

The value of asking questions

Ronald D. Vale

Department of Cellular and Molecular Pharmacology, Howard Hughes Medical Institute, University of California, San Francisco, San Francisco, CA 94158

ABSTRACT Science begins by asking questions and then seeking answers. Young children understand this intuitively as they explore and try to make sense of their surroundings. However, science education focuses upon the end game of “facts” rather than the exploratory root of the scientific process. Encouraging questioning helps to bring the true spirit of science into our educational system, and the art of asking good questions constitutes an important skill to foster for practicing scientists.

Monitoring Editor
Keith G. Kozminski
University of Virginia

Received: Jan 3, 2013
Revised: Jan 7, 2013
Accepted: Jan 9, 2013

INTRODUCTION

“It is easier to judge the mind of a man by his questions rather than his answers.”—Pierre-Marc-Gaston, duc de Lévis (1764–1830)

“I get it; science is just like spelling. You just have to memorize it and it doesn’t make any sense.”—Anonymous U.S. elementary school student

The juxtaposition of these quotes illustrates a serious shortcoming of K–12 science education. The foundation of science is to ask questions about the natural world and then seek answers. If a student sees spelling and learning science as similar experiences, then we are failing to communicate the fundamental reason why science exists as a discipline and what it has to offer.

The student’s quote, sadly, reflects our approach to teaching science: Learn the facts and don’t deviate from that script. However, before organizing scientific data into “facts,” science begins by asking questions as a form of intellectual exploration. Young children are full of questions, spawned by true curiosity rather than a desire to impress. But over the course of their education, students and adults ask fewer questions and more passively accept facts as “the way things are.” I have witnessed this trend in my experiences in school classrooms. However, I would like to think that it is not an inevitable outcome of the educational pipeline. Thus it is worthwhile to ask whether we could be doing more to promote questioning as

a fundamental tool for science education and in the practice of professional science.

THE ART OF ASKING A GOOD QUESTION

You can’t expect to wake up one morning and run a marathon without training. Similarly, asking good questions is a skill that requires practice, training, and mentoring. If a child (or adult) is placed in an environment that does not encourage active questioning, then that skill will not become an active habit of mind.

The purpose and practice of active questioning has its roots in ancient philosophic traditions. Socrates is well known for using questioning to probe the validity of an assumption, analyze the logic of an argument, and explore the unknown. Questions were a means to educate his students by drawing out their understanding of a subject and then leading them to discover a set of logical conclusions instead of lecturing them on what is true or false. Socratic questioning is still advocated as a powerful contemporary teaching method (Brill and Yarden, 2003).

Questioning is a core principle of Eastern philosophies as well. In the Prashna-Upanishad, one of the earliest of the Upanishad texts that serve as a foundation of Hinduism, pupils pose six great questions to a wise teacher (*prashna* means question in Sanskrit). The Buddha also encouraged questioning by his disciples, and a fundamental role for questioning is still embraced in the practices of modern Buddhism. I recently had the pleasure of visiting Dharamsala, India, where I watched Tibetan Buddhist monks debate—a daily practice that involves one monk continually questioning another monk for an hour, often on esoteric points of Buddhist thought. The impressive aspect of this practice is how the monks use this method of questioning/answering to hone their skills in logic and to probe complex questions. The questioning involves great mental concentration and intense exchange, punctuated by

DOI: 10.1091/mbc.E12-09-0660

Address correspondence to: Ronald D. Vale (vale@cmp.ucsf.edu).

© 2013 Vale. This article is distributed by The American Society for Cell Biology under license from the author(s). Two months after publication it is available to the public under an Attribution–Noncommercial–Share Alike 3.0 Unported Creative Commons License (<http://creativecommons.org/licenses/by-nc-sa/3.0>).

“ASCB®,” “The American Society for Cell Biology®,” and “Molecular Biology of the Cell®” are registered trademarks of The American Society of Cell Biology.

episodes of laughter and joy. Interestingly, the use of questioning for intellectual exploration and teaching evolved independently in Socratic and Buddhist schools of thought, and both developed this skill through a high degree of discipline and practice.

Philosophy and science grew up together and were inseparably intertwined; logical argument and inductive thinking were ways of exploring/explaining the natural world. There were few “facts” to memorize, and the framework of using experimentation/data gathering to formulate scientific theories gained hold only in the middle of the second millennium. Since that point, science and philosophy have grown steadily apart in subject areas and methodologies. It would be rare to find a scientist and philosopher exchanging ideas with one another at a meeting. However, the art of questioning is practiced by scientists, philosophers, and educators, and these disciplines might learn from one another and explore and exploit each other’s practices and ideas.

POSING A QUESTION AS A BASIS OF INDEPENDENT LEARNING AND INQUIRY

Virtually all educators agree that teaching science should involve more inquiry-based learning and less fact-based memorization (Committee on a Conceptual Framework for New K-12 Science Education Standards, 2012). Many educators are now developing experimental modules that engage students in the practice of scientific inquiry in a laboratory setting and are trying to export these experimental modules and ideas to many schools.

Pursued properly, a good question also can be an excellent vehicle with which to start a process of inquiry. Investigating an answer to a question need not require a laboratory, special equipment, or money. The goal of asking and answering a question is not necessarily to probe a completely untouched area of science (which is unrealistic for K–12). Rather, it should be a personal quest to resolve a curiosity and grapple with trying to understand the answer. Furthermore, researching one question often results in a further round of questions that dig deeper into a phenomenon.

Let’s consider some examples of questions. Alan Alda, the famous actor/director/writer, who is now on the advisory board of the Center for Communicating Science at Stony Brook University, posed a challenge in *Science* of answering the question, “What is a flame?” (Alda, 2012). This challenge was based on his experience as an 11-year-old asking his teacher this same question and receiving the disappointing, few-syllabic answer, “It’s oxidation.” Last spring, Alda received more than 800 answers to that question from scientists, and the answers were judged by 6000 11-year-olds. This example illustrates that a lot of thought is required to understand and explain “simple” questions about our everyday experiences. “Why is the sky blue?” can be used to learn an enormous amount about light and the atmosphere. Even the question “What is light?” is enough to set off an endless string of subsequent questions. “It is both a wave and a particle.” What does this nonintuitive answer mean? What evidence supports light’s behavior as a wave? Why do we say that it is a particle? And for more advanced students, “How can single photons aimed at a pair of slits create interference patterns on the other side, as though they passed through both slits simultaneously?” By posing questions, one appreciates that science is not all about filling in the correct bubble with a #2 pencil. Some mysteries lack good answers or have partial answers with fuzzy boundaries. That might frustrate a subset of teachers and students who want clear-cut answers. But it can make science “cooler” and better prepare students to think about evidence and to navigate in a complex world that does not always have precise answers.

Questioning can be used to promote independent learning in a school setting in a variety of ways. The key ingredients are that students should have some freedom to choose a question in which they are interested, have an opportunity to research the answer on their own, and then have an opportunity to teach others (peers and the teacher) what they learned. I witnessed one especially successful example of spontaneous, curiosity-driven questioning in the “Katta,” a volunteer science discussion group for college students led by Milind Watve, then at Garware College, Pune, India (Jog, 2009). A *katta* in Marathi (the regional Indian language) means a place where people can meet, talk, and exchange ideas. In Watve’s Katta, students drive the discussion. Many questions arise and quickly subside. However, in some instances, students begin to swarm around a question, wanting to know more. This experience often ignites a student, or a group of students, to investigate the question more deeply on their own and then present what they discovered at a later Katta. Sometimes the group of students decides to investigate the question in a scientific manner, using tools of a laboratory, math, field studies, and so on, as appropriate. In several cases, those investigations went all the way to publications in well-known journals.

Watve’s role is as a catalyst, providing a safe environment where students can feel free to ask a question without worrying about whether it is good, bad, intelligent, or crazy. Usually, no one in the room (including Watve) is an expert in the subject. But he encourages them to pursue the question regardless, stimulating them to take ownership of the question and think in new ways that possibly may not have occurred to scientists in the field.

PURSUING ANSWERS TO QUESTIONS: THE NEW ROLE OF THE INTERNET

When I was a child and needed to research a topic for school or find an answer to a question, I pulled out the *World Book Encyclopedia*, our family’s prized possession. I did not always have to go the library; I was fortunate to have a source of knowledge at home.

How different the world has become for my teenage kids. Through the Internet, they have unprecedented access to information encompassing virtually the entire scope of human knowledge. This information is now available on a time scale of seconds, as if it has become a virtual extension of our cerebral cortex. If an interesting question pops into one’s mind, one can research it immediately and from multiple sources, rather than visit the library tomorrow or next week. Furthermore, global connections can now be made between a child in India with a question and a scholar in England who can provide a response. However, the rapid blooming of the Internet into a vast, thick jungle of information poses a couple of problems—our time is limited, and there is no easy formula for integrating information. *Thus the most important skill for the twenty-first century, in my opinion, is learning how to judge and integrate information from multiple sources to generate conceptual understanding or a new idea.*

Although integrating information is becoming increasingly important for future success, the educational community has not fully grappled with how to teach students these skills. Many teachers, for example, say that Wikipedia is unreliable and cannot be used as a resource. Some make blanket statements that .org or .gov sites are good and .com sites are bad. Kids are savvy enough to know that such statements are too simplistic and not true. Yes, one can find errors in Wikipedia, although several studies suggest that there are relatively few (Giles, 2005). But a state-approved high school biology textbook also can have out-of-date information and incorrect simplifications. It is also folly to think that teenagers

who seek an answer to one of *their own* questions will go to their textbook or their teacher; they will head straight to the Internet, and with some judgment, they will find a good resource in short time. In addition, we are already living in a world where most adults are turning to the Internet as a source of information about science (Brossard and Scheufele, 2013).

Rather than severely restricting kids from Internet research, more attention needs to be paid to teaching them best practices, such as directing them to good Internet sources, teaching them how to identify potentially flawed information, how to integrate information from multiple sources, and how to reference them. Categorically stating that Wikipedia is unreliable is insufficient; rather specific pages or examples on Wikipedia where information might be incomplete or inaccurate need to be illustrated (and these are rare from my experiences with bigger scientific topics). Students also need to gain a more mature view of knowledge, understanding that it is dynamic and that there are points of contention that demand judgment rather than blind memorization. Importantly, there is no need to create two camps of scholarship by creating separate instruction manuals for what kids need to do to get the best grade for a classroom assignment versus how they should assimilate knowledge beyond school. Most schools have mottos about teaching students to “become life-long learners,” but this will not happen unless students see connections between how they research a question for school and how they would research a question on their own.

BARRIERS TO ACCEPTING QUESTIONING AS A BASIS OF TEACHING

Questioning may seem like a good educational approach, so why is it not a more common practice in science education? Several cultural factors present barriers. First is the perception that the teacher is an almighty vessel of knowledge who imparts information to students. In that formulation, a difficult question with no immediate answer or an uncertain answer can be threatening to a teacher and disappointing to a student. However, that view is unfair to teachers. Teachers also need to be students. A teacher should feel completely comfortable saying, “I do not know the answer to that question, but let me look it up—or let’s look it up together.” Many questions do not have quick, easy answers and thus become seeds for investigation. Students also should be able to teach their peers when they look up an answer to a question. In this model, teachers and students become partners in their mutual education.

A second impediment to using questioning as an educational tool is that questions are unpredictable by their nature. One cannot know what students are going to ask in a particular year. It can be hard to plan around such uncertainty. With state-mandated curricula, there is little, if any, time to deviate from the script. The ability to ask a question, research the answer, and present it to the class requires some degree of flexibility in the weekly lesson plan. Most teachers, particularly in state-run schools, do not have that luxury.

A third impediment to using questioning is that it is not a trivial skill to learn. I already discussed that ancient Greeks and contemporary Buddhists practice this skill for many years. Similarly, teacher training would be required to implement such ideas in a classroom.

As discussed in recent editorials by Bruce Alberts (2012a,b), at the root of all three obstacles is the lack of time in K–12 education for in-depth investigation by students or teachers. State science curricula mandate a list of “required” topics and information that is so long that it becomes quite difficult for teachers to pack it all in during a school year. This comprehensive, memorization-based approach is great for testing but poor for producing kids who are interested in science or even know what science is truly about. A conceptual understanding of how cells use and make energy is more important than regurgitating all of the steps in glycolysis, which can be quickly relearned online. State educators need to reduce the amount of required material in their science curricula to allow more the time for in-depth learning, teacher initiative and professional development, and exploration of questions. Finland is adopting such strategies, with substantially better educational outcomes than the United States (Sahlberg, 2011).

QUESTIONING AS A SKILL FOR PROFESSIONAL SCIENTISTS

Identifying a good question and being able to articulate it well is not just an exercise for high school students, but is also a key skill in becoming a successful scientist. A grant proposal often receives a poor score not because the proposed experiments are poorly conceived, but because the questions being asked are not interesting or not clearly articulated. It is easy to fall into this trap, because specific aims are often written in terms of achieving a specific technical goal rather than from the standpoint of framing and answering a compelling question. Weaving good questions into the text of a grant can be a way to communicate the goals of a project.

Articulating interesting questions also is essential for delivering a scientific talk. Many seminars are lackluster because they are swimming in data but lack a captivating question to motivate the data collection. Raising questions throughout a seminar engages the audience and involves them in the thought process. Posing a single question on a slide also can be an effective means of framing the steps involved in answering that question in subsequent slides.

In summary, asking questions is a part of the joy of science. It begins as soon as we can utter the word “why.” Even much later, as a seasoned, well-educated scientist, one can continually learn from and strive to perfect this gift of human intellect.

REFERENCES

- Alberts BM (2012a). The failure of skin deep learning. *Science* 338, 1263.
- Alberts BM (2012b). Mobilizing scientific societies. *Science* 338, 1396.
- Alda A (2012). The flame challenge. *Science* 335, 1019.
- Brill G, Yarden A (2003). Learning biology through research papers: a stimulus for question-asking by high-school students. *CBE Life Sci Educ* 2, 266–274.
- Brossard D, Scheufele DA (2013). Science, new media, and the public. *Science* 339, 40–41.
- Committee on a Conceptual Framework for New K-12 Science Education Standards (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, Washington, DC: National Academies Press, 54–55.
- Giles J (2005). Internet encyclopedias go head to head. *Nature* 438, 900–901.
- Jog M (2009). The “Science Katta” at Pune: catching them young. Available at: www.indiabioscience.org/node/24 (accessed 27 February 2013).
- Sahlberg P (2011). *Finnish Lessons: What Can the World Learn from Educational Change in Finland?* New York: Teachers College Press.