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Reinventing Science Fairs

BY FREDERICK GRINNELL

Science fairs have a remarkable hold on the public's attention. President Obama, in his 2011 State of the Union address, said, "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." The 2018 film *Science Fair* won that year's Sundance Film Festival favorite award. The 2018 book *The Class* chronicled a year in a classroom where science fairs are at the center of science education. And a recent GEICO "Science Fair of the Future" television commercial had more than 11 million views on YouTube in its first month.

As conspicuous examples of kids learning about science, science fairs ought to receive a lot of attention from the education community, but they do not do so as much as might be expected. For example, in three major National Academies of Sciences, Engineering, and Medicine (NASEM) reports on science education—*Successful K–12 STEM Education* (2011), *A Framework for K–12 Science Education* (2012), and *Next Generation Science Standards for States by States* (2013)—the term "science fair" appeared once, in a footnote.

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Science fairs can take many shapes, and it turns out that the variables matter. Is the goal to reach eventual scientists and engineers, or to increase the knowledge of science of students on any career path? Should students be required to participate, or should science fairs be voluntary? Is it about winning and losing, or just participating?

Science fairs began almost one hundred years ago under the auspices of a civic organization called the American Institute of the City of New York. At a 1932 meeting, the city's science teachers and administrators discussed bringing after-school science clubs together into a federation. The organizing committee was led by Morris Meister (who would later found the Bronx School of Science). Meister's ideas about science fairs evolved from his studies of after-school science clubs, which met in spaces that became known as science play shops. Following the philosophy of John Dewey, Meister focused on "the scientist at work rather than the work of the scientist." Dewey strongly advocated for learning by doing, and Meister, extending Dewey's ideas, saw the inventiveness and experimentation by students in the science play shops as analogous in an experiential sense to the playfulness of the scientist doing research.

The first science fairs consisted mostly of demonstration rather than discovery projects, but this changed after the 1939–1940 New York World's Fair. In a science fair housed in the Westinghouse Company's exhibit building, several thousand high school students from the American Institute's science and engineering clubs displayed their projects and conducted live "experiments" for an estimated ten million visitors. A few years later, in partnership with Science Service (now the Society for Science and the Public), science fairs became the central feature of the Westinghouse Science

Talent Search. After Westinghouse, Intel Corporation and, most recently, the biotechnology company Regeneron Pharmaceuticals became program sponsor. After the New York World's Fair, science fairs increasingly became viewed as a means to encourage and help students find their way to science and engineering career paths.

Winners vs. learners

The National Science Teaching Association (NSTA) has offered guidance about how science fairs should be conducted. According to NSTA, science fairs should be voluntary, with an emphasis not on the competition but on the learning experience.

Several years ago, I began a research program to study students' experiences with high school science fairs, working in collaboration with Simon Dalley, president of the Dallas regional science and engineering fair; Karen Shepherd, science coordinator of the independent school district in Plano, Texas; and Joan Reisch, head of the statistics group at the University of Texas Southwestern Medical Center. We looked at two major student groups: regional and national cohorts of high school students who recently had participated in science fairs, and college students on biomedical science trajectories who had or had not participated in science fairs during high school. Using voluntary and anonymous surveys, we have collected answers from more than 700 students about the types and sources of help they received with their science fair projects, the obstacles they encountered, the strategies they used to overcome obstacles, and the impact of science fairs on their interest in science and engineering.

Of respondents who had participated in a science fair, more than 60% of the high school students and 40% of the post-high school students had been required to do so, suggesting that NSTA's guidance is widely ignored. By a four-to-one margin, the students overwhelmingly opposed the notion of being compelled to compete in a science fair, whether or not they personally had been required to do so. Moreover, the negative consequences of the requirement were tangible. When we asked high school students "did your science fair experience increase your interest in the sciences or engineering?" those who had chosen to participate reported a more positive impact than did students who had been required to participate. Of those who had been obligated to participate, only about 50% said the experience increased their interest in science and engineering, compared with 75% of those who chose to participate. Even worse, of the students who said they were not interested in a career in the sciences or engineering and who were required to compete in a science fair, almost 10% reported having engaged in research misconduct—fabricating data or copying their data from someone else.

We also learned that in competitive science fairs, the student focus was on winning rather than learning. It's true that the competitive aspect can be positive or negative depending on the student's personality: the most frequent negative comments fell into the category *don't like to compete* and positive comments into the category *competition provides an incentive*. Less than 1% of the students mentioned science fairs as an introduction to the scientific process.

When asked about noncompetitive science fairs, student views were more nuanced. The high school students still were mostly negative about requiring participation, but the post-high school students now on a biomedical path were split evenly about whether the fairs should be required or optional. Of particular importance, we found that when students considered noncompetitive science fairs, their positive comments fell mostly in the categories of *introduction to the scientific process* and *general learning*—in short, their focus shifted noticeably from competition to learning. So our surveys suggest that if the goal is to increase a general interest and understanding of science and engineering among all students, requiring students to participate in competitive science fairs can be counterproductive, and offering students a noncompetitive science fair alternative could provide a way to change the focus of science fairs from winning to learning.

In what ways do competitive and noncompetitive science fairs differ? Criteria used to judge projects in the International Science and Engineering Fair competition include the project's contribution to the field of study, new possibilities for future work, and the potential impact on science, society, or economics. To win, competitive science fair participants are subject to the same kinds of standards as working scientists and engineers.

In noncompetitive science fairs, students can be evaluated differently, with the focus on their understanding and implementation of individual scientific practices rather than their getting the "right" answer. The Next Generation Science Standards describe eight practices of science and engineering based on an analysis of what science and engineers commonly do on the job: ask questions and define problems (for science and engineering, respectively); develop and use models; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; construct explanations and design solutions (for science and engineering, respectively); engage in argument from evidence; and obtain, evaluate, and communicate information. Students whose project includes all these elements will have learned a lot about science or engineering by bringing together problem selection, experimental design and implementation, data analysis, and communication of research findings.

Another important potential difference between noncompetitive and competitive science fairs concerns students' posters. In real life, science is typically presented in one of three forms. Student textbooks offer a collection of facts with little if any explanation about how the facts were discovered. Scientific memoirs and biographies (along with journalistic, social science, and philosophical accounts of science) describe what happened in everyday practice—research adventures where the path to discovery can be highly convoluted with many dead ends, failure is frequent, and ambiguity ever present. And published research papers and conference posters, in which scientists recast these adventures as stories that follow a linear path from hypothesis to discovery, hide the real-world complexity of scientific practice. In competitive science fairs, students' posters follow the same format as scientists' research papers. In noncompetitive science fairs, however, students have no need to follow the linear format. Instead, they have an opportunity to describe what actually happened over the course of carrying out their project, including the failures or ambiguities that they experienced.

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Noncompetitive and competitive science fair formats correspond to what the education literature characterizes as mastery-oriented and performance-oriented goals. Mastery means competition with oneself with an emphasis on understanding and improving skills and knowledge. Performance means competition with others to demonstrate one's higher ability and capacity to win. Science and engineering are highly competitive careers. For those students already interested in a career in these areas, competitive science fairs may be valuable as an opportunity to experience that competition firsthand. For everyone else, noncompetitive science fairs provide an equally important opportunity to experience the practices of science with the focus on learning, precisely those practices described above. Consequently, noncompetitive science fairs can provide a wide range of students with a broad appreciation of where scientific knowledge comes from and how it is used in the twenty-first century world.

Science unfair?

Another important benefit of noncompetitive science fairs concerns fairness. Researchers who have studied what contributes to student success in science fairs (read: winning them) have identified several key factors: parental support and encouragement, access to social and research resources, and access to higher-level facilities outside school. Although many students are able to compete and succeed through their own sheer intellect and determination, students with the key resources will have a strong advantage. Consequently, some critics argue that science fairs are fundamentally unfair, and biased against students with fewer resources. In our study, one student put it this way: "The ceiling of the project mainly depends on how well you are connected to a researcher at a higher institution. Many participants had family members or good connections for them to work in their lab. As a result, the playing field felt unfair to those who were not well connected in science or who had families who didn't have scientific backgrounds." Indeed, our research found that students who had received help from scientists reported an easier time getting their project ideas and less difficulty getting the resources necessary to carry out their projects. In noncompetitive science fairs, where the goal no longer is winning, the fairness issue recedes.

Morris Meister's doctoral thesis focused on the role of science toys, such as Meccano erector sets and Chemcraft chemistry sets, in informal science education. Students active in the science clubs that became part of the federation promoting science fairs were already engaged in competitive and noncompetitive activities centered on the use of science toys. On the competitive side, toy manufacturers offered generous cash prizes to winners based on original use of their products that would be of general interest to others and not simply variations of already published ideas. On the noncompetitive side, club members could win prizes based on their accumulative individual achievements.

In a May 22, 1932, article in the *New York Times* describing the meeting at which the after-school science clubs formed a federation, the group's stated goals closely echoed those of today's STEM (science, technology, engineering, and mathematics) education—"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." Based on our research, we suggest that incentivizing voluntary student participation and offering students the choice of science fair formats—both noncompetitive and competitive—would best achieve these broad educational aims. Competitive and noncompetitive programs were part of science fairs at their inception. It's time to bring both options back.

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