Students’ questions: fostering a culture of inquisitiveness in science classrooms

Christine Chin

Students’ questions are powerful thinking tools: they encourage meaningful learning and provide useful feedback for the teacher about students’ understanding.

When Isidore Rabi, Nobel prize-winner in physics, was asked what had helped him become a scientist, he was reported to have said:

"Every other Jewish mother in Brooklyn would ask her child after school: 'So, what did you learn in school today?' But not my mother. 'Izzy,' she would say, 'did you ask a good question today?'

The Nobel laureate maintained that asking good questions was what made him become a scientist.

The importance of students’ questions

Questioning is key to active and meaningful learning, and is the cornerstone of scientific enquiry. The formulation of a good question is also a creative act, and at the heart of what doing science is all about. Questions help us to make sense of the world, and to construct meaning from data and information. They are psychological tools for thinking as they help to explore and scaffold ideas, steer thinking in certain specific directions, and can advance students’ understanding of scientific concepts and phenomena.

Questions asked by students help them to fill recognised knowledge gaps and solve problems. They can also provide teachers with insights into students’ thinking and conceptual understanding (White and Gunstone, 1992; Watts, Gould and Alsop, 1997), their alternative frameworks and confusion about various concepts (Maskill and Pedrosa de Jess, 1997), their reasoning, and what they want to know (Elstgeest, 1985).

Reflective learners ask themselves questions that help monitor the status of their understanding and provide feedback. This helps them to redirect their use of learning strategies. Self-questioning allows an internal dialogue with oneself, driving the mind to look for patterns and connections, establishing relationships with prior knowledge and building bridges to new perceptions, as well as converting raw data into new meaning. Thus, the effectiveness of self-questioning is attributed to both its cognitive and metacognitive (thinking about the thinking process that created one’s thoughts) functions.

How does question-asking facilitate knowledge construction? Questions, particularly those asked in response to wonderment, stimulate students to generate explanations for things which puzzle them and to propose solutions to problems. These questions trigger the use of deep-thinking strategies which may not be invoked if the questions had not been asked;
Students' questions thus they play an important role in engaging students' minds more actively. Such questions can help learners initiate a process of hypothesising, predicting, thought-experimenting and explaining, thereby leading to a cascade of generative activity and helping them to acquire missing pieces of knowledge or resolve conflicts in their understanding (Chin and Brown, 2000). When students engage socially in talk and activity about shared problems or tasks, an individual's questions can also stimulate another group member to use these strategies and thinking processes. The questions embedded in the conversation of peer groups help learners co-construct knowledge.

In typical classroom settings, students are more often expected to answer questions rather than to ask them. Few students spontaneously ask high-quality thinking questions (White and Gunstone, 1992, p. 170). Tisher (1977) reported that low levels of questioning and explanation on the part of students were negatively correlated with achievement, and concluded that strategies used in the classroom and in the curriculum must require more questioning and explaining on the part of students.

Research on student-generated questions

Watts and Alsop (1995) found that students' questions were diagnostic of the state of students' thinking, revealed their unorthodox understanding of science and were indicative of the routes through which students were seeking understanding. Watts, Gould and Alsop (1997) discussed three categories of questions (consolidation, exploration and elaboration) that illuminated distinct periods in the process of conceptual change. Keys (1998) found that students' questions asked during science investigations determined the depth and breadth of the concepts to be learnt, the scientific processes to be used and the cognitive difficulty of the investigative tasks. The questions stimulated curiosity and encouraged profound thinking about relationships between questions, tests, evidence and conclusions. Maskill and Pedrosa de Jesus (1997) found that students' questions were a good source of information about each specific moment of the lesson, and provided the teacher with a great deal of information with which to organise future teaching according to students' needs. The study by Dori and Herscovitz (1999) indicated that students' question-posing capability could be used to evaluate higher-order thinking, and suggested the potential of question-posing as an evaluation tool that offers an alternative to conventional evaluation methods.

Chin, Brown and Bruce (2002) found that students' basic information (factual and procedural) questions were typical of a surface-learning approach, whereas wonderment (comprehension, prediction, anomaly detection, application and planning) questions were indicative of a deep approach. Unlike wonderment questions, which stimulated the students to hypothesise, predict, engage in thought-experiments and generate explanations, basic information questions were typically either ignored or generated little productive discussion. Problem-solving activities elicited more and a wider range of wonderment questions than teacher-directed activities, which produced mainly procedural questions.

The above review indicates that, besides providing useful information and feedback for the teacher about students' thinking, puzzlement and the status of their understanding, students' questions also play an important role in directing students' learning and guiding their construction of knowledge. Questions posed at a higher cognitive level, in particular, can promote conceptual talk that relates to important concepts, thereby leading to enhanced learning. Students need to come up with good questions to elicit interesting and productive answers (Shodell, 1995); therefore, the skill and habit of question-asking needs to be fostered in students.

Encouraging students' questions

What strategies can teachers use to encourage student questioning and to foster a 'culture of inquisitiveness' in science classrooms?

Before starting a new topic, the teacher could ask the class to think of questions about the topic. The questions could be recorded on chart paper or the board. Once the questions are listed, it is useful to go through an exercise of categorisation, asking the students how they might group and label the questions. These categories can then provide the basis for organising and structuring the lessons or any investigations for the next few days or weeks. The teacher could also show students how a broad, overarching question could give rise to several other
Students' question-posing is used to encourage student engagement and to evaluate higher-order thinking. Bruce (2002) found that students who ask questions during a surface-learning approach, such as comprehension, prediction, application and planning, are more likely to be engaged in deep learning. Unlike students who follow a more surface approach, these students are typically either ignored or given superficial answers. To encourage a deeper approach to learning, students need to be given opportunities to ask questions. Students' questions can be used to drive lessons and to develop a receptive classroom atmosphere. Students can be taught different types of questions that begin with 'Why', 'What', 'Where' and 'How'. The aim of the activity is to help students to think about the relationship between the question and the topic. Possible questions include 'What is the significance of the R, value (retention factor) that I calculated?', 'How is chromatography applicable to everyday life?' and 'What factors determine the size of the candle flame?'. Asking questions as a habit of mind whenever they encounter a problem and spontaneously ask such questions, students can begin to untangle the problem and find a solution on their own.

Students' questions can also be used to help students to define the parameters involved (e.g. 'What are the factors involved here?'), locate missing information (e.g. 'What other information do I need that is not given?'), invoke prior knowledge (e.g. 'How can I make use of what I already know about things related to this problem?'), and consider alternatives (e.g. 'What are all the things I could do?'). In this way, students can begin to think about the relationship between the question and the topic. Possible questions include 'What does the pattern of spots on the chromatogram mean?' and 'Why is the candle flame not uniform in colour?'. Subsequently, the teacher can help students to solve problems and to make them aware that different types of questions elicit different thinking processes that help build up a culture of inquisitiveness.

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For instance, comprehension questions prompt students to generate explanations for things that puzzle them; hypothetical questions let students test their suppositions; inferential questions help them to find patterns and relationships, and construct meaning from given data; while planning questions help them to think about how they will structure their search, consider the best way to organise tasks and develop a plan of action. When students generate questions for each category, this helps provoke thought and questions in categories which they might not otherwise consider. King (1994) found that giving students thought-provoking question stems, such as ‘What is the difference between ... and ...?’, ‘How does ... affect ...?’, and ‘What are the strengths and weaknesses of ...?’, helped them to generate questions that prompted them to compare and contrast, infer cause and effect, note strengths and weaknesses, evaluate ideas, explain and justify.

Students can also be taught to formulate ‘productive’ questions (Elstgeest, 1985) which stimulate productive physical or mental activity and reasoning, and take them forward in their thinking. Although originally conceived in the context of teacher-questioning, productive questions can also be raised by students. These questions include measuring questions (e.g. ‘How would I measure the amount of gas evolved in this reaction?’), comparison questions (e.g. ‘What patterns do I notice in the atomic structure and properties of the elements in the Periodic Table?’), action questions (e.g. ‘If this paper chromatography experiment were repeated at a higher temperature, would the spots separate more quickly?’) and reasoning questions (e.g. ‘Why is there an increase in temperature when sodium carbonate dissolves in water but a decrease in temperature when ammonium chloride dissolves?’).

Teachers can also ask students to write questions about aspects of what they are learning which are puzzling to them (White and Gunstone, 1992). Students can record any questions that they have in a diary or learning journal, thus documenting a set of ‘I wonder’ questions, and the teacher can compile selected questions into a class list of ‘Questions that we wonder about’ (e.g. Kulas, 1995). The teacher can pause at convenient intervals during the lesson and ask the students to write down questions they wish to ask, and then use these questions as ‘thought provokers’ for stimulating discussions (Maskill and Pedroso de Jesus, 1997). After a moment to jot down questions related to the reaction between zinc and dilute sulfuric acid would be ‘What would happen if a few drops of copper sulfate are not added?’, ‘What if we use calcium/magnesium instead of zinc?’ and ‘How would the rate of reaction be affected if we use larger/smaller pieces of zinc?’ Identify and manipulate variables are central to understanding cause-and-effect relationships in scientific enquiry, and operational questions are a means of encouraging students to think about such relationships.

To develop a receptive classroom atmosphere, teachers need to establish an accepting questioning climate. Students’ enquiry skills can develop only when they feel free to ask questions and share their ideas without fear of censure, criticism or ridicule. No matter how silly their questions may appear to be, the teacher should restrain judgmental cues and the students to think about how they will structure their search, consider the best way to organise tasks and develop a plan of action. When students generate questions for each category, this helps provoke thought and questions in categories which they might not otherwise consider. King (1994) found that giving students thought-provoking question stems, such as ‘What is the difference between ... and ...?’, ‘How does ... affect ...?’ and ‘What are the strengths and weaknesses of ...?’ helped them to generate questions that prompted them to compare and contrast, infer cause and effect, note strengths and weaknesses, evaluate ideas, explain and justify.

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Students' questions

The type of tasks that teachers set and the level of thinking required of students influence the kinds of questions that students ask, and thus how active their minds will be. When the assigned tasks simply require students to follow given instructions and step-by-step procedures, this does not engage students at high cognitive levels. They would ask mainly procedural and factual questions to make sure they do things right, according to the teacher’s expectations. Such a setting does little to encourage students’ curiosity or wonderment about objects, events or phenomena. In contrast, an open-ended, problem-solving activity would engender exploration of ideas and result in a greater number and variety of wonderment questions and talk at higher conceptual levels. Thus, to elicit deep-thinking questions in their students, teachers should present their laboratory activities in the spirit of enquiry and problem-solving instead of as a verification exercise.

Students do not always ask wonderment questions spontaneously, perhaps because they are not even aware of what they do not know or understand. Unless they are stimulated to think about such questions, many will not ask them. Students also do not necessarily say if they have problems or doubts, maybe because they are too shy or afraid to reveal their ignorance. Thus, their questions and puzzlement may not be addressed as the teacher may not be aware of them. Much potential conceptual talk could be unappreciably if these questions are not asked. Teachers cannot fully depend on students to ask questions spontaneously and hope that this will occur naturally in the course of classroom activities. Rather, they must explicitly steer their students towards asking questions, for example, by specifically requiring them to generate questions in one way or another; questions, for example, by specifically requiring them to generate questions in one way or another; or the Internet, consult experts, or even have the students to search for answers from printed resources. Such phenomena. In

Implications for science teaching

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Students may feel uneasy with the idea of" encourage students to think even if they have the answers to all the questions. In such a setting, the teacher can then address some of these questions in the next lesson, or incorporate students’ questions in the development of subsequent lessons. Students’ journals can be handed in at the end of each week, and evaluation could consist of teacher comments and answers, as well as bonus points for thoughtful and insightful questions.

A ‘question board’ can be used to display students’ questions relating to the topic being taught and these questions may be used as starting points for scientific investigations (Dixon, 1996). Such a board can encourage less vocal students to put forward their questions, as well as providing a forum for discussion and the exchange of ideas. If placed in a corner of the classroom for an extended period of time, students can also refer to the board outside of their science lessons, for instance during break times. They can research the answers to the questions by looking in books, asking someone or carrying out investigations themselves to obtain first-hand information.

Watts, Gould and Alsop (1997) have also suggested including specific times for questions such as a period of ‘free question time’ within a lesson, a question ‘brainstorm’ at the start of the topic, a ‘question box’ on a side-table where students can put their (anonymous) questions, turn-taking questioning around the class where each student or group of students must prepare a question to be asked of others, and ‘question-making’ homework. Teachers can also establish a ‘problem corner’ in the classroom and encourage students to supply ‘questions of the week’ (Jelly, 1985).

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Epilogue

When Roald Hoffmann, Nobel prize-winner in chemistry, was referring to the 'Hoi y Grail' of science (Hoffmann and Torrence, 1993), he commented:

*The secret of the Holy Grail is that it is to be found not in the consummation but in the search .... The moral, that of science, is clear: keep asking.*

In scientific enquiry and the learning of science, curiosity and thoughtful questioning are of paramount importance in taking students' thinking a step or a leap forward. Thus, teachers should strive to foster a culture of inquisitiveness in science classrooms and encourage students to ask a 'good question' daily. With the emphasis today on lifelong learning, one could rephrase the traditional oft-quoted proverb to:

*Give a student a question and he enquires for a day. Teach him how to question and he enquires for a lifetime.*

References


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