THE SCIENCE FAIR

A New Look at an Old Tradition

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Emily McComas with her 2010 prize-winning science fair project, which examined mistletoe distribution in trees in the parks of Fayetteville, Arkansas.

Observations, reflections, and recommendations from our guest editor

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As a science teacher educator and former science teacher, I've long known that the science fair should be part of my professional experience, but I hadn't given it much thought until recently. The school where I taught didn't participate in science fairs, and I had no experience as a mentor, though I have volunteered as a judge at local and regional science fairs for many years. I generally thought of science fairs as a time-honored part of science instruction, but one I knew little about in terms of process versus product.

Then, one day last fall, my daughter came home from school and announced, "We have to do a science fair project this year, I have no idea what to do, and I need your help!" My daughter's request presented not only a wonderful parenting opportunity but also a unique window into the complex nature of the science fair itself. As we worked together on her project—examining the ecology and distribution of mistletoe—my basic awareness of these fairs gradually turned into passion and reflection. As her project progressed, I became increasingly convinced that it's time to reconsider the range of activities we call *science fairs*.

In this article, I use the term *science fair* for projects and programs that give students authentic and personal experiences in *doing* science (this can include expositions, olympiads, and other design competitions). Here, I present some reflections on and recommendations for these types of projects.

The science fair, past and present

It's hard to say precisely when science fairs and research competitions first appeared on the educational scene, but such activities have, for many students, become an annual rite of passage—eagerly anticipated by some and dreaded by others. The traditional science fair can be dated to at least 1928, when the American Institute of New York City hosted its first research competition at the American Museum of Natural History. Local, district, regional, and state competitions grew from there, with the first national fair in Philadelphia in 1950. The scope of this fair broadened over the years, and it is now known as the Intel International Science and Engineering Fair (see the Rillero article on p. 44 for more information on this)—the largest and most prestigious science fair in the world (Society for Science & the Public 2011).

At the local level, businesses, industries, and higher-education institutions have typically contributed the mainstay of financial assistance to science fairs and provided mentors and judges. National and international tech and media companies—such as Science Service, Westinghouse, 3M, Siemens, Discovery Education, Toshiba, DuPont, Disney, WestEd, the Conrad Foundation, the National Science Teachers Association (NSTA), and Google, which launched the world's first online science fair this year—support these annual events in various ways.

A wide variety of groups—from nature societies to professional associations of scientists—either provide direct funding or award prizes and scholarships in a particular area of science. Some of the top national and international competitions have five-figure individual prizes, and the total award money reaches millions of dollars each year (Google Science Fair 2011; Society for Science & the Public 2011).

Though the support for science fairs seems strong, there are clouds on the horizon. Even as science-fair success stories pop up in the media, no data exist on the extent of implementation (i.e., number of participants) of these fairs. Certainly, those students who participate are affected, but there is no information about how many total students engage in science fairs and related activities each year. In a recent poll conducted by NSTA (Petrinjak 2011), of the 75% reporting that their school hosted a science fair last year, only 68% said they would do so in the coming year. Furthermore, 65% of respondents said that science fairs are becoming less common.

The New York Times reports that sponsorship in a number of key science fairs has declined (Fitzsimmons 2010), and science fair participation and support have declined across the nation (Harmon 2011). The reasons for this decline are unclear but, in general, educators seem to be opting out of science fairs because of the large amount of work required and the lack of reward. In addition, the increasing focus on end-of-course tests and other learning goals has gradually taken time away from activities that some may see as optional.

As these issues are revealed, this seems a good time to examine the advantages and challenges of the science fair and offer suggestions for how this tradition might be updated and even expanded.

The arc of science

For decades, most in the science education community have embraced the notion of authentic inquiry as a worthy goal of science instruction. The *National Science Education Standards* (NRC 1996) offers many references in support of inquiry—a theme that continues in the recently released *A Framework for K–12 Science Education* (NRC 2011). These documents make two special pleas with respect to inquiry: First, they recommend that students have opportunities to appreciate and understand that inquiry is how scientists investigate and make sense of the world. Second, they support the goal that students have opportunities to experience authentic inquiry themselves. The first goal—providing students with knowledge of inquiry—is generally met in science classrooms. But few science learners actually experience inquiry firsthand.

Debate over the ideal form of inquiry continues, but for most science educators, the key is that the student controls most or all aspects of the investigation. A simple and useful measure for evaluating the depth of inquiry a task demands is to ask three questions:

1. Who proposed the problem?
2. Who designed the research method?
3. Who makes sense of the data?

If the student is responsible for all three tasks, there is little doubt that the activity involves high-level inquiry (McComas 2005).

Inquiry may also be thought of as having personal experience with the "arc of science." This arc is the entire suite of methods scientists apply as they probe, and ultimately make sense of, the natural world. The arc consists of

- designing research questions,
- conceptualizing an appropriate research method,
- collecting data,
- making sense of these data (including arguments with the self and others about what these data mean), and
- reporting results in ways that are convincing to others.

To many, this may feel like the traditional "scientific method," but there is a distinction. The myth of the scientific method—which seems to transcend science classes and texts—is that scientists have a single, multistep formula they use *every time* they try to solve a problem. In reality, doing science is an idiosyncratic pursuit that applies many shared methods (e.g., rigorous and sufficient data collection, careful record keeping, intellectual honesty, the application of induction and deduction) in pursuit of problem solving and data collection.

Two of the hundreds of projects at the Northwest Arkansas Regional Science and Engineering Fair held at the University of Arkansas, Fayetteville.

Certainly, classroom teachers could deliver lectures on the arc of science or participate in inquiry-based projects, but there can be few more effective ways to teach these lessons than by having students work their way through problems as part of a science fair. There are few other learning experiences that equal the science fair in teaching students about true inquiry while also acquainting them with the nature of science. Having interviewed many students as a science fair judge, I am certain that these apprentice scientists truly understand that science is full of false starts, blind alleys, unjustified assumptions, and unexpected findings.

One of the biggest challenges in engaging students in high-level inquiry is figuring out when they are ready to go solo and when they still need some hand-holding. It makes no sense to simply announce to students that they must prepare a science fair project. Without background instruction and prior experience, this can be a recipe for disaster. It may even encourage some science fair participants to falsely conclude that they can't do science.

Kirschner and colleagues (2006, p. 75) have suggested that inquiry is ineffective and point out: "Minimal guidance during [inquiry] instruction does not work." However, by providing prior experiences that demonstrate elements of the arc of science, students will be well prepared to work individually on science fair projects and other inquiry tasks in the future. This view is incorporated in the following section.

Reconsidering the science fair: Suggestions and recommendations

How can teachers best incorporate the arc of science and create meaningful inquiry experiences for students? Here are a few tips and considerations for producing great science fair projects:

Education of the educators

Initial science teacher preparation and continuing staff development programs must include strategies for successfully managing science fairs. It makes little sense to assume that teachers will want to engage in such programs if they don't know how to contribute. There is no reason to expect success if teachers must reinvent the wheel as they learn what works and what doesn't.

Additional time

Support for the science fair must include balancing demands of the standard curriculum with the time required to help students prepare for their projects. Schools that have had the most success with science fairs frequently offer after-school support sessions, embed science fair preparation into research courses, and treat the science fair much like a sport or other cocurricular activity. In any event, teachers must be given appropriate release opportunity—or some other accommodation—to help compensate for time spent supporting science fair students and related activities.

Long-term preparation

School districts should adopt a longitudinal perspective to help students prepare for science fairs. For example, students in early grades might benefit from preparing presentations of scientific phenomena and move, in the upper elementary grades, to solving problems that are presented to them. Middle and high school students have the necessary background to engage in projects that encompass the entire arc of science.

Whole-class activities

To help students understand how all of the elements of the arc of science fit together, teachers might model the activities inherent in a successful science fair with a whole-class inquiry activity. This provides a wonderful opportunity for teachers to illustrate and discuss the parts of the arc of science before students are asked to develop their own individual projects.

It is what it is

Students often choose names for their work that are more clever than illustrative. As a judge, one of my favorite projects was curiously titled "What Miss Fluffy Does at Night." Though this is certainly an intriguing title, it tells us nothing. The subtitle—"A Qualitative and Quantitative Examination of Nocturnal Hamster Behavior"—explains the purpose of the project. Students should be encouraged to choose titles related to the phenomenon being examined. For ideas, they may want to look at the titles in a publication such as *Nature* or the *Journal of Cell Biology*.

Experimental vs. nonexperimental research

Science fair rules must recognize that many worthy projects are designed to gain background information and don't require a research hypothesis. After all, in the minds of some, a hypothesis is an educated guess; but if the student hasn't completed any data collection, the hypothesis will be more guess than education. This requirement may reinforce misconceptions about the role and distinction of experimental vs. nonexperimental research (see "On the web" for more information on this dichotomy).

Authentic inquiry

To ensure that science fairs engage students in the highest possible form of inquiry, teachers should avoid equating projects such as product testing and demonstrations of scientific phenomena with those that involve the full arc of science (see "On the web" for a proposed list of the five types of science fair projects). Such projects may be recommended for other purposes but not for illustrating high-level inquiry.

Teamwork in science and science fair

Grobman (1993) makes the compelling point that science fair participants should work in teams—in part to simulate the nature of work in science itself. Of course, team projects are permitted within the rules of the science fair, but it might be useful if students are encouraged, or even required, to work as part of a small group—particularly for their first projects.

Judge training

Science fair judges should have some training each year—both to ensure that they are looking at the "right" things and to provide some level of reliability within the group of evaluators. An easy way to do this is to save projects from the previous year and have the judges make decisions, as a group, on how to evaluate them. Judging should be valid (i.e., focusing on important elements) and reliable (i.e., making judgments consistently) but, unfortunately, that is not always the case.

At home or in the lab

To level the playing field, perhaps future science fairs might have two competition categories, so that students who work on their own are judged separately from those who work in professional laboratory settings. These types of projects are often quite different. A project completed in a lab might have a "wow" factor simply because the students used professional equipment or worked on what seems to be a high-level problem. The goal of science fairs should be to help students gain appreciation for the processes of science, not for students to make fundamental scientific discoveries. This two-tiered option doesn't currently exist but it is worth consideration, particularly at the local level.

The role of "disappointing" data

Those who mentor students should help them understand that unexpected, or even disappointing, data are worth reporting and don't represent a failed endeavor. Even in the world of professional science, it can be difficult to find a place to publish "negative" data. However, such data are an important element of both science and successful science fair projects. The negative result of a science fair project might just be the beginning of a future research initiative.

Parental involvement

Parents must be advocates for students' completion of science fair projects. However, if students are to gain personal experience with the arc of science, the project must not become their parents' work. Parents who want to be more involved can volunteer to assist the teacher by mentoring small groups of students as they work through elements of the arc of science and, in doing so, guide their own child, help the teacher, and support other students in the class.

For example, for my daughter's science fair project (see photo, p. 34), I was her lab assistant. We spent many cold days driving from park to park, assessing how much mistletoe graced the winter trees. However, when it came to making sense of what we saw, proposing patterns, and addressing the research questions, she was in charge.

A heavily mistletoe-infested tree in one of the city parks in Fayetteville, Arkansas.

Scientists and science fairs

Just as parents should consider the nature of the help they provide, students too must recognize when others provide too much assistance. For example, students who work with professional scientists should develop personally relevant research questions, rather than work as technicians on ongoing investigations. As Craven and Hogan (2008, p. 679) state: "From our perspective as science educators, we all too often see that the final projects at school science fairs don't accurately reflect either the enterprise of science or the students' interests." To experience true inquiry, students must choose their own projects, then collect and wrestle with their data.

Final thoughts

My daughter helped me gain a new appreciation for the science fair and its role and challenges in science instruction. I am pleased to report that her project, which focused on the distribution of mistletoe in the parks of Fayetteville, Arkansas (see photo), won first prize in both our local and regional fairs and third place in the statewide competition. She learned much about the ecology of mistletoe but, more important, she gained firsthand experience in the way that science functions. She asked the questions, defined the research method, collected the data, wrestled with the meaning of those data, and presented the results. This is how science works: In any field, contributions from scientists across the globe slowly provide data that paint increasingly detailed pictures of how the world around us operates. Each publication is another piece of the puzzle.

Future scientists and citizens must understand the strengths and limitations of science as a way of knowing. For many students, this understanding arrives only when they have the opportunity to experience science through a science fair. It's time, then, to lift the status of the science fair from an occasional experience for some to a central feature of science instruction for all. ■

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On the web

A description and comparison of the five types of science fair projects—true experiments, nonexperimental investigations, product testing, technological or engineering challenges, and modeling scientific phenomena: *www.nsta.org/highschool/connections.aspx*

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