What Are the Similarities between Scientific Research and Science Education Reform?

Draft by

Cherilynn A. Morrow
Space Science Institute
Boulder, Colorado

Please send comments to camorrow@colorado.edu

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SPACE SCIENCE INSTITUTE

3100 Marine Street, Suite A353
Boulder, CO 80303-1058
Phone: 303.492.3774
Fax: 303.492.3789

Email: info@spacescience.org
Web: http://www.spacescience.org

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Abstract: Scientists and educators have an opportunity to discover the common ground in the similarities between the way scientists practice science and the ways science education reform is calling upon educators to teach science. Discovering this common ground can be a useful way of focusing the talents and knowledge of scientists in support of science education reform.

NOTE: This paper is one in a series written primarily to support government-funded scientists and scientific research groups at universities and scientific institutions who are attempting to respond well to the charge of becoming more actively and effectively involved in K-12 education and public outreach (EPO). The paper will also serve the EPO professionals who are assisting scientists in making a meaningful response.

Background and Introduction

In the interest of cultivating the public interest, attentiveness, and understanding required for the health of the scientific enterprise, federally funded scientists are increasingly being given opportunities and incentives to contribute to K-12 education and public outreach.[1,2] Scientists offer much that is needed in K-12 education, including 1) respect and influence in their communities; 2) deep knowledge of science and scientific process; 3) exciting connections to real-world exploration; 4) access to data and facilities; and 4) role modeling ("science as a human endeavor") for students. Although there are many roles scientists can play besides partnering with an educator or school district to help implement science education reform,[3] such partnerships are extremely important. Bruce Alberts, President of the National Academy of Sciences has written:

> I now view effective science education partnerships between scientists and pre-college education science teachers in a completely different light – as the only hope for lasting systemic change in pre-college science education and, therefore, as an important national priority for the United States.[4]

This paper will begin by acknowledging the cultural differences between scientists and educators that can inhibit the success of their partnerships, but it will quickly turn an eye to the common ground between scientific research and science education. Scientists and educators have an opportunity to discover common ground in the way scientists practice science and the way science education reform is calling upon educators to teach science. Discovering this common ground can be a useful way of focusing the talents and knowledge of scientists in support of science education.

Crossing Cultures

Scientists who chose to contribute substantively to K-12 education often discover the challenge of crossing cultures. Experiences in five workshops for scientists on K-12 education[5] and struggles in a partnership between educators and scientists to develop an educator guide for a NASA planetary science mission, have all exposed substantive cultural differences between the realms of scientific research and those of science education. For example, scientists are generally very competitive by nature and they prefer to confront and solve problems head on. Scientists are intellectually confident people who are well used to criticizing each other's work in quest of scientific truth.

On the other hand, educators are more collaborative by nature and tend to work around problems rather than confront them directly. Educators tend to feel intellectually and personally intimidated by a scientist's more critical and confrontational style, as well as by the greater prestige society holds for the achievements of a scientist. Educators think nothing of borrowing each other's ideas freely if it will help accomplish their mission to facilitate student learning. Meanwhile, for a scientist to use someone else's idea in their work without taking care to assign proper credit is considered an extreme professional taboo.

Discovering the Common Ground

Identifying cultural differences and preparing to encounter them in a constructive way is certainly a useful and important thing to do in quest of a successful partnership between scientists and educators. However it may be of even greater value to examine and anticipate *similarities* in the professional efforts of both scientists and educators. We may ask: *"What is the same between the characteristics of scientific research and those of science education reform?"*

The first obvious answer to this question is that knowledge in both science and science education has a basis in prior and ongoing research by academicians and other experts in the field. In education, there is research into such fields as how students learn, how cognitive capabilities develop with time, how best to make use of technology in education, and so on. Upon deeper consideration, it becomes evident that scientists and educators have an even more profound common ground between them that can serve to focus their collective talents and knowledge more fruitfully in support of science education and its reform.

It remains for many scientists and educators to discover and internalize that modern science education reform is about teaching students in a so-called "inquiry-based" fashion – a way that bears enormous similarity to how scientists practice science as opposed to how they learned it in school. Most of today's scientists have been taught science (and thus continue to teach science) in traditional ways, involving predominantly lectures, memorization, and textbooks. To illustrate potential problems with traditional teaching and assessment methods, Jay Hackett of the University of Northern Colorado -- a 1995 presenter in a workshop for scientists on K-12 education[5] -- showed the following viewgraph:

The Monotillation of Traxoline
(attributed to Judy Lanier)

> It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is monotilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then bracter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.
>
> Directions: Answer the following questions in complete sentences. Be sure to use your best handwriting.
>
> 1. What is traxoline?
> 2. Where is traxoline monotilled?
> 3. How is traxoline quaselled?
> 4. Why is it important to know about traxoline?

The presentation of the "Traxoline" story illustrates how it is possible to "pass the test" without really knowing or understanding much of anything. Students can memorize and use sophisticated vocabulary words, but be devoid of any deeper conceptual understanding rooted in their own experience. Table 1 below summarizes an analogy between practicing science and teaching science in the inquiry-based fashion advocated by the National Science Education Standards (NSES). [6] The fundamental difference is that scientists are operating on the boundary between the known and unknown for all of humanity, whereas educators are facilitating students across the boundaries between their individual "known" and "unknown". Guiding students to approach and solve problems like a scientist gives them thinking skills that are valuable in all academic disciplines as well as in everyday living.

Table 1: Practicing Science vs. Teaching Science

Scientific Research Approach	Inquiry-Based Teaching Approach
Raise fundamental question of interest that is addressable via scientific investigation.	Engage student interest; guide the development of questions [i.e. establish basis for **inquiry**) in a specific area of content.
Research what is already known	Discuss with students what they already "know" or think they know [**prior knowledge assessment**] to help address the question(s).
Make a prediction or hypothesis in answer to the question of interest	Ask students to make a prediction or hypothesis in answer to the question of interest
Plan and implement an experiment to test the prediction.	Plan and implement an experiment to test the prediction [**hands-on activity**]
Reflect on the results of the experiment and how they affect what was known before. Be alert for how the new data does or does not readily fit into the existing structure of scientific understanding.	Reflect with students on the results of their hands-on activity/investigation and use their predictions to assist them with gaining new/deeper understanding of content. Be alert for any shifts from "prior knowledge" as students integrate their new experiences.
Communicate new knowledge via talks and papers. Science community judges the validity and value of the results. New questions are raised.	Communicate new knowledge via presentations, papers, demonstrations, exams **[assessment methods**]. Teachers judge students' learning and guide them to apply it to new circumstances.

Table 1 plainly demonstrates that the inquiry-based approach to learning has many similarities to the way they themselves learn new things in scientific research. It is ironic that several scientists in workshops on K-12 education[5] have expressed strong skepticism of the value of an inquiry-based approach to learning. In some cases this resistance was primarily because such an approach does not advocate teachers telling students immediately when they are wrong. Some scientists felt that failing to tell students they were wrong about their preconceptions was a grave disservice and an unnecessary attempt to protect their self-esteem at the expense of science learning. But with inquiry-based learning it is the teacher's task to lead students to conduct discussions, investigations, and activities that challenge their false ideas and allow them to think and construct their own understanding of what is correct.

Table 2 below re-emphasizes the differences between traditional and inquiry-based learning, and amplifies further the similarities between the practice of science and the practice of science teaching. Note that "hands-on" is a necessary but not sufficient quality for being "inquiry-based".

Table 2: Comparing Approaches to Teaching and Assessment[7]

Conventional Approach	Hands-On Approach	Inquiry-Based Approach
The teacher tells students that trees can be classified by examining their bark and their leaves. She shows pictures of trees in a textbook and asks students to memorize the names of the different types of trees according to the sort of bark and leaves they have.	The teacher tells students that trees can be classified by examining their bark and their leaves. She shows pictures of trees in a textbook and takes students to the park and asks them to match the pictures with the real trees. She asks students to memorize the tree names for the test. The class moves on to another hands-on activity about plants and flowers.	The teacher tells students that scientists classify trees by the different features they have. She asks them to come up with ideas for what features would distinguish one tree from another. She takes them to the park to explore their ideas and to make observations and gather data that would help them create their own classification scheme for trees. She asks them to compare to established classification schemes and to present reports on their results. She follows up with a lesson about the nature and classification of trees in other climates.

Note that an exemplary inquiry-based lesson sets the stage for a new lesson that builds on the old one. Ideally, inquiry-based teaching does not consist of a string of isolated, "one-shot" activities anymore than science consists of a string of isolated "one shot" experiments. In both science and reformed science teaching the results of one experiment (or activity) answers some questions and raises others that can be addressed by new experiments.

Concluding Remarks

Scientists' deep knowledge of scientific process is especially valuable to today's educators and the movement to reform science education in America. Science education reform challenges today's teacher to facilitate a process of "students as scientists", wherein students learn by raising questions and conducting investigations in quest of answers that extend or deepen their understanding of fundamental concepts. In this inquiry-based scenario, educators facilitate students' activities and research in support of finding their own answers and constructing their own understanding rather than asserting professor-like authority about what is right or wrong. Such a teaching practice gives students valuable experience in thinking and reasoning, and a concomitant opportunity to gain confidence and experience joy in figuring things out. This inquiry-based approach to teaching and learning has many similarities to the way scientists' practice science as opposed to the traditional ways in which they learned it. The evident sameness between the way scientists practice science and the way science educators are being challenged to modify their teaching of science offers scientists an opportunity to make vital contributions to their partnerships with educators.

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[1] *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs* (1995) http://spacescience.nasa.gov/education/edprog.htm

[2] *Geosciences Education: A Recommended Strategy*. A report based on a workshop of the Geoscience Education Working Group to the Advisory Committee for Geosciences and the Directorate for Geosciences of the National Science Foundation (29-30 August 1996). NSF 97-171

[3] Bybee, Rodger W. and Cherilynn A. Morrow, "Improving Science Education: The Role of Scientists", *Newsletter of the Forum on Education of the American Physical Society,* Fall 1998. [To request a copy, please email camorrow@colorado.edu]

[4] Alberts Bruce M., "Why Science Education Partnerships?", from *Science Education Partnerships: Manual for Scientists and K-12 Teachers,* University of California, San Francisco, 1993.

[5] Over 200 space and earth scientists have benefited from NASA- and NSF-funded workshops for scientists on K-12 education conducted by the Space Science Institute in Boulder, Colorado [follow the "Workshops" link from http://www.spacescience.org]

[6] The National Research Council: *National Science Education Standards* (1996), National Academy Press, Washington DC http://www.nap.edu/readingroom/books/nses/html/

[7] This illustration was developed in collaboration with Dr. Tim Slater of Montana State University