Explaining Science

By Mark J. Gagnon and Sandra K. Abell

The National Science Education Standards state that there should be less emphasis on "science as exploration and experimentation" and more emphasis on "science as argument and explanation." Can my students do this? Can I?

What is explanation and why is it important in science?

We often think of science as exploration and experiment. However, classrooms that portray only this view of science fail to capture an essential feature of science—evidence-based explanation. When scientists encounter patterns in the world, they construct theories to explain them. What does it mean to explain in science? Explanation is more than summarizing the data that have been collected. Explanations tell *why* phenomena occur. Explanations involve a leap of imagination; scientists explain by building and testing models of how the world works. Scientific explanations emphasize evidence and employ accepted scientific principles. For example, different states of matter are explained by the arrangement and movement of molecules. The best explanations are the simplest and take into account the most evidence. The central role of explanation in science should be part of science classrooms. According to the National Academies Committee on Science Learning, Kindergarten through Eighth Grade (Duschl, Schweingruber, and Shouse 2007), elementary science should be aimed at helping students "know, use, and interpret scientific explanations… [and] generate and evaluate scientific evidence and explanations" (p. 36). But can elementary students generate viable explanations using scientific evidence?

Can children generate and evaluate explanations from evidence?

To what extent is it reasonable to ask elementary students to generate scientific explanations? Several educational psychologists have explored this question in clinical settings. Sodian, Zaitchik, and Carey (1991) presented first and second graders with two conflicting hypotheses and asked them to choose a test to decide between them. Seventy-five percent of the first graders and all of the second graders were able to choose a conclusive test. Samarapungavan (1992) interviewed first, third, and fifth graders to find out

what criteria they used for choosing among alternate explanations about the relative shapes, positions, and movements of heavenly bodies. She found that even the youngest children could use logic to choose the best explanation based on evidence. Ruffman and colleagues (1993) used a set of interview tasks in the form of stories with four- to seven-year-olds to investigate how children understood the relation of evidence and explanation. They found that by age six, most children recognized how the characters in the stories might form correct or incorrect explanations based on the evidence. These studies demonstrate the potential of young children to think scientifically in psychology laboratories. However, how do students perform in classroom settings?

What do classrooms focused on explanation and evidence look like?

Several studies about students' ability to construct scientific explanations have taken place in elementary classrooms with classroom teachers as part of the research team. The researchers have found that students at various grade levels can be successful in generating scientific explanations from evidence. Kawasaki, Herrenkohl, and Yeary (2004) examined the evolution of students' explanation building and modeling in a unit on sinking and floating. They found that students initially did not offer explanations but merely described the phenomenon. With time and prompting by the teacher, students began to discuss relations among variables and eventually used model-based reasoning, where they realized that explanations might need to change in light of new evidence. In Taiwan, Wu and Hsieh (2006) studied how sixth graders constructed explanations about force and motion and electricity. Like Kawasaki and her colleagues, they found that, although at first students did not include data as evidence in their discussions or presentations, with more experience they were able to support their explanations with data. Abell and Roth (1995) found that fifth graders could generate their own models of energy flow from plants to herbivores to predators through an ecosystem that took into account evidence from their classroom terraria, but the students had difficulty understanding the standard scientific model of the energy pyramid. In a study of third graders' reasoning about principles of sound, Abell, Anderson, and Chezem (2000) found that students used evidence to support their explanations and to select among explanations. However, not all students ended the sound unit agreeing about how sound is produced. What these classroom-based studies tell us is that learning to generate and use scientific explanations is a reasonable expectation in elementary science classrooms, but it does not happen automatically without specific scaffolds provided by the teacher.

How can teachers build a classroom atmosphere for developing explanations?

We can learn ways to support students as they generate explanations in science by reading how other teachers have accomplished this in their classrooms. Karen Gallas (1995) conducted numerous "science talks" with first- through fourth-grade students. She described the anatomy of a science talk, including the role of the teacher in helping students uncover children's questions and explanations. Her examples are useful models. Folsom and her partners (2007) helped kindergartners develop evidence-based explanations about animals. They described specific techniques—asking students to write evidence-based explanations and defend them, probing students for evidence when they offer an explanation ("What makes you think that?"), asking guiding questions about how students might figure something out, and holding students "scientifically accountable" for their explanations (versus merely correcting their ideas). In the examples of classroom-based research presented above, the role of the teacher is clear. Teachers helped students compare and think through their developing explanations during scientist meetings, gave students opportunities to argue and explain their ideas, and listened to their explanations to understand their thinking. In classrooms where scientific explanations are the focus, the student becomes the center of sense-making while the teacher carefully structures and directs the work from the side. ■

Mark J. Gagnon has taught elementary and middle school science and worked with teachers in science professional development settings. He is currently a doctoral student in science education at the University of Missouri–Columbia (MU). Sandra K. Abell (AbellS@missouri.edu), a former elementary science teacher, is Curators' Professor of Science Education at MU, where she directs the MU Science Education Center

References

Abell, S.K., G. Anderson, and J. Chezem. 2000. Science as argument and explanation: Inquiring into concepts of sound in third grade. In *Inquiring into inquiry learning and teaching in science,* eds. J. Minstrell and E. van Zee, 65–79. Washington, DC: American Association for the Advancement of Science.

Abell, S.K., and M. Roth. 1995. Reflections on a fifth-grade life science lesson: Making sense of children's understanding of scientific models. *International Journal of Science Education* 17(1): 59–74.

Duschl, R.A., H.A. Schweingruber, and A.W. Shouse. 2007. *Taking science to school: Learning and teaching science in grades K–8.* Washington, DC: The National Academies Press.

Folsom, J., C. Hunt, M. Cavicchio, A. Schoenemann, and M. D'Amato, M. 2007. How do you know that? Guiding early elementary students to develop evidence-based explanations about animals. *Science and Children* 44(5): 20–25.

Gallas, K. 1995. *Talking their way into science: Hearing children's questions and theories, responding with curricula.* New York: Teachers College Press.

Kawasaki, K., L.R. Herrenkohl, and S.A. Yeary. 2004. Theory building and modeling in a sinking and floating unit: A case study of third- and fourth-grade students' developing epistemologies of science. *International Journal of Science Education* 26(11): 1299–1324.

Ruffman, T., J. Perner, D.R. Olson, and M. Doherty. 1993. Reflecting on scientific thinking: Children's understanding of the hypothesis-evidence relation. *Child Development* 64(6): 1617–1636.

Samarapungavan, A. 1992. Children's judgments in theory choice tasks: Scientific rationality in childhood. *Cognition* 45(1): 1–32.

Sodian, B., D. Zaitchik, and S. Carey. 1991. Young children's differentiation of hypothetical beliefs from evidence. *Child Development* 62(4): 753–766.

Wu, H-K., and C-E. Hsieh. 2006. Developing sixth graders' inquiry skills to construct explanations in inquiry-based learning environments. *International Journal of Science Education* 28(11): 1289–1313.