

In Praise of Questions: Elevating the Role of Questions for Inquiry in Secondary School Science

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In science classrooms, teachers and students ask questions for many reasons. Science teachers commonly ask questions to review content with students or to manage classroom interactions. Students' questions are often attempts to make sense of science content or are organizational in nature, often related to issues such as the date for the quiz or the specific content on the test. Rarely in secondary science classrooms are questions asked about the natural world, but such questions are the basis of *doing* science.

Question posing, which consists of question generation and evaluation, is essential to the conduct of scientific inquiry. Usually scientific investigations begin with a question generated from experiences with phenomena. Helping secondary students identify and construct questions that promote scientific inquiry is important and explicitly called for in the National Science Education Standards (NRC 1996). Moreover, identifying and constructing questions help students recognize the central role of questions in science and help students become more effective inquirers. So the initial impetus for question posing is to provide learning environments where students can interact with phenomena.

If scientific inquiry is to be part of the focus in secondary school science, teachers must develop learning situations in which question posing is essential and they must help students learn how to pose scientifically oriented questions. In focusing on questions, teachers and students both play an important role in the classroom. Teachers provide rich inquiry-based opportunities for students, while students engage in exploring the phenomena they encounter in class.

Creating a Learning Environment for Question Posing

Use a Question Focus Rather Than an Answer Focus

Much secondary school science focuses on the products of scientific inquiry. This focus obscures the importance of questions in inquiry, the importance of phenomena to build science knowledge, and the role that theory plays in the questions that can be asked. In this context, science knowledge or phenomena are presented at the beginning of a unit or lesson, which gives students few opportunities to ask questions. Students need opportunities to pose questions that help them develop an understanding of phenomena in nature that includes facts, models, laws, and theories.

In adopting a question focus, teachers can use introductory experiences to elicit questions from students. For instance, before discussing or lecturing about chemical reactions, a teacher could have students complete the activity described in Figure 9.1. This experience encourages students to propose a range of questions that

FIGURE 9.1. QUESTION-GENERATING ACTIVITY

Overarching Question: What drives chemical reactions?

Measure out 7 grams of citric acid and 10 grams of sodium bicarbonate and then mix these compounds in a plastic bag that can be closed. When the compounds are mixed, put a thermometer into the mixture and record the temperature. Measure out 10 ml of water into a small container and make sure the outside of the container is dry. Carefully place the container with water in the plastic bag without spilling water. Close the bag around the thermometer, and then tip over the container of water in the bag and observe any changes that take place. Record any questions that come to you during your observations. After 10 minutes, clean up as directed by the teacher.

orient them to the topic of chemical reactions. Other types of initial experiences include a demonstration, a reading of a scientific study, or close observations of the community outside of school or of phenomena inside the classroom.

Elicit Questions From Experiences

In science, questions to be investigated come from scientists' ongoing involvement with phenomena and theories about which they have both interest and experience. Similarly, as students become involved with phenomena, they ask questions related to their experience. The example in Figure 9.1 can illustrate this point. When first confronted with the phenomenon, students can write questions that come to them as they observe the reaction, such as, "Why was the mixture boiling?" and "How did the ice get in the container?" These questions originate from the prior experiences of the students, and their tentative answers may not align with the scientifically accepted explanation. The orientation toward asking questions allows students to reveal their level of understanding about the topic and encourages them to generate an interest in the topic. However, proposing questions is only the beginning. Students need questions they can investigate, which leads us to the next point...

Develop Questions That Can Be Investigated

Sometimes initial questions cannot be answered directly because they are too broad to investigate (e.g., "How does the human brain work?"). Broad questions, however, can provide the starting point for questions more amenable to investigation. In this example, understanding the mechanisms associated with the brain can result in a focus on brain activity, learning, speaking, or memory. In addressing these questions, scientists often work with model organisms (such as mice and roundworms) to answer specific questions.

Additionally, some questions can be answered with a quick Web search or by examining reference material. Such narrow questions often have a predetermined answer that may not be appropriate for students to investigate. Finally, some questions are not related to science. Questions such as, "Which paper towel is the best?" or "What color is best to wear to the prom?" do not address phenomena in nature (see Chapter 1 for a discussion on this point). Ultimately, questions in science need to be focused, involve the collection of data, and be related to nature.

Questions to Ask in the Science Classroom

Questions help students negotiate the tricky terrain between experiencing the phenomenon and the final explanation. Broadly, questions in science are associated with looking for patterns in nature and developing and using theories and models that explain phenomena in nature. In this section, the focus is on questions related to experiences of phenomena. Using different types of questions contributes to a student's understanding of a concept. *Definition questions* help students identify events that are well accepted in the science community. *Experimental questions* allow students to explore how variables are linked to one another. *Observational questions* give students a chance to explore patterns that exist in nature. Collectively, these types of questions are different avenues for exploring phenomena, leading to different conclusions (see Table 9.1).

Definition Questions

Definition questions correspond to an investigational process, resulting in answers that are accepted in the scientific community and that are usually shared prior to an investigation. The questions provided in Table 9.1 correspond to chemistry and result in answers that are reported in textbooks or other curricular materials. It might appear that definition questions should not be pursued by students because they can simply confirm known ideas. These questions should be investigated, though, because they can allow students to construct their own knowledge about the topic. For the science teacher, the challenge of getting students to generate these questions is (a) to refrain from providing the answer first and (b) to provide an event that can serve as a starting point for additional investigations.

These types of questions can lead to different questions that can be pursued in the science classroom. For example, when students pursue the question “Is water necessary for the reaction to occur?” they can expand on their findings to identify additional questions exploring concentration, composition, or reaction rates. These types of questions can be experimental or observational in nature. Developing concept maps or word webs related to their conclusions will help students create different questions. More importantly, when students generate their own questions, they are often more interested in answering them, and their practice is more consistent with the practice of science.

TABLE 9.1. TYPES OF QUESTIONS AND METHODS OF INQUIRY

Question Type	Sample Questions	Method of Inquiry	Forms of Appropriate Answers
Definition	<p>What is the gaseous product?</p> <p>What type of reaction is this?</p>	Observing a phenomenon and relating it to an idea in science	Definitions
Experimental	<p>How does changing the concentration of one chemical impact the reaction rate?</p> <p>What temperature ensures that the reaction will be completed in the least amount of time?</p>	Exploring the empirical relationship between the dependent and independent variable	Cause and effect relationships
Observational	<p>How is the reaction similar to the reaction of an instantaneous ice pack?</p> <p>What would have happened if we used a solvent other than water?</p>	Using direct and instrumental observation of phenomena to identify possible relationships	Correlations and classifications

Experimental Questions

Experimental questions correspond to strategic observations of events and often include specific variables. These variables are defined as the independent variable, which is manipulated by the experimenter, and the dependent variable, which responds to the independent variable. These types of experiments are a result of the refinement of science over time and reflect the manipulation of nature to obtain better findings (Carnap 1995). It should also be noted that the findings from these types of questions rarely overturn long-standing or accepted scientific theories, but they contribute to the ongoing development of the model or theory.

Experimental questions help students develop supported explanations, which emerge from designed experiments. Glickstein (2002) provided a good example of an experimental question that can have competing explanations. When Glickstein was in junior high school, his science teacher placed a burning candle under a jar. The candle was standing in a tray of water, and as the candle went out, water rushed in and seemed to occupy the space in the jar. His teacher told the class that the space occupied by the water was 20% of the total space under the jar, thereby confirming that the candle went out because as it burned it used all the oxygen and the water rushed in to take up the space formerly occupied by the oxygen. As a consequence of this demonstration, Glickstein investigated other questions that challenged this conclusion and ultimately determined that the teacher's explanation was incorrect. For instance, adding more candles (independent variable) resulted in more water (dependent variable) filling the jar, not just 20% of the space. In the end, the explanation offered by Glickstein aligned with theories about heat, pressure, and the movement of particles.

Observational Questions

Questions that don't manipulate nature and use observations as sources of information are observational questions. These questions often come about when a student notices an anomaly or irregularity in the natural world. Observations generate ideas about the phenomenon and lead to a question that requires additional observations. Once developed, observational questions require as many observations as possible. When enough data are collected to allow for a conclusion that describes the event, the conclusion will often describe a pattern or a connection. More importantly, the patterns or relationships that emerge come from an "onlooker" as opposed to a person manipulating the natural world (Carnap 1995). These types of investigations are limited, as conducting all the observations necessary to make a robust conclusion is impossible.

Observational questions are important in describing regularities in nature and can lead to additional investigations. Often, observational questions can be the precursor to experimental questions. Take, for instance, the observations often made by students trying to understand the different phases of matter. Such an investigation can begin with ice and then the ice changing to water and then water vapor. In watching these changes, students may conclude that water can occur in different phases and elect to watch other materials change phase. After watching different substances change phase, students may conclude that matter can exist in a solid, liquid, or gas state. But this is just the beginning. With further exploration, students may raise questions about optimal points in which matter changes phase, which may result in an experiment that pursues descriptions of various phase changes.

Questions in the Larger Context

In science, questions are essential. For instance, those engaged in science ask questions prior to engaging in an exploration. As data are collected, questions are asked about the data, the phenomena, and the process by which data are collected. When data are analyzed, there are questions about the process used to examine the data, the method used to represent the data, the findings that are important to the study, and the means used to present information to the recipients. There are also questions about how the study fits with the proposed theory, as investigations support the development of theories. Because science is about questions, science in the secondary classroom should also focus on questions.

When the teacher begins a process of scientific inquiry, his or her first question is not the question that becomes the focus of the inquiry, but an invitation to inquiry. If students are to develop a richer understanding of inquiry, then the teacher needs to assist them in developing questions that can be addressed using scientific inquiry. The strategies for generating questions outlined in this chapter can be used in all science courses taught in secondary school. Once students have generated different questions, teachers can revisit Table 9.1 and ask, “What type of question do we have and what does that mean about the methods we might use to answer this question?” The answer to this question will set students on the path to different inquiries.

There are challenges associated with creating learning environments in which secondary students are encouraged to ask questions about phenomena. Question posing is a skill that requires continual use and refinement, and it should remain a focus for all levels of education. If scientific inquiry is to be part of

the focus in secondary school, students must be taught about the types of questions that serve to guide scientific inquiry, how these questions can be developed, and how they are interrelated to one another. In short, teachers need to develop learning situations that allow students to ask different types of questions, just as they do in science.