What is so Important about Asking Questions?

Michael P. Clough, Editor

Effective teaching promotes a highly interactive environment. Creating and maintaining that kind of atmosphere is very complex. While interesting and developmentally appropriate content, tasks, activities and materials spark students' curiosity and set a stage for learning, the actions of teachers orchestrate the necessary interaction that results in desired conceptual understanding. My editorial in the last issue of *ISTJ* stressed the teacher's crucial role in helping students learn through inquiry. Here I will focus on one aspect of that role – questioning.

To begin, intellectually engaging questions help stimulate and focus students' thinking while helping the teacher understand their thinking. Weiss et al. (2003) write that "this kind of effective questioning is relatively rare in [United States] mathematics and science classes." Yet, asking higher level questions has been shown to facilitate learning (Redfield & Rousseau, 1981; McGlathery, 1978) Extended-answer questions are phrased to avoid "yes/no" responses and begin with words such as "how" or "what" rather than "can," "did," or "will." The expectations created by these subtle changes in phrasing of questions raise the intellectual climate that permeates a classroom and require students to show more of their thinking, thus providing important diagnostic information to the teacher that ought to guide future instructional decisions.

Just as important, initiating questions at an appropriate level of difficulty and then scaffolding to more challenging questions is necessary to avoid intimidating students and stifling interaction. Numerous classification systems for questions exist, but most of these are based on a taxonomy of cognitive objectives introduced by Bloom, *et al.* (1956). More recently Penick *et al*. (1996) suggested a questioning strategy particularly suited to science teaching in that it emphasizes students' prior experiences and using these experiences to build relationships, apply knowledge, and create explanations (Figure 1).

Figure 1: HRASE Questioning Hierarchy Suggested by Penick, Crow and Bonnstetter (1996)

History – questions that relate to students' experience:
- What did you do . . . ?
- What happened when you . . . ?
- What happened next . . . ?

Relationships – questions that engage students in comparing ideas, activities, data, etc.:
- How does this compare to . . . ?
- What else does this relate to . . . ?
- What do all these procedures have in common?

Application – questions that require students to use knowledge in new contexts:
- How could this idea be used to design . . . ?
- What recognized safety issues could this solution solve?
- What evidence do we have that supports . . . ?

Speculation – questions that require thinking beyond given information:
- What would happen if you changed . . . ?
- What might the next appropriate step be?
- What potential problems may result from . . . ?

Explanation – questions that get at underlying reasons, processes, and mechanisms:
- How does that work?
- How can we account for . . . ?
- What justification could be provided for . . . ?

While effective questioning need not always begin in any one place nor occur in a linear sequence (Good & Brophy, 1994), attending to a question's level of difficulty and carefully scaffolding questions are critical for encouraging student participation. Asking questions that accurately diagnose students' thinking, effectively help students see the problem with their thinking, and move students towards desired conceptual understanding is challenging. These sorts of questions require teachers to deeply understand science content (Tobin & Garnett, 1988) and use students' ideas while in the act of teaching.

That effective questioning engages students and reveals their thinking is readily apparent. The role of questions in helping students make desired connections is just as important, but not so evident. However, questioning is crucial for helping students see problems with their current conceptions and build more accurate ideas. For example, consider an interaction that took place several years ago between me and one of my high school chemistry students. Several weeks prior to the dialogue I will describe, the student and his classmates had successfully completed a learning cycle sequence exploring characteristics of chemical change, including the conservation of mass (Clough & Clark, 1994a). In that activity, students improve their experimental design several times to prevent escape of the gas produced, and with each sequential improvement the mass "loss" due to gas leaking out of the system became smaller. Through this approach, students came to the conclusion that if perfect conditions existed (e.g. no substances lost/gained by the system, perfect balance, etc.) that mass would remain exactly the same as before a chemical reaction.

For several weeks afterwards, a variety of activities and discussions took place addressing typical chemistry content such as balancing chemical reactions, the mole concept, and stoichiometry – all which the student in question appeared to understand. Now, students were enthusiastically attempting to determine the products of that prior chemical reaction (Clough & Clark, 1994b) using all that they had learned during the entire year in chemistry. Several days into this activity, the student in question approached me, and the following conversation ensued:

Student: Mr. Clough, the mass of my system went down.
Me: How do you account for that?
Student: A gas was formed and gases have no mass.
Me: (*Maintaining an accepting and inquisitive appearance.*) What do you think gases consist of?
Student: Atoms.
Me: What do you know about atoms and mass?
Student: Atoms have no mass.
Me: (*Still maintaining an accepting and inquisitive appearance, but searching for a way to help the student see his misunderstanding.*) From a chemical perspective, what are you made up of?
Student: Atoms. (*The student paused with a paradoxical look on his face.*) And I have mass.

This illustrates the most complex and unpredictable portion of teaching interacting with students to better understand their thinking and help them create intended meanings. In this particular interaction (only one among many in any class) the student initiated the interaction with a statement about something he had noted in the laboratory. Rather than interpret the phenomenon for the student, I posed a question to have him elaborate on his statement. The student shot back an incorrect answer (i.e. "gases have no mass"), a misconception that is common and persistent among students (Stavey, 1990). Using non-judgmental, but encouraging non-verbal behaviors, I continued the interaction keeping in mind the need to listen intently to my student's thinking, acknowledge his ideas without judging them, and responding with questions that played off his thinking.

The irony of this interaction is that while the student was telling me that atoms have no mass, immediately behind him on the classroom wall was the periodic table of elements with the atomic masses clearly displayed – numbers this student consistently used in successfully solving stoichiometric problems, some which explicitly addressed the mass of reactants and products in the gaseous state! Quite often, our interaction with students is where we get an accurate picture of what they really think. Questioning is key for teasing out what students really think, helping them see the inadequacy of misconceptions, and piecing together a more accurate understanding.

Readers know that the *ISTJ* editors strive to ensure that all activities appearing in the journal make clear the crucial role of teacher questioning in helping students make desired connections. This reflects the overwhelming evidence that science activities alone will not result in desired understanding of science concepts. How teachers interact with students during activities makes the most significant difference in achieving desired ends. Questioning is an essential tool that effective teachers always carry with them and use for understanding students' thinking and promoting a deep and robust understanding of science.

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