Essential Features of Inquiry

Essential Feature 1: Learners are engaged by scientifically oriented questions.

Scientifically oriented questions center on objects, organisms, and events in the natural world; they connect to the science concepts described in the content standards. They are questions that lend themselves to empirical investigation and lead to gathering and using data to develop explanations for scientific phenomena. Scientists recognize two primary kinds of scientific questions. Existence questions probe origins and include many "why" questions. Why do objects fall towards the earth? Why do some rocks contain crystals? Why do humans have chambered hearts? Many "why" questions cannot be addressed by science. There are also causal/functional questions, which probe mechanisms and include most of the "how" questions. How does sunlight help plants to grow? How are crystals formed?

Students often ask "why" questions. In the context of school science, many of these questions can be changed into "how" questions and thus lend themselves to scientific inquiry. Such change narrows and sharpens the inquiry and contributes to its being scientific.

In the classroom, a question robust and fruitful enough to drive an inquiry generates a "need to know" in students, stimulating additional questions of "how" and "why" a phenomenon occurs. The initial question may originate from the learner, the teacher, the instructional materials, the Web, some other source, or some combination. The teacher plays a critical role in guiding the identification of questions, particularly when they come from students. Fruitful inquiries evolve from questions that are meaningful and relevant to students, but they also must be able to be answered by students' observations and scientific knowledge they obtain from reliable sources. The knowledge and procedures students use to answer the questions must be accessible and manageable, as well as appropriate to the students' developmental level. Skillful teachers help students focus their questions so that they can experience both interesting and productive investigations.

Essential Feature 2: Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

As the Standards note, science distinguishes itself from other ways of knowing through use of empirical evidence as the basis for explanations about how the natural world works. Scientists concentrate on getting accurate data from observations of phenomena. They obtain evidence from observations and measurements taken in natural settings such as oceans, or in contrived settings such as laboratories. They use their senses, instruments such as telescopes to enhance their senses, or instruments that measure characteristics that humans cannot sense, such as magnetic fields. In some instances, scientists can control conditions to obtain their evidence; in other instances, they cannot control the conditions or control would distort the phenomena, so they gather data over a wide range of naturally occurring conditions and over a long enough period of time so that they can infer what the influence of different factors might be. The accuracy of the evidence gathered is verified by checking measurements, repeating the observations, or gathering different kinds of data related to the same phenomenon. The evidence is subject to questioning and further investigation.

The above paragraph explains what counts as evidence in science. In their classroom inquiries, students use evidence to develop explanations for scientific phenomena. They observe plants, animals, and rocks, and carefully describe their characteristics. They take measurements of temperature, distances, and time, and carefully record them. They observe chemical reactions and moon phases and chart their progress. Or they obtain evidence from their teacher, instructional materials, the Web, or elsewhere, to "fuel" their inquiries. As the Standards note, "explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific."

Essential Feature 3: Learners formulate explanations from evidence to address scientifically oriented questions.

Although similar to the previous feature, this aspect of inquiry emphasizes the path from evidence to explanation rather than the criteria for and characteristics

of the evidence. Scientific explanations are based on reason. They provide causes for effects and establish relationships based on evidence and logical argument. They must be consistent with experimental and observational evidence about nature. They respect rules of evidence, are open to criticism, and require the use of various cognitive processes generally associated with science -for example, classification, analysis, inference, and prediction, and general processes such as critical reasoning and logic. Explanations are ways to learn about what is unfamiliar by relating what is observed to what is already known. So, explanations go beyond current knowledge and propose some new understanding. For science, this means building upon the existing knowledge base. For students, this means building new ideas upon their current understandings. In both cases, the result is proposed new knowledge. For example, students may use observational and other evidence to propose an explanation for the phases of the moon; for why plants die under certain conditions and thrive in others; and for the relationship of diet to health.

Essential Feature 4: Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

Evaluation, and possible elimination or revision of explanations, is one feature that distinguishes scientific from other forms of inquiry and subsequent explanations. One can ask questions such as: Does the evidence support the proposed explanation? Does the explanation adequately answer the questions? Are there any apparent biases or flaws in the reasoning connecting evidence and explanation? Can other reasonable explanations be derived from the evidence?

- To use inquiry to answer a question, you have to become good at knowing what you don't know. I would argue that that's exactly the opposite of what happens in schools. Classrooms focus on what you do know (or are supposed to know) and leave you unprepared to deal with the things you don't know.

(Source: National Science Foundation. 1999. Inquiry: Thoughts, Views, und StrMegies for the K-5 Classroom. Foundations, Volume 2. Arlington, VA: Division of Elementary, Secondary, and Information Education, National Science Foundation, p. lO9)

- Inquiry is a content different from other content. It's not something to be studied for a short time and then left behind. Inquiry has a meta-content character that demands its presence while all the other content is being learned.

(Source: Wheeler, G.F 2000. The Three Faces of Inquiry. Inquiring into Inquiry Learning and Teaching in Science. Ed: Minstrell, 1. and E.H. van Zee. Washington, D.C.: American Association for the Advancement of Science (AAAS), p. 18)

- To implement inquiry in the classroom, we see three crucial ingredients: (1) teachers must understand precisely what scientific inquiry is; (2) they must have sufficient understanding of the structure of the discipline itself; and (3) they must become skilled in inquiry teaching techniques.

(Source: National Science Foundation. 1999. Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom. Foundations, Volume 2. Arlington, VA: Division of Elementary, Secondary, and Information Education, National Science Foundation, p. 48)

- Inquiry science requires student discussion with others working cooperatively and sharing ideas. In addition to these being important skills to learn, dialogue and socially gathered and shared information is a powerful means toward building individual conceptual understanding.

(Source: Bybee, R.w. 2000. Teaching Science as Inquiry. Inquiring into Inquiry Learning and Teaching in Science. Ed: Minstrell, J. and E.H. van Zee. Washington, D.C.: American Association for the Advancement of Science (AAAS), p. 30)

Essential Feature 5: Learners communicate and justify their proposed explanations. Scientists communicate their explanations in such a way that their results can be reproduced.

This requires clear articulation of the question, procedures, evidence, proposed explanation, and review of alternative explanations. It provides for further skeptical review and the opportunity for other scientists to use the explanation in work on new questions. Having students share their explanations provides others the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations. Sharing explanations can bring into question or fortify the connections students have made among the evidence, existing scientific knowledge, and their proposed explanations. As a result, students can resolve contradictions and solidify an empirically based argument.

Does inquiry always look the same? Hopefully not. Think about the variations of classroom inquiry along a continuum. Sometimes the amount of self-direction by learners is high, at other times the amount of direction from the teacher is high.

Inquiry Is Content The *National Science Education Standards* (NRC, 1996) challenge us to consider three perspectives of inquiry: the teaching strategies that support student inquiry, the abilities of inquiry, and the understandings of inquiry. This is a far cry from the simplistic "processes of science" that characterized these discussions years ago. In fact, the authors of the standards indicate that the abilities and understandings of inquiry are actually essential components of the science content in the K-12 science curriculum. Many state standards documents support this position also, although not always as explicitly as the national standards.

Next read and consider the following excerpts from the NSES content standards describing what all students should be able to do and understand with respect to scientific inquiry upon finishing eighth grade and upon completing their K-12 science education.

By the end of eighth grade, all students should have developed the following abilities of scientific inquiry:

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Use mathematics in all aspects of scientific inquiry.

By the end of high school, all students should have developed the following abilities of scientific inquiry:

- Asking and identifying questions and concepts to guide scientific investigations.
- Designing and conducting scientific investigations.
- Using appropriate technology and mathematics to enhance investigations.
- Formulating and revising explanations and models.
- Analyzing alternative explanations and models.
- Accurately and effectively communicating results and responding appropriately to critical comments.
- Generating additional testable questions.