8 Essentials of Inquiry-Based Science, K-8

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EDUCATION

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Introduction

Inquiry-Based Science and the Inquiry-Based Classroom

DEFINING INQUIRY-BASED SCIENCE

Professional organizations and National Standards projects point to the importance of inquiry as the process through which students acquire knowledge and develop an understanding of and appreciation for the discipline of science.

In *Science for All Americans,* the AAAS recommends that "all students leave school with an awareness of what the scientific endeavor is and how it relates to their culture and their lives" (AAAS, 1990).

Inquiry is defined by the National Science Education Standards (National Research Council, 1996) as:

> the diverse ways that scientists study the natural world and propose explanations based on the evidence derived from their work and as the activities used by students to formulate an understanding of the work that scientists do. As a multifaceted activity-inquiry involves
>
> making observations
>
> posing questions
>
> accessing and using relevant information
>
> planning and carrying out data rich investigations
>
> using tools and technology to collect, analyze, and interpret data
>
> proposing answers, explanations, and predictions, and
>
> communicating findings

> The inquiry process fosters the use of critical thinking as well as logic and reasoning skills. (National Research Council, 1996, p. 23).

It is not enough to know science in order to teach science effectively. We know that pedagogical content knowledge is different from knowledge of general teaching methods, and that both are important for understanding how effective learning occurs in the disciplines.

> Expert teachers have a firm understanding of their respective disciplines, knowledge of the conceptual barriers that students face in learning about the discipline, and knowledge of effective strategies for working with students. Teachers' knowledge of their disciplines provides a cognitive roadmap to guide their assignments to students, to gauge student progress, and to support the questions students ask. The teachers focus on understanding rather than memorization and routine procedures to follow, and they engage student in activities that help students reflect on their own learning and understanding. (National Research Council, 2000, p. 188)

Musial and Hammerman (1992) developed a model for teaching thinking in science using the National Standards and philosophical beliefs about teaching and learning, which they applied to action research with hundreds of inservice teachers throughout the 1990s. Their work led to greater clarity of what it means to teach for understanding and to insights that support inquiry as a process for learning.

Inquiry as a Process for Learning

Learning is the dynamic process of shaping and reshaping thoughts based on new knowledge and experiences. It is the creative, ongoing synthesis of observations, reflections, and information about the physical and social worlds. The process of inquiry defines the context and processes that enable the knower to craft understanding. Inquiry is the careful, ongoing questioning of our understandings about the world around us; it is a dynamic, creative endeavor filled with wonder and surprise. These components of inquiry relate to the very heart of naturalistic knowing.

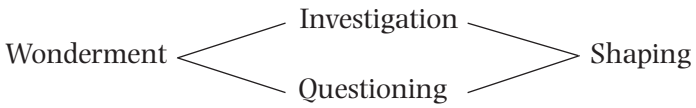
Exploring one's environment, asking theoretical and operational questions, making observations, developing hypotheses, engaging in experimentation and investigation, collecting and analyzing data, drawing

conclusions, making inferences, and formulating new questions are some of the exciting processes that are practiced through inquiry-based science. Inquiry is the art of investigating questions, formulating interim answers, and, perhaps most important, critiquing potential alternative answers. Science as inquiry, then, is a social and thoughtful activity requiring much more than the practice of skills or the completion of a set of steps leading to the "right answer."

Teaching science through inquiry requires some knowledge of the ways that scientists develop questions, engage in research, and create their own frames of thought. Philosophers contend that inquiry has a bipolar character: it is anchored by two seemingly opposing forces. These are: (1) The inquiring mind is open and free. Inquiry, like the mind's nature, includes a dimension that makes us question all that is already known and understood, yet the inquiring mind has a quality of undoing and messing up the orderliness of what we know and understand. We innately have a desire to question our understanding of ideas and concepts, and experience a sense of wonder about what we don't know. (2) Inquiry is also anchored in a second dimension: the desire to shape and complete an understanding or idea. Inquiry is driven by a desire to create patterns that explain what is known. As such, there is a dimension of orderliness, structure, and finality to inquiry. This dimension of inquiry brings a sense of closure to questions, yet is challenged by the counter-dimension of wonderment.

Inquiry bridges these dualistic dimensions through the investigative process. The scientist harnesses wonderment by asking questions that lend themselves to investigation. The dimension of investigation is what connects the scientist's drive to wonder about the world to the scientist's need to shape answers and define concepts.

Dimensions to Inquiry:



Inquiry, then, is a process of questioning within a context of wonderment, investigation, and shaping of tentative conclusions. Inquiry is the unending process of questioning and requestioning personalized understandings of the world around us.

How does this view of inquiry translate into the classroom? If teachers organize instructional experiences according to these different dimensions of inquiry, students will be more motivated and better able to develop naturalistic thinking frames.

Instruction that is patterned according to the dimensions of inquiry will:

- be rich with opportunities for students to experience and explore the world
- offer time and opportunity for students to wonder and ask questions
- permit authentic investigations wherein students develop questions; make observations; collect, record, graph, and analyze data; make sense of data, and ask new questions related to their own experiences or phenomena that affect their lives
- allow students to synthesize information, describe or create patterns, and apply their understanding to new contexts

Through the process of sharing ideas and information, new ideas and questions emerge that energize and perpetuate the cycle of learning.

TEACHING THINKING SKILLS THROUGH INQUIRY

Using an inquiry approach to instruction provides a means for addressing process and thinking skills. The nature of inquiry is rooted in the practice of using process skills and thinking strategies. Throughout all phases of inquiry, the process and thinking skills inform and assist the learner. An inquiry approach provides a natural context that enhances the acquisition of both skills and concepts. The process skills of science should be made explicit throughout the three dimensions of inquiry-based instruction. In the beginning, teachers must mediate the use of skills, redirect processes and thinking as needed, and assist students in shaping their understanding and reflecting on their skill development. The skill names should become familiar to students so that they use these words when they explain their work, reflect on what they did, and communicate findings. The metacognitive process aids in the shaping of concepts for understanding and the development of skills.

TEACHING SCIENTIFIC HABITS OF MIND THROUGH INQUIRY

Another important component of science consists of a set of dispositions or habits of mind that underlie and characterize the working scientist. Scientists seek truth about the universe by being involved in laboratory or field investigations or experimentation. Scientific behaviors that exemplify the attitudes and beliefs of scientists can be modeled by teachers and practiced by students through inquiry-based science. Dispositions such as curiosity, cooperation, honesty and integrity, open-mindedness, respect for life,

willingness to suspend judgment, willingness to modify explanations, and demonstration of a respect for evidence are some examples of the habits of mind that students can practice through inquiry-based science.

Through laboratory or field investigations, students can practice safety, accuracy, good laboratory technique, systematization and organization of data, persistence, cooperation, honesty, effective communication, analysis of strategies, and replication of work. When students are able to perform in ways that scientists work, they have the best chance to develop the habits of mind that are so highly regarded by those in the field of science and in the society, in general.

Guiding and Facilitating Learning Through Inquiry

Learning in the context of inquiry requires the teacher to organize instruction according to the dimensions of inquiry. The National Science Education Standards identify five ways of guiding and facilitating learning in the context of inquiry. The standards state that teachers of science should:

- focus and support inquiries while interacting with students
- orchestrate discourse among students about scientific ideas
- challenge students to accept and share responsibility for their own learning
- recognize and respond to student diversity and encourage all students to participate fully in science learning
- encourage and model the skills of science inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science

SOURCE: Reprinted with permission from National Research Council, *National Science Education Standards* (Washington, DC: National Academies Press, 1996, p.32).

Focus and support inquiries: Teachers can guide, focus, challenge, and encourage students at all levels of learning. Successful teachers are skilled observers. They match their actions to the needs of students, while deciding how and when to guide, when to challenge students, and when to provide information, tools, and resources. Effective teachers mediate the learning process by continually making decisions that help students make sense of their experiences through explanations, clarifications, examinations, and assessments of their work.

Orchestrate discourse: Oral and written discourse that focuses the attention of students on how they know what they know and how their knowledge

connects to larger ideas, other domains, and the world beyond the classroom is an important part of the shaping dimension of inquiry. Teachers can directly support and guide discourse in two ways: (1) they can require students to keep accurate records of their work, and (2) they can promote different forms of communication, such as verbal, written, pictorial, graphic, electronic, or mathematical. Using a collaborative group structure, teachers encourage interdependency. Here, the teacher's role is to encourage broad participation, guide discussion, help make connections, and lead students to recognize the value of evidence and argument in an atmosphere of respect and support.

Challenge students to accept and share responsibility for their own learning: Teachers must create opportunities for students to take responsibility for their work in situations when they work individually and when they work in a group. Students should be accountable for both the processes they use during inquiry and their findings.

Teacher behaviors that encourage the development of responsibility are:

- giving students active roles in the design and implementation of investigations
- providing ways for students to be able to share their work with others
- providing tools through which students can assess the quality of their own work

Recognize and respond to diversity: Teachers need to make accommodations to provide for the diverse needs of students in their classrooms. All students should have access to equipment and be actively involved in the learning process. Some ways that teachers can monitor the learning process are by encouraging all students to ask questions and suggest answers by involving students in active learning, by modifying equipment and assignments to meet individual needs, and by encouraging diversity in the ways students communicate the results of their work.

Encourage and model the skills of scientific inquiry: By exhibiting enthusiasm and interest in the inquiry process and speaking of the beauty of scientific understanding, teachers can instill in their students similar attitudes and values. The ability of teachers to model skills of inquiry requires that they develop a knowledge of and comfort level with the content of science and with the inquiry-based teaching and learning process.

Teachers must have the opportunity to develop their own understandings and appreciation of inquiry through ongoing professional development including opportunities to work collaboratively with colleagues to share ideas, to plan instruction, to assess the effectiveness of their work, and to modify their approaches. As teachers practice the skills of inquiry through

their own professional growth, they will be even more capable of modeling them in the classroom.

Implications for the Classroom

Inquiry might be thought of as the operational heart of the nature of science. It is the process that drives the scientist and determines how one interprets the world. It is through this process that concepts and principles are linked to other areas of science; to other disciplines; to technology; to the lives of students; to the community, the state, and the nation; and to the world.

The Eight Essentials of inquiry-based science address and provide further insight into each of the five ways of guiding and facilitating learning in the context of inquiry. The models and examples in the text focus on interactive instructional strategies similar to those that define the inquiry process.

Eight Essentials for Inquiry-Based Science, K-8 provides unit and lesson models that include experiences through which students can discuss their work and engage in discourse through thought-provoking questions for processing information, elaborating on findings, and creating meaning. Formative assessment tools can be used by teachers and students to provide immediate feedback, monitor learning, and develop student responsibility for learning. Opportunities for relearning or extended learning respond to diversity and allow all students to participate fully. In an atmosphere of inquiry, it is important that teachers model the skills of science inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.

If curriculum and instruction are organized around the dimensions of inquiry and if teachers develop and practice the five qualities noted in the Standards, students will be more likely to develop naturalistic ways of knowing. The implementation of this vision requires that teachers be given necessary resources, including time, materials, professional development, support, and flexibility of scheduling to enable inquiry-based teaching to occur.

Thought and Discussion

1. How does the process of inquiry relate to the natural ways that humans seek knowledge and expand their learning?
2. What are some of the barriers that impede the development of naturalistic ways of knowing in the classroom? Identify some causes for the barriers. What are some ways to overcome the barriers?
3. Design an action plan for overcoming one or more of the barriers. What are the implications for professional development related to overcoming the barriers to inquiry-based instruction?

Using the Eight Essentials as Criteria for Assessing Curriculum and Informing Instruction

The Eight Essentials provide a set of criteria for assessing high quality curricular materials necessary for implementing an inquiry-based approach to learning. As one travels through the Eight Essentials, thought and consideration might be given to curricular materials and the ways they address each Essential.

The alignment form in Figure I.1 may be used by the reader to analyze curriculum materials for the presence or absence of the Eight Essentials and comment on how they can be incorporated.

Figure I.1 Alignment of Instructional Materials With Eight Essentials

Title: _____

Inquiry-Based Science . . .	*Way(s) Addressed in the Materials*	*Comments, Recommendations, & Suggestions*
1. Develops an Understanding of Basic Concepts		
2. Develops Process & Thinking Skills		
3. Actively Engages Students in a Learning Cycle		
4. Builds Understanding of Ways That Science Is Linked to Technology & Society		
5. Provides Experience Necessary to Support & Develop or Modify Interpretations of the World		
6. Enhances Reading & Writing		
7. Allows for a Diversity of Strategies for Learning		
8. Allows for a Variety of Ways for Students to Show What They Know and Are Able to Do.		

Traditional Versus Inquiry-Based Classrooms

The behaviors of the teacher, the role of student, and the nature of the student work are three categories of beliefs and practices that define the classroom climate. In Figure I.2, indicators that characterize the traditional classroom and the inquiry-based classroom are shown for each of the three categories: Behaviors of the Teacher, Role of the Student, and Nature of the Student Work. The inventory provides a tool for identifying the degree to which each indicator relates to the inquiry-based classroom and provides a basis for discussion of beliefs and practices.

Activity

Place an X on the number that best represents the current position of your classroom with relation to each of the indicators.

Use the findings to identify one or more professional development goals that would take you closer to providing an inquiry-based classroom for your students. As you use this book, you can also return to this chart to assess development of inquiry in your teaching practice.