs in engaging students in high-quality scientific inquiry, arguing that science fair projects constrain students to a narrow and prescribed investigative process (Craven & Hogan, 2008; Hampton & Licona, 2006) and that significant time and support are required of teachers in order for students to engage in argumentation (Chen Lin, Hsu & Lee, 2011). In addition, research examining science learning at various ages has demonstrated that science instruction is most effective when it includes high levels of guidance in a structured context—specifically a combination of inquiry experiences with explicit guidance and support—rather than just "discovery learning" or open-ended inquiry (Kirschner, Sweller, & Clark, 2006; Sweller, 2009). Klahr and Nigam (2004) investigated varying instructional approaches to teaching children the control-of-variables strategy in experimental design. Children were asked to design several experiments to answer specific questions about physical phenomena. While all children had access to the same materials to try out various experiments, some children also received direct feedback from an instructor who explained the concept of confounding variables. Perhaps not surprisingly, children who received direct instruction achieved significantly greater mastery of the control-of-variables strategy. In the context of possible science fair experiences, students may receive direct instruction or they may be expected to engage in "discovery learning". In other words, they may be scaffolded through the process of completing a project, or they might simply be assigned a project with the expectation that they will develop a viable research question, come up with an appropriate way to test that question, carry about the investigation and interpret the results on their own. Given the demands on classroom teachers to provide support to an entire classroom of children, as well as following a regular science curriculum, children may not receive detailed or individualized support for a science fair project. As a result, children participating in a science fair may glean other benefits, but may not be engaging in SEPs at a level of sophistication that leads to significant learning or merits the time or resources needed to undertake such an experience.

Second, some studies have raised concerns about the extent to which science fairs and their attendant judging protocols favor children from higher income families (Bellipanni & Lilly, 1999; Bencze & Bowen, 2009; Jackson, 1995). For example, children who spend more money on their materials and displays, or have access to laboratories or other science-related resources may be advantaged in science fair competitions. Related to this issue are questions about the nature and extent of parental involvement (Craven & Hogan, 2008; McComas, 2011). Children's success in completing a science fair project may be largely dependent on the help of a parent, and higher-income parents may have more time and material resources to be able to provide that help. These equity issues are particularly important because they indicate how science fairs may further disadvantage students who are already underrepresented in the sciences.

1.1 Current study

Science fairs may provide unique opportunities beyond those typically offered in science classrooms. However, despite their wide implementation and the amount of resources devoted to them, research literature on science fairs has been isolated to only a few studies of the components of the experience; there have been no large-scale, systematic studies of their implementation and outcomes. Although concerns have been raised about the amount of support children receive in conducting science fair projects, we know almost nothing about how teachers across the country support their students in these contexts. It is necessary to understand how science fairs are implemented and the roles that teachers play in supporting students' science fair work. This will not only illuminate the benefits of the fairs themselves, but also provide insights into how to engage students in science and engineering practices in general. This paper describes the results from the first phase of a four-year national study on science fairs that aimed to document and describe the essential components of school-level science fairs, explore the relationships between these components and student outcomes, and shed new and much-needed light on this intervention. Specifically, this paper addresses two primary research questions:

- What are the approaches of teacher support provided to middle school students in conducting a science fair project?
- How do these approaches to teacher support vary according to school demographic characteristics and school science program characteristics?

1.2 Theoretical framework

This work is grounded in research supporting the effectiveness of direct or *guided instruction*, relative to minimally guided instruction or discovery learning, in supporting students to derive meaning from learning experiences and develop understanding of the "concepts and procedures of a particular discipline" (Kirschner, Sweller & Clark, 2006). A major learning objective for science fairs is for students to deepen their understanding of the concepts and procedures that are particular to science and engineering, or the science and engineering practices. Research has demonstrated that, with direct instruction, students learn these practices more efficiently and more deeply, with greater ability to transfer the practices to other contexts (Klahr & Nigam, 2004). This work was guided by theories related to human cognitive architecture, and the connection between working memory and long-term memory in learning (Anderson, 1996; Glaser, 1987). For novices in a particular discipline, who lack domain-specific schemas for problem solving, attempting to solve a problem with minimal guidance makes great demands on working memory; cognitive processing capacity is then limited for acquiring new problem-solving schemas, or committing them to long-term memory (Sweller, 1988). In the context of a middle school science fair, novices in the disciplines of science and engineering are attempting to solve the problem of conducting an investigation. Based on these theories, students require considerable guidance in navigating this problem space in order to successfully internalize domain-specific problem-solving schemas, or science and engineering practices. According to the National Research Council (NRC) of the National Academy of Sciences, students can engage in SEPs through sustained investigations, and so develop deeper understanding of the core ideas and crosscutting concepts of science and engineering as well (NRC, 2012). In order for this deeper learning to occur, however, it is necessary for educators to carefully structure investigations based on the level of proficiency of the learner (p. 255). The research presented here explores the role that teachers play in guiding students' work on science fair projects and the degree to which current practices in middle school science fairs adhere to a guided instruction approach in teaching science and engineering practices.

2 METHODS

In order to address the questions around the implementation of school science fairs, including the teachers' role in supporting students work through a science fair, we conducted a survey to understand the landscape of science fair models. We developed and deployed the Science Fair Inventory (SFI) which was administered to science fair leaders in middle schools across the country with the goal of identifying whether and how science fairs vary and how they function, including the teachers' role and other components of the fairs that were hypothesized to influence the implementation.

The constructs and development of items in the SFI were guided by the literature described above related to the implementation of science fairs and teacher support for inquiry as well as informal discussions with project advisors. These constructs are illustrated by the model in Figure 1, which includes the components of science fair experiences that we hypothesized may differentiate science fair models and potentially influence student outcomes.

The items in the survey were designed to address each of the design elements, teacher factors, and school factors laid out in the descriptive model. For example, to address "Resources" for the science fair, we asked whether or not the school or district budget included monetary support for the science fair; to address "Principal Support of Science", we asked which supports, if any, school administration provided for science teachers' professional development (PD; e.g. provides information about PD opportunities, allows release time for PD, provides substitutes during PD, provides funds for PD). Survey items consisted of multiple choice and checklist-types of questions in order to provide descriptive information such that we could make comparisons based on school characteristics and basic approaches to supporting the science fairs. In addition, items were included to understand the goals of the fair and the perceptions of the benefits of the fair for the students. Our sampling procedure (described below) provided additional information from the

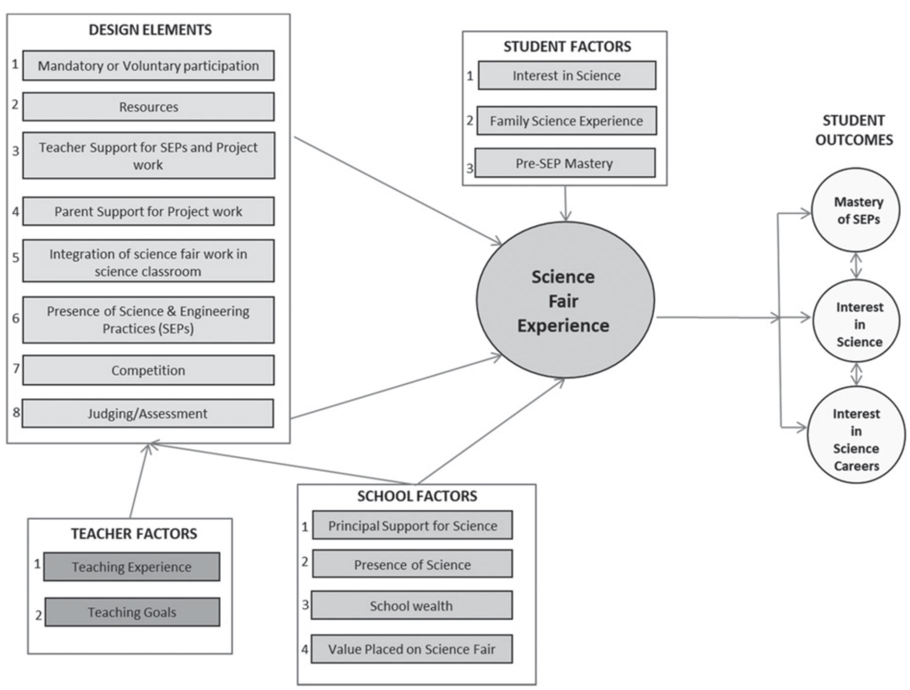

Figure 1. Descriptive model for a school science fair.

Common Core of Data public use files which enabled descriptive information about the school, including the region, school metro status, size, and student demographics. Once the items were near completion, the full survey was tested through cognitive interviews with science fair coordinators from middle schools in the Northeast U.S. Revisions were then made to the overall length of the survey and to ensure clarity of survey questions.

2.1 Sampling

Our target population was all U.S. public and charter schools that serve exclusively grades 6-8 and conduct school-level science fairs. We used the 2011-2012 Common Core of Data (CCD) public use files to identify this target population of schools (Keaton, 2013). Schools that were private, or alternative, special education, or vocational schools, as well as any schools covering different grade ranges (e.g. K-6, 7-8, K-12, etc.), were excluded. In addition, schools that were ungraded or did not provide data on grades were excluded, as were Department of Defense schools, schools in Puerto Rico and the territories, and schools that were reported as closed. Based on these criteria, we identified a total of 9,698 potentially eligible schools, contingent upon whether or not they conducted school-level science fairs. Previous research indicated that approximately 40% of public 6-8 schools participate in local or regional science fairs (Banilower et al., 2013). Using this percentage, we estimated that our total target population was approximately 3,879 schools.

All potentially eligible schools in the CCD dataset were then stratified based on three subgroupings: Census region (Midwest, Northeast, South, West), school metro status (rural, suburban, town, urban), and school income level (lower-income schools with 50% or more students eligible for free or reduced-price lunch, higher-income schools with less than 50% eligible students). This resulted in 32 strata (4 regions x 4 school metro statuses x 2 income levels). We then selected a sample of 600 schools across these strata, so that the number of schools representing each stratum within the sample was proportionate to the number of schools representing each stratum within the target population of middle schools. For example, the first stratum makes up 2.71% of the target population, so 2.71% of 600, or 16 schools were sampled from that stratum. To do this, schools were sorted according to a random number generator within each stratum and then selected based on the desired sample size for each stratum. The percentages of schools in the target population within each stratum and the number of schools sampled from each stratum are presented in Table 1. Since we could not determine a priori whether or not the sampled schools conducted science fairs, we anticipated that we would need to contact significantly more schools in order to reach 600 who were, in fact, eligible for participation in the study. To account both for schools that indicated they did not have a science fair and those that did not respond to our initial queries to determine eligibility, we designated five replacement schools for each sampled school within the same stratum.

2.2 Recruitment

To recruit schools, we first conducted an internet search to find school contact information. We then contacted each school by phone or email to confirm that they were a 6-8 school and determine whether or not they held a school science fair. Schools that responded "no" or that only participated in a district- or state-level fair were considered ineligible and a replacement school was designated. For schools that were determined eligible, we sent a link to the SFI to the science fair coordinator or other science teacher deemed knowledgeable about the science fair. If we were not able to determine eligibility after 5 contacts, the school was dropped and a replacement was designated. We sent the SFI to science fair coordinators at a total of 325 schools with confirmed eligibility. Eligible schools that did not respond to the survey after two reminders and a personal email and phone call, were considered non-responders and were not replaced. We obtained responses from a total of

Table 1. Percent of target population, number sampled, and number of responses obtained by strata

		School Income Level					
		Lower Income			Higher Income		
Region	School Metro Status	% of Target Population	N Sampled	N Obtained	% of Target Population	N Sampled	N Obtained
Midwest	City	2.71	16	8	1.45	9	5
	Suburb	1.84	11	3	4.64	28	10
	Town	1.76	11	5	2.78	17	5
	Rural	2.30	14	4	5.68	34	6
Northeast	City	3.58	21	9	0.71	4	2
	Suburb	1.24	7	3	5.91	35	14
	Town	0.22	1	0	1.03	6	4
	Rural	0.41	2	2	2.17	13	6
South	City	4.50	27	10	1.85	11	3
	Suburb	4.76	29	7	3.97	24	11
	Town	2.85	17	7	0.78	5	1
	Rural	6.38	38	11	4.20	25	4
West	City	6.92	42	11	4.50	27	6
	Suburb	3.57	21	4	3.75	23	3
	Town	3.28	20	9	1.48	9	1
	Rural	4.78	29	4	4.00	24	7

Table 2. Percent of desired and obtained respondents from each stratification subgroup

	N Sampled	% of Desired Sample	N Obtained	% of Obtained Sample
Region				
Midwest	139	23.2	46	24.9
Northeast	92	15.3	40	21.6
South	176	29.3	54	29.2
West	194	32.3	45	24.3
School Metro Status				
City	157	26.2	54	29.2
Suburb	178	29.7	55	29.7
Town	85	14.2	32	17.3
Rural	180	30.0	44	23.8
School Income Level				
Lower-income	307	51.2	97	52.4
Higher-income	293	48.8	88	47.6

185 schools, representing a response rate of 57%. We received at least one response from science fair coordinators in all but one stratum (Lower-income towns in the Northeast, which represented a very small proportion of the target population). The number of responses obtained from each stratum are presented in Table 1. Although we had varying success in obtaining the desired sample within each individual stratum, the percentage of respondents from each major stratification subgroup within the obtained sample was relatively well aligned with the desired percentage of respondents from each subgroup (See Table 2).

2.3 Sample

The majority of respondents reported that their primary position in their school was as a science teacher (87%); some taught other subjects such as English Language Arts, Math or Social Studies (4%), some were school administrators (8%), and some had other non-teaching roles (9%) such as science supervisor or gifted program coordinator. When asked about their role in their school's science fair, the majority reported that they were either the lead or assistant coordinator or director of the fair (74%); the remaining respondents played supporting roles in the fair (e.g. helping with logistics or recruitment) or were participating teachers (26%). Respondents came from schools in 41 different states and represented a range of school size, income levels (based on percent of students qualifying for free or reduced-price lunch), and racial/ethnic makeup. Average school demographics of the study sample were similar to those of the total population of potentially eligible schools (See Table 3).

Knowing that science fairs may be conducted in different ways across grades within the same school, we asked respondents to indicate the grades for which they had sufficient knowledge to report on science fair characteristics; we then asked about various characteristics separately for the grades they had indicated. When analyzing the data, in order to avoid issues of nesting of science fairs within schools, we designated a primary grade for each respondent based on the grade level that they reported. Two respondents indicated that they were not knowledgeable about the science fairs specific to any of the three grades, and so are excluded from the current analyses. Forty-seven percent of the remaining respondents indicated that they were knowledgeable about the science fair for only one grade in their school; this grade was designated as their primary grade. Fifty-three percent of respondents were knowledgeable about science fairs for two or three grades in their school. For these respondents, the grade that they taught was designated as the primary grade; if they taught multiple grades, the youngest grade was chosen. This resulted in an even breakdown of one third of respondents (61) representing each of the three grades.

Table 3. School demographics of SFI respondents and the population of all potentially eligible schools, based on the Common Core of Data

	SFI Respondents (N = 185)		Total Population (N = 9,698)	
	Mean	SD	Mean	SD
School Enrollment	719.7	355.1	641.1	348.0
School Proportion of Low-Income Students	.493	.242	.492	.260
School Proportion of White Non-Hispanic Students	.545	.312	.550	.324
School Proportion of Black/African-American Non-Hispanic Students	.139	.197	.158	.228
School Proportion of Hispanic Students	.209	.251	.212	.259

2.4 Data analytic approach

Our exploratory analysis of the SFI data revealed a tremendous amount of variation in science fair implementation. In essence, there were as many approaches to running science fairs as there were science fairs represented in the study. For the purposes of this study, we sought to identify the broad categories of approaches to science fairs, based specifically on the kinds of teacher support provided to students and the relationships between the science fair experience and regular science instruction, as we hypothesized that these may be important determinants of the impact of a science fair on students' development of SEPs. We defined science fair approaches based on several dichotomous variables (coded as 0 or 1) related to the implementation of the science fair within the classroom, which we divided into these three categories:

- Structural Features
  - Whether or not participation was mandatory for all members of the science class (*Mandatory*)

Table 4. Overall responses to LCA variables across the study sample

LCA Variable	Proportion of Respondents Endorsing Each Item
Mandatory	.80
Integrated	.71
Class Time	.68
After School	.23
Topic Support	.76
Progress Support	.77
General Support	.77
Design Support	.44
Conduct Support	.29
Analysis Support	.26
Interpretation Support	.41
Presentation Support	.38

    ◦ Whether or not the science fair was integrated with the regular science curriculum and/or curricula across other subjects (*Integrated*)
    ◦ Whether or not time was provided for working on projects, for example instructional time during class (*Class Time*) or after school (*After School*)
- General set-up Support
    ◦ Whether or not teachers provided help to students in choosing their science fair project topic (*Topic Support*)
    ◦ Whether or not teachers provided help by keeping track of students' progress on their science fair projects (*Progress Support*)
    ◦ Whether or not teachers provided on-going trouble-shooting for students' project work (*General Support*)
- Investigation Support
    ◦ Whether or not teachers provided help to students in designing their investigations (*Design Support*),
    ◦ Whether or not teachers support students in conducting the investigations (*Conduct Support*),
    ◦ Whether or not teachers support students with analysis of data (*Analysis Support*)
    ◦ Whether or not teachers support students in the interpretation of their data (*Interpretation Support*)
    ◦ Whether or not teachers support students in preparing to present their investigations (*Presentation Support*)

We then used latent class analysis (LCA) to identify classes of respondents who showed similar patterns of response across these variables. Of the 185 respondents, 178 (96%) had sufficient data on these variables of interest in order to be included in the analyses.

3 RESULTS

Overall average responses to the key variables are presented in Table 4, representing the proportion of respondents who endorsed each item across the sample.

3.1 Latent class analysis

First, because we consider the mandatory or voluntary nature of a science fair to shape the way a science fair can be related to regular classroom activities, we constrained this variable to be equal to 0 or 1 for all classes. This meant that any given class would contain either all schools that were mandatory or all schools that were voluntary. We tested models with the following number of classes and combinations of mandatory and voluntary classes: a 3-class solution with 1 voluntary and 2 mandatory classes (Model 1), a 4-class solution with 2 mandatory and 2 voluntary classes (Model 2), a 4-class solution with 1 voluntary and 3 mandatory classes (Model 3), and a 5-class solution with 3 mandatory and 2 voluntary classes (Model 4). Models were compared based on log-likelihood, BIC, entropy[1], and the interpretability or face validity of the classes (Berlin, Williams & Parra, 2013). Model fit statistics are presented Table 5.

The four models did not differ dramatically in fit. Models 1 and 2, however had the highest entropy, indicating that the classes were most distinct. These two models also produced groups that were the most easily interpretable, with classes showing either high or low levels for indicators related to investigation support. Model 2 included 4 classes that were clearly interpretable: mandatory schools with high and low teacher support, and voluntary schools with high and low teacher support. The class representing voluntary science fairs with high teacher support, however, included only 9 schools. While we felt that this class represented an interesting approach to science fairs that potentially merits further study, including a class with so few schools would limit the extent to which group differences could be tested. For this reason, we selected Model 1 as the final model; its three classes were easily interpretable, large enough to allow for group comparisons, and represented three general science fair approaches.

The three groups are described below and presented graphically in Figure 2:

- Mandatory, High Support Class (23% of respondents) – all mandatory, high likelihood of integration of the science fair with curriculum, providing class time, and providing all types of teacher support
- Mandatory, Low Support Class (57% of respondents) – all mandatory, lower likelihood of integration of the science fair with curriculum, providing class time, and providing teacher support related to actually carrying out science fair projects (designing, conducting, analyzing, interpreting, presenting)
- Voluntary, Low Support Class (20% of respondents) – all voluntary, lowest likelihood integration of the science fair with curriculum, providing class time, and low likelihood of providing teacher support related to actually carrying out science fair projects (designing, conducting, analyzing, interpreting, presenting)

[1] Log-likelihood and BIC are indicators of overall goodness-of-fit, where a lower number indicates better fit of the model to the data. Entropy is an indication of how distinct the classes are, with a value of 1 meaning a 100% probability that each respondent would be classified in its assigned class and 0% probability of being assigned to one of the other classes.

Table 5. LCA model fit statistics and characteristics

Number of classes	Model 1 3-class (1 voluntary, 2 mandatory)	Model 2 4-class (2 voluntary, 2 mandatory)	Model 3 4-class (1 voluntary, 3 mandatory)	Model 4 5-class (2 voluntary, 3 mandatory)
Loglikelihood	-1043.324	-994.472	-1017.287	-968.437
# of free parameters	35	47	47	59
BIC	2268.011	2232.488	2278.118	2242.598
Entropy	0.930	0.946	0.888	0.904
Class sizes	36, 40, 102	9, 27, 40, 102	36, 29, 32, 81	9, 27, 29, 32, 81

All schools in the Mandatory + High Support group provided students help in choosing a topic and designing their experiments, and these schools were more likely to provide support with multiple aspects of the science fair project. Table 6 shows the descriptive data for the number of basic supports (out of 3) and investigations supports (out of 5) provided by schools in the three classes. All Mandatory + High Support schools provided at least three types of investigation support, whereas the Mandatory + Low Support schools provided a maximum of three types of investigation support.

3.2 Differences among latent classes

Next, we tested for differences across these groups in other variables of interest using ANOVA for continuous variables and chi-square tests for categorical variables. We found that the groups did not differ significantly by primary grade (whether they represented sixth, seventh, or eighth grade science fairs), χ^2 (4, N = 178) = 2.28, p = .684, region, χ^2 (6, N = 178) = 1.17, p = .978, or school metro status, χ^2 (6, N = 178) = 6.37, p = .383. The groups also did not differ based on the presence of monetary support from school or district budget, χ^2 (2, N = 173) = 0.64, p = .725, or the number of administrative supports provided for science teachers professional development, F(2, 164) = 0.431, p = .650.

Next we tested for differences in school demographics (See Table 7). We did find that the latent class groups differed significantly in variables related to student income and student race. There was a significant difference across the groups in the proportion of students qualifying for free or reduced-price lunch, F(2,166) = 3.11, p = .047. Post hoc Tukey testing showed that the Mandatory + Low Support group had a marginally higher average proportion of students who received free or reduced-price lunch compared to the Voluntary group, p = .081. Mandatory + Low Support was not significantly different from the Mandatory + High Support group, p = .176, nor was the Volunatry group significantly different from the Mandatory + High Support group, p = .931. There was also a significant difference across the latent class groups in the proportion of African American students, F(2,175) = 4.12, p = .018. Post hoc Tukey testing showed that the Mandatory + Low Support group had a marginally higher average proportion of African American students compared to both the Voluntary group, p = .053, and the Mandatory + High Support group, p = .069. The Mandatory + High Support group was not significantly different from the Voluntary group, p = .985.

We also found that the three groups differed significantly in their goals for the science fair (See Table 8). Respondents were asked to rank their top three student goals for the science fair, out of a set of nine possible goals. We classified these choices as either learning-related goals (e.g., build a connection between what is learned in class and what happens in real life; improve understanding of science content; improve ability to use the science and engineering practices) or interest-related goals (e.g., promote general interest in and enthusiasm for science; provide an opportunity to pursue a topic of personal interest; increase interest in science among traditionally underrepresented students, e.g., girls, minorities). Mandatory + Low Support schools were significantly more likely to endorse a learning-related goal as their top goal, as opposed to an interest-related goal, $\chi^2(2)$ = 7.96, p = .019.

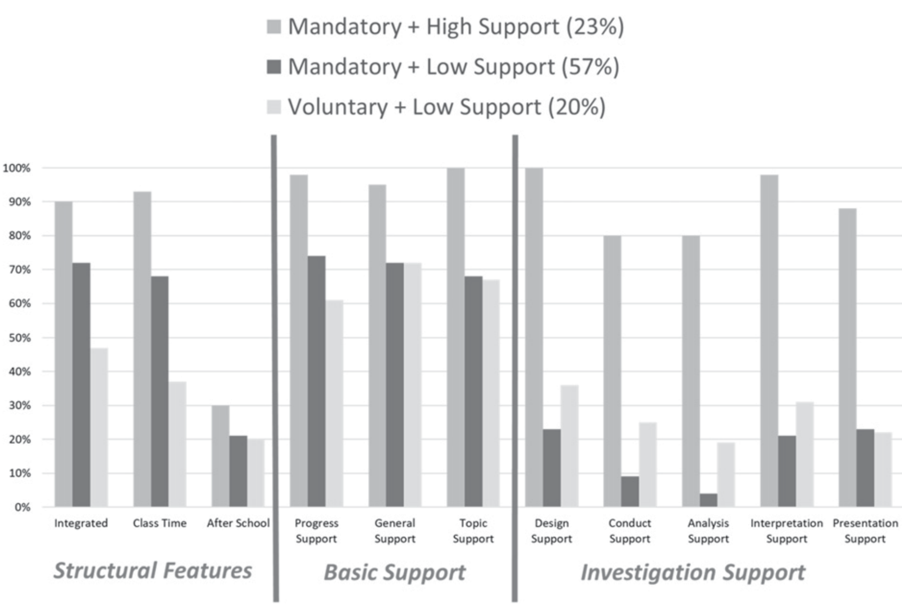

Figure 2. Proportion of schools in each LCA class offering different types of support.

4 DISCUSSION

This first step in our larger research on science fairs has implications for understanding the ways in which science fair

Table 6. Descriptive data for number of basic and investigation supports provided by schools in each LCA group

LCA groups	Number of Supports	Min	Max	Mean	SD
Mand + High Support	Basic Supports	2	3	2.93	0.27
	Investigation Supports	3	5	4.45	0.81
Mand + Low Support	Basic Supports	0	3	2.14	0.86
	Investigation Supports	0	3	0.79	0.90
Voluntary	Basic Supports	0	3	2.00	1.15
	Investigation Supports	0	5	1.33	1.80

experiences engage students in SEPs. Broadly, while science fair implementation varies widely, there are some common approaches that can be defined by the types of student participation and teacher support offered. Our research indicates that there are three broad approaches to implementing science fairs that relate to the participation of the students and the types of support teachers provide for student work. Schools that provide fairs that are mandatory and where teachers provide limited support are more likely to include goals related to student learning, and schools that have a high proportion of African American or low income students were also more likely to fall into this group.

4.1 Teacher support

The three classes that emerged provide evidence of different approaches for implementing science fairs, and the types of support teachers provided. Perhaps the most notable finding of this study is that the majority of middle school science fairs provide a low-level of support to students in carrying out their science fair projects. Yet, the literature on teacher support has shown that teachers' instructional support, including scaffolding and other instructional practices, are important in impacting students' science learning, particularly their learning of scientific explanations (Anghel, 2015; McNeill & Krajcik, 2008) and experimental design (Klahr & Nigam, 2004). By providing opportunities for authentic inquiry-based experiences, science fairs that have an appropriate level of teacher scaffolding have the potential to engage students in SEPs and in doing so, may provide precisely the kinds of experiences that would foster their understandings of scientific work. However, this work has not yet addressed the extent to which the variation in teacher scaffolding or the types of support provided may influence these outcomes. Furthermore, the current study only addressed whether or not teachers provided any support for various aspects of students' science fair projects. These data do not address the depth or quality of support that was provided. Additional research is still needed to understand more specifically what it means for teachers to provide a high or low level of support to students as they work on their science fair projects, and the extent to which science fairs actually vary in the nuances of their implementation and support for student learning. In addition, although this study indicates that Mandatory + Low Support fairs were more likely to have students' learning as a primary goal, further research will be needed to provide evidence of the relationships between implementation—specifically teacher support for science fair projects—and students' developing understandings of SEPs.

4.2 Equity

Previous research has indicated that certain aspects of science fairs, including reliance on parental involvement, the presence of competition, and the amount and types of teacher support offered, may provide more positive experiences and outcomes for students from higher income families, or from better resourced schools. The relationships examined in this study, particularly those between the science fair models and proportions of African American students and those receiving free and reduced-price lunch have potential implications for ensuring equitable participation and providing high-quality experiences that are accessible to all students. Specifically, Mandatory + Low Support schools had, on average, greater proportions of African-American and low-income students, indicating that African-American students and lower income students were more likely to have experiences that included less support for their project work. It is also interesting to note that although Mandatory + Low Support schools had, on average, greater proportions of African-American and low-income students, they were also more likely to endorse a learning-related goal for the science fair above interest-related goals. These findings raise important

Table 7. Student demographics and enrollment

	Overall	Mandatory + High Support	Mandatory + Low Support	Voluntary		
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*F*	*p*
Ave Proportion of FRL Students	.489 (.237)	.448 (.238)	.528 (.235)	.428 (.228)	3.11*	.047
Ave Proportion of White Students	.553 (.310)	.621 (.265)	.515 (.323)	.584 (.310)	1.92	.150
Ave Proportion of Hispanic Students	.205 (.251)	.181 (.203)	.209 (.260)	.219 (.278)	0.25	.779
Ave Proportion Black/African-American Students	.138 (.198)	.093 (.136)	.174 (.232)	.086 (.114)	4.12*	.018
Average Proportion of Asian Students	.045 (.081)	.054 (.083)	.040 (.075)	.047 (.094)	0.51	.600
Student Enrollment	700 (334)	698 (355)	700 (333)	700 (322)	0.00	.999

Table 8. Crosstabulation of LCA groups and learning- vs. interest-related SF goals

	Mandatory + High Support	Mandatory + Low Support	Voluntary	χ^2	*p*
Learning-related top goal	11 (-0.5)	37 (2.5)	5 (-2.5)	7.96*	.019
Interest-related top goal	29 (0.5)	58 (-2.5)	31 (2.5)		

Adjusted standardised residuals are in parentheses beside group frequencies.

questions for the types of support that students might be receiving and for the possibility of providing equitable experiences for learning science and engineering practices.

Data from the Early Childhood Longitudinal Study indicate that, in both fourth and eighth grade, African American students continue to lag behind their white peers in science achievement by a large margin (more than one standard deviation; Quinn & Cooc, 2015). Given this gap and the potential for science fairs to bolster students' science learning, it is not surprising that schools serving more African American students would have a goal of supporting students' learning. It is unfortunate, however, that these schools were also more likely to provide low levels of support, and we suspect, less likely to achieve the goal of science learning. Mandatory + Low support schools place a greater burden on parents to support students with their projects, and yet research suggests that African-American and low-income students may be less likely to receive support for science at home; one study showed that African-American girls were less likely to experience science-related activities at home compared to Asian girls (Kang et al, 2018) and our own work suggests that lower-income parents are less likely to provide substantive support for their students' science fair projects compared to higher-income parents (Fields, DeLisi, Kook, Winfield, & Levy, 2019). Furthermore, research suggests that supporting students' interest in science is key for supporting science achievement and career aspirations (Dabney et al., 2012). Research has shown that, compared to their White peers, African-American sixth graders report lower confidence in their ability to complete science courses, greater anxiety towards science, more negative science self-concept, lower valuing of science, and less desire to do science (Perry, Link, Boelter & Leukefeld, 2012). Science fair coordinators may need to consider exactly what their goals are, and how the implementation of the science fair can achieve those goals for their students, particularly in schools with high proportions of students who may already be experiencing disadvantages in opportunities to learn science and build science interest. Although further research is necessary to understand how science fair approaches relate to student outcomes, science fairs that place greater burdens on students and families to complete projects may be doing more harm than good for students who begin the process with negative feelings about science and their ability to succeed in it.

4.3 Areas for further exploration

Although Mandatory + Low Support schools were more likely to have goals related to student learning, our data do not yet provide evidence to understand what or how much students learned from these experiences. Analysis of student outcomes in the second phase of this study will help to illuminate the extent to which science fair experiences further student outcomes, such as learning science and engineering practices, or students' interest in STEM or STEM careers. The second phase of this study will also provide more information about the variation in teacher support. For example, how do teachers support students in designing investigations, and how do they balance science fair work with standards and curriculum? Science fairs hold the potential to impact students' science interest and learning in positive ways, as long as the supports and access are available to all students.

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