Teaching Scientific Inquiry:

Exploration, Directed, Guided, and Opened-Ended Levels

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THE TEACHING AND LEARNING OF SCIENTIFIC INQUIRY is viewed as an essential component of all current K-12 science curricula. Science educators have historically been concerned with students' ability to apply their science knowledge to make informed decisions regarding personal and societal problems. The ability to use scientific knowledge to make informed personal and societal decisions is the essence of what contemporary science educators and reform documents define as scientific literacy. However, many scientists and science educators have difficulty agreeing on what scientific literacy is, let alone knowing how to teach and assess it. This paper presents the various perspectives of scientific inquiry as well as the continuum of levels of instruction of inquiry that are necessary to engage students in authentic scientific experiences.

Teaching Scientific Inquiry

Students' understandings of science and its processes beyond knowledge of scientific concepts are strongly emphasized in the current reform efforts in science education (AAAS, 1993; NRC, 1996; NSTA, 1989). In particular, the National Science Education Standards (NSES)(1996) state that students should understand and be able to conduct a scientific investigation. The Benchmarks for Science Literacy (AAAS, 1993) advocates an in-depth understanding of scientific inquiry (SI) and the assumptions inherent to the process. Both documents clearly support the importance of students possessing understandings about scientific inquiry, not just the ability to do inquiry. Research, however, has shown that teachers and students do not possess views of Scientific Inquiry that are consistent with those advocated in reform documents. Moreover, research illustrates teachers' difficulties in creating classroom environments that help students develop adequate understandings of Scientific Inquiry (Lederman, 1992). Many classroom environments do not include explicit attention to the teaching and learning of scientific inquiry or systematic assessment of students' learning with respect to aspects of scientific inquiry.

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What is Scientific Inquiry?

Although closely related to science processes, scientific inquiry extends beyond the mere development of process skills such as observing, inferring, classifying, predicting, measuring, questioning, interpreting and analyzing data. Scientific inquiry includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge. From the perspective of the *National Science Education Standards* (NRC, 1996), students are expected to be able to develop scientific questions and then design and conduct investigations that will yield the data necessary for arriving at conclusions for the stated questions. The *Benchmarks for Science Literacy* (AAAS, 1993) expects that all students at least be able to understand the rationale of an investigation and be able to critically analyze the claims made from the data collected. Scientific inquiry, in short, refers to the systematic approaches used by scientists in an effort to answer their questions of interest. The visions of reform, however, are quick to point out that there is no single fixed set or sequence of steps that all scientific investigations follow. The contemporary view of scientific inquiry advocated is that the questions guide the approach and the approaches vary widely within and across scientific disciplines and fields.

At a general level, scientific inquiry can be seen to take several forms: Experimental, Correlational and Descriptive. Experimental designs very often conform to what is presented as the Scientific Method and the examples of scientific investigations presented in science textbooks many times are experimental investigations. Classic experiments are those investigations that include controlling variables. But we want our students to understand that there are other valid inquiry methods used by scientists to answer their questions. Most of what we know about the disciplines of Astronomy and Anatomy comes from Descriptive scientific methods. Descriptive research describes the nature of physical phenomena. The purpose of research in these areas is very often simply to describe. But very often, descriptive investigations lead to new questions that can be answered with experimental and correlational methods. The initial research concerning the cardiovascular system by William Harvey was descriptive in nature. However, once the anatomy of the circulatory system had been described, questions arose concerning the circulation of blood through the vessels. Such questions lead to research that correlated anatomical structures with blood flow and experiments based on models of the cardiovascular system. Correlational inquiry involve investigations focusing on relationships among observed variables. The evidence that cigarette smoking is linked to lung cancer is derived from Correlational research. It would be unethical to actually do an experiment on humans!

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Applying the Research

Scientific inquiry is a complex concept possessing many nuances and facets. Because of this, teachers often become confused about exactly what it means to teach and do scientific inquiry. But no matter what method of inquiry is being employed there are always three basic parts to any scientific investigation: a question, a procedure and a conclusion.

The NSES Content Standards for Science as Inquiry suggests the following fundamental abilities necessary for elementary students to do Scientific Inquiry:

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations.

The basic components of these recommendations imply that all scientific investigations begin with a question, followed by an investigation designed to answer the question, that ultimately develops data that can be analyzed to develop an evidence based conclusion.

In the late 1960s and early 1970s, researchers developed a tool for determining the level of inquiry promoted by a particular activity. Known as Herron's Scale, the assessment tool is based on a very simple principle: How much is "given" to the student by the teacher or activity? Using this question as a framework, Herron's Scale describes four levels of inquiry:

Level 1. Exploration

The *problem, procedure,* and correct *interpretation* are given directly or are immediately obvious. During these activities, students are give the question and instructions about how to go about answering the question. They are already familiar with the concepts being presented and they already know the answer to the question being asked. This type of activity involves confirmation of a principle through an activity in which the results are known in advance. For young children, this level of Inquiry is necessary for them to become familiar with what a good testable question looks like, how to safely design a procedure to answer the question, and how to collect and analyze data to form an evidence based conclusion. This level of Inquiry if often employed at the beginning of a new unit. They can serve as an advanced organizer for the learning to come and allow teachers to taps students' prior knowledge and understanding of the concepts. Exploration levels often create experiences that cause students to become more curious and ask more questions!

Level 2. Direct Inquiry

The *problem* and *procedure* are given directly, but the students are left to reach their own conclusions. Students are often asked to make predictions about what they believe will be the outcome of the investigation. In this type of activity, students investigate a problem presented by the teacher using a prescribed procedure that is provided by the teacher. Here they now have the opportunity to develop their own conclusions by analyzing the data and coming up with their own evidence-based conclusions.

Level 3. Guided Inquiry

The *research problem* or *question*, is provided, but students are left to devise their own methods and solutions. During this level of inquiry, students have the opportunity to apply their analytical skills to support their own evidence-based conclusions to the question being investigated. Guided inquiry provides opportunities for students to take more responsibility during the investigation. Students may have choices of methods, materials, data organization and analysis, and conclusions.

Level 4. Open-ended Inquiry

Problems as well as methods and solutions are left open at this level of Inquiry. The goal is for students to take full responsibility for all aspects of the investigation. These activities involves students in formulating their own research questions, developing procedures to answer their research questions, collecting and analyzing data, and using evidence to reach their own conclusions.

Conclusion

Obviously, the four levels Inquiry are hierarchical. In other words, students cannot be expected to successfully complete a Guided activity without plenty of experience with Exploration and Directed Inquiry activities. Furthermore, although it may be desirable for elementary students to participate in some Guided, and Open-ended investigations , it is not meant to imply that the ultimate goal is to make all inquiry activities Open-ended investigations. Rather, teachers should strive for a mix of inquiry levels appropriate to the abilities of their students. However, providing students only with activities at Exploration levels denies them the opportunity to develop and practice important inquiry skills and gives them an incomplete view of how science is done. It is only with experience with all of these levels and methods of Scientific Inquiry that our students will achieve the ultimate goal of becoming "Scientifically Literate"!

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