Building Better Questions

Three dialogic strategies to promote students' scientific thinking

By Ronald Rinehart and Mason Kuhn

Exploring a new energy-related phenomenon in class, whether it is electrical circuits lighting up light bulbs, toy cars crashing, or even videos of great horned animals butting heads, can be exciting for students. However, even when highly engaged, students may not necessarily develop high quality scientific questions about the phenomenon. Although students are naturally curious, research suggests that higher quality science questions often do not emerge spontaneously (Chin and Kayalvizhi 2002). Teachers can support students with specific strategies to elicit questions that lead to higher quality investigations (Chin 2007). As part of a multi-year project working with teachers on a fourth-grade unit exploring energy concepts, we have adapted several strategies to use as a toolkit of dialogic instructional techniques for productively managing student discussions around building better scientific questions. These insights are drawn from a series of 13 lessons in which students engaged in phenomena explorations while constructing open-ended investigable questions aimed at knowledge transformation around concepts of energy as described in the *Next Generation Science Standards* for energy (4-PS3-1 to 4-PS3-4; NGSS Lead States 2013).

Our toolkit focuses on dialogic scaffolding techniques for *building* questions rather than merely *posing* questions. In many classroom science investigations, students spontaneously pose questions. These questions can be off-target, unmanageable, and not amenable to scientific investigation (Chin and Kayalvizhi 2002). Typical questions involve simple concepts or fail to aim at uncovering causes of phenomena. Students may also pose questions that cannot be investigated for various reasons (equipment, safety, access to experimental tools or a geographic location, etc.). A purposefully built question, on the other hand, is one that reflects the deeper aims of the inquiry process like developing a causal explanation, uncovering patterns, and making predictions.

WHY FOCUS ON QUESTIONING?

Learning to ask high-quality questions is a way for students to bridge the cognitive gap between what they currently know and what they would like to know. The formulation of high-quality questions as a creative knowledge-building practice is recognized in the *Next Generation Science Standards* (*NGSS*) as one of the eight core science and engineering practices (SEP), Asking Questions and Defining Problems. Generating, building, revising, and resolving high-quality questions are essential phases that can lead to deep knowledge-building experiences for students.

Teachers can build questions for students ahead of an investigation, but this does not provide students with an authentic science experience. The techniques described in this article help teachers move from teacher-constructed questions and teacher-centered, IRE-style discussions, toward student questions constructed through deeper dialogic forms of discussion. IRE-style discussions (Mehan 1979) focus on the teacher Initiating a question, a student Responding to the question, and the teacher Evaluating the correctness of the response. This provides students and teachers both with superficial cognitive engagement. In this article we outline three techniques that can be used individually or in unison to create a more cognitively rich and scientifically robust classroom environment focused on building scientific questions.

CLOSED VS. OPEN-ENDED QUESTIONS

Closed questions provoke a simple response from a respondent. An open-ended question is one that cannot be answered with a "yes" or "no" response, or with a static response like a memorized definition. Open-ended questions require a deeper commitment to cognitive processes like reasoning, elaborating, and explaining (Chin and Kayalvizhi 2002).

The question *Did the ram get hurt?* is focused on a surface feature of the phenomenon, two rams colliding, and does not get at the deeper content (forms of energy and energy transfer). One way to help students make their questions more open-ended is to engage in a dialogic *reflective toss* (van Zee and Minstrell 1997). In the reflective toss, the teacher identifies a key component in need of further reflection by the students and without answering it, puts the question dialogically back into the domain of the students. In this teacher-to-student interaction we see several examples of reflective tossing as a strategy to help students make their question more open-ended.

T: So, what question did you come up with after watching the video?

S1: We thought it looked dangerous!

S2: Yeah the horns are big and scary looking!

S1: So, we wanted to know if the rams get hurt? (*posed question*)

T: Okay, we have a question about the rams, but is it really about energy?

S1: No.

T: Is it an open question that needs a complex answer or a simple question with a yes or no answer?

S2: It is simple.

T: How can we make it about energy? (*reflective toss*)

S2: I am not sure. Maybe the horns have a lot of energy?

T: Yes; but I want you to think back on what you thought was scary; it wasn't the horns by themselves but you were worried about what they do with the horns. What do they do with the horns? (*reflective toss*)

S1: When they hit each other. So can it be about the energy when they hit each other?

T: Yes. So how can we make that into a scientific question? (*reflective toss*)

S2: Maybe what happens to the energy when they collide with each other? (*revised, open question*)

INVESTIGABLE QUESTIONS

For questions to be investigable, they need to fit within the affordances and constraints of the classroom (or in exceptional cases, a field trip). Posing investigable questions has been shown to be difficult for students (Chin and Kayalvizhi 2002). An investigable question is one that leads to practical investigations. A non-investigable question does not lead students to collect data or first-hand evidence that will answer the question (Harlen and Qualter 2018). This is not to say that second-hand information should not play a role in the classroom, but the focus of this article is on helping students construct questions that they can investigate and collect data on in their own educational setting.

The question *Why are some toy cars faster than others?* on its surface, would appear to be investigable by students. However, the formulation of the question does not lend itself well to controlling the myriad of variables that could be responsible for the speed of a toy car. The *NGSS* SEP for questioning at the grade 3–5 level directs teachers to help students make connections with prior knowledge as students build their own questions (NGSS Lead States 2013). In the example below the teacher avoids an IRE-style discussion by guiding students, using their own ideas and prior knowledge, toward an investigable revised question through the technique of *cognitive pumping* (Hogan and Pressley 1997).

T: What have we thought about so far, team?

S1: We noticed that some of the cars seem faster so we want to know about that.

T: Tell me what your scientific question is then.

S1: Well it's about their speed.

S2: We wanted to know why some of the cars are faster than others?

T: That is a good start for a question, but what are all the different things that you think might make one of the cars go faster or slower? (*cognitive pumping*)

S1: Maybe the size of the car?

S2: The size of the wheels?

S3: What if it is slippery or smooth? Like what if the car is on a smooth surface?

S2: The ramp is pretty smooth so maybe if we make the ramp steeper instead?

T: Good. So during our last experiment we figured out we should change how many variables at a time? (*cognitive pumping*)

S3: Just one.

T: So do we have too many variables? (*cognitive pumping*)

S1: Yes. Way too many.

S3: Okay, I think we have to pick one.

S2: Let's do the ramp and just make it more steep and less steep with the same car. (Investigable question: *Will the toy car travel faster if we increase the angle of the ramp?*)

S1: Yeah don't use the truck and the car because then that is too many things. Just the car.

CONSOLIDATION VS. EXPLORATION QUESTIONS

Consolidation questions confirm well known ideas in simple terms and are answerable with a yes or no answer or perhaps a short explanation or definition. Exploration questions seek to expand knowledge and test constructs (Watts et al. 1997). Exploration begins with a cognitive achievement, meaning that the students have already developed a certain amount of knowledge and facility with a topic and seek to expand their cognitive boundaries and go further.

In this exchange the teacher uses the technique of *focusing and zooming* to help students shift from a consolidation question that re-affirms what they already know (*Do the swinging* *balls still make a sound if we swing them faster?)* to an exploration question where they can develop a new understanding. Focusing and zooming (Chin 2007) is a responsive questioning technique where the teacher's subsequent questions are posed to help students construct new understandings or develop new ideas. In this case the students are able to develop a measurement of sound energy based on distance from the swinging balls of a Newton's Cradle.

T: Where are we at with our understanding?

S1: Well, we know that the balls have energy when they move.

S2: And some of the energy becomes sound when we swing them a normal amount.

S1: So we were wondering what happens to the sound if we change it?

T: What are you thinking of changing?

S1: The speed. Can we swing them faster?

T: Let's focus on what you want to find out. It seems like you are thinking about sound. What do you want to know about it? (*focusing and zooming*)

S2: Well, we were thinking it should be louder if we swing them faster. But it always seems to make the same clacking sound every time.

S1: Yeah but we didn't really swing it faster; it was about the same every time.

T: Let's focus on how you could figure out if it is louder. How could you tell if it was louder? (*focusing and zooming*)

S1: If it is louder, we should be able to hear it from far away.

T: Let's stay on that; would there be a way to measure how much louder it gets? (*focusing and zooming*)

S2: Yes. Remember when we measured the distance of the cars on ramps based on how many tiles on the floor they rolled over? What if we did that but just figured out how many tiles away from the cradle we could be and still hear it.

S1: Yes, but what if we try a normal one and a faster one and see what the difference is?

S2: Every tile is a foot long so maybe we can measure it based on that.

CONCLUSION

Here we have presented three question types (open questions, investigable questions, and exploration questions) that every teacher can promote as students engage in scientific inquiry, along with three dialogic techniques for helping students move from questions they initially pose toward more robust scientific questions. The process of building a scientific question is cognitively complex. Each type of question discussed here is progressively more complex and ideally students will develop skills with creating their own questions that include all three features: open-ended, investigable, and exploration oriented. This process of cognitive construction can be supported by the teacher while still providing intellectual autonomy to students by using richer forms of dialogic feedback like reflective tossing, cognitive priming, and focusing and zooming.

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