A Dynamic Alternative to the Scientific Method

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Source: BioScience, 59(1) : 15

Published By: American Institute of Biological Sciences

URL: https://doi.org/10.1525/bio.2009.59.1.4

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Open a biology textbook to the table of contents and you will undoubtedly see a chapter devoted to the scientific process. Typically, this is presented as a four- or five-step "scientific method," a recipe that all must follow if scientific experimentation is to generate irrefutable results. These steps may be adequate for a science report, but, explains Judy Scotchmoor at the University of California's Museum of Paleontology, it is not really how scientists do their work.

Scotchmoor and a team of natural scientists, social scientists, philosophers, and educators developed a Web site called Understanding Science (*www.understandingscience.org*) to explain to teachers, students, and the general public "how science *really* works." The site, launched in January 2009 and funded by the National Science Foundation, presents an alternative to the scientific method: the science flow chart.

The flow chart illustrates how scientific investigations may be inspired by a wide range of inputs, from serendipitous occurrences to practical problems in need of a solution. Next is the gathering and interpretation of data through "testing ideas," which is at the center of the flow chart and at the core of science. From here, the next step may be interactions with the scientific community, further testing, investigation of new questions, or applying scientific knowledge. The chart emphasizes that science is an iterative, dynamic process involving a community of scientists engaged in many different activities.

The flow chart itself was developed through an iterative process. Scotchmoor initially asked the advisory board to think about what they wanted to tell people about science. This result, she says, was "masses of arrows going all over the place." Although other projects and Web sites exist that focus on the nature and process of science, the science flow chart and the broad range of additional materials on the Understanding Science Web site are unique. "I haven't found any other site of this breadth or depth that illustrates the dynamic, nonlinear, creative scientific process and that is appropriate for teachers and the general public," Scotchmoor says.

The traditional scientific method was formalized in the middle of the 20th century, explains Michael Weisberg, assistant professor of philosophy at the University of Pennsylvania and an advisory board member of Understanding Science. Part of the attractiveness of the method was its focus on testing and confirmation. But justification, or outcome-based science, is quite different from discovery, states Weisberg. The discovery aspect of science needs equal time. "We, the scientific community, have an opportunity to be proactive and excite people about science," says Weisberg, who is confident that this new way of looking at science will generate interest and enthusiasm.

The teacher resources on the Understanding Science Web site explain the need for this paradigm shift. They also include examples of how to introduce the science flow chart to students using case studies and stories about scientists that explicitly describe the variety of paths their research has taken. The goal, says Scotchmoor, is to show that "science really is an adventure. There are certain rules that you need to follow, but really you can't predict where questions will take you."

Jennifer Collins, a middle-school science teacher, was part of the development team and an early adopter of the science flow chart: "I had my students look at the chart before I ever told them anything about it and then tell me what they think it shows about how science is done. They were able to recognize that science can happen in many ways, that there are different parts to science investigations. Many were interested in the ways scientists begin their research, that is, what inspires them." Collins provides opportunities for her students to do different things on the flow chart.

Natalie Kuldell, advisory board member and instructor of biological engineering at the Massachusetts Institute of Technology, has used the science flow chart in her undergraduate orientation lecture. "I use it to stress that science cannot be oversimplified to make a good story," says Kuldell. Data that get in the way of neat conclusions cannot simply be wiped away. The flow chart helps her explain this, as does the site's growing collection of research pathways, which are real examples of the iterative, dynamic process of science.

Kuldell recognizes that educators face time constraints but strongly encourages everyone who teaches science to find time to include the process of science in their curricula. It can be as simple as replacing a fact or two with a process of science moment. "I think by demonstrating that science requires creativity and imagination," adds Kuldell, "more students will be attracted to a career that is truly a fun and exciting endeavor."

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doi:10.1525/bio.2009.59.1.4