Introduction to the Special Issue: Learning and Instruction in the Natural Sciences

Benjamin D. JEE  
College of the Holy Cross, Worcester, MA, USA

Florence K. ANGGORO  
College of the Holy Cross, Worcester, MA, USA

Education in the natural sciences is receiving increased interest worldwide. The president of the United States, Barack Obama, has consistently affirmed his commitment to a renewed focus on science education, and other world leaders have also expressed the need to re-imagine science education to better prepare students for the jobs and important challenges of the future. An understanding of science will be vital as the next generation of global citizens confronts complex problems such as climate change, sustainable energy, food production, and the control of disease and illness. Indeed, the educational systems of the future must not only prepare the next generation of scientists, but also produce an informed citizenry, capable of understanding and using scientific evidence to inform their opinions and choices.

A number of factors complicate the growing need to educate students in the natural sciences. For one, increasing urbanization has widened the disconnection between humans and nature (e.g., Atran, Medin, & Ross, 2004; Birnbaum, 2004; Wolff, Medin, & Pankratz, 1999). Students may have very little exposure to the natural world, and thus may have difficulty understanding the scale, properties, and behavior of natural objects (Birnbaum, 2004). The ethnic makeup of many countries is also changing rapidly; yet, relatively few minority students pursue degrees in natural science. For example, of the over 23,000 Bachelor’s of Earth Science degrees awarded in the U.S. between 1996 and 2001, only about 5% were awarded to minorities (Stokes, Baker, Briner, & Dorsey, 2007). Given the growing minority population in the United States and other countries, this lack of minority representation poses a significant threat to the future of industries and institutions that depend on science graduates. Another challenge is that many students have negative attitudes toward science (e.g., Atwater, Wiggins, & Gardner, 1995; Simpson & Oliver, 1985). Several researchers have found that students’ attitudes toward science decline as they progress through school (Atwater et al., 1995; Cannon & Simpson, 1985; Hill, Atwater, & Wiggins, 1995; Simpson & Oliver, 1985). These attitudes covary with science achievement (e.g., Freedman, 1998), such that students with the most negative attitudes tend to also perform the worst. Poor achievement, in turn, leads to increasingly negative feelings (e.g., Mattern & Scheau, 2002).

As cognition and learning researchers, our background leads us to think about these educational issues in terms of student learning, and the instructional approaches that can
enhance this learning. If more students can be given the support to achieve in the natural sciences, this may promote positive attitudes, and encourage a wider range of students to pursue a career in science and fulfill the important needs of the future. Our aim as editors of this special issue was to bring together a variety of research approaches that share the common goal of understanding and improving learning and instruction in the natural sciences.

The articles in this special issue address some of the diverse factors involved in children’s learning in the natural sciences. One important factor is the *pre-existing belief structures* that children hold during instruction. Children possess naïve theories about the natural world—preconceptions that often deviate from scientific theories and are resistant to change. Varela presents an in-depth study of 1st grade students learning about fundamental topics in astronomy. His paper describes the class discussions that supported students’ transition to a more sophisticated and coherent understanding. Varela suggests that discussions involving an instructor and fellow students can make children reconsider their naïve theories and promote conceptual change toward scientific models. The paper by Shtulman and Checa also considers how discussions with others, in this case a parent, can help children to avoid and resolve misconceptions. The research captured children’s reasoning in the context of an interactive museum display about biological evolution. Children were less likely to express common misconceptions when the conversation between parent and child was more back-and-forth. Both studies portray a dynamic learning process in which children are exposed to limitations in their naïve theories and presented with alternative ideas from an instructor, parent, or peer.

Another important factor that affects children’s learning of natural science is the *thinking and reasoning skills* that they bring to bear. Libarkin and Schneps present the findings from interviews in which children were asked to explain various phenomena related to Earth science. This task required children to perform retrodictive reasoning—describing possible causes of observed phenomena. All children showed the ability to reason retrodictively, yet they generated a wide range of explanations by drawing on different beliefs about domain-specific and domain-general mechanisms in Earth science as well outside-domain analogies. Griffin, Wiley, Britt, and Salas present evidence that individual differences in children’s commitment to logic, evidence, and reasoning (CLEAR thinking) predicts their learning from a multiple-document inquiry task in science. Children who were more committed to the use of scientific evidence to inform their beliefs, for example, were generally more effective at comprehending and integrating the content of a series of science texts. These articles speak to an apparent bidirectional relationship between reasoning skills and science learning: general reasoning skills can shape a child’s science knowledge, and science knowledge can inform a child’s explanations of natural phenomena.

In addition to naïve conceptions of the natural world and scientific reasoning skills, children’s learning in the natural sciences is affected by the structure and content of formal instruction. As Anggoro, Stein, and Jee discuss, formal instruction on the molecular properties of the states of matter is often incomplete and incoherent. To support learning, children must be presented with a causally coherent lesson, and visual models must be used to show children the invisible molecular properties of the states. Yet, even when the lesson’s content is arguably ideal, instruction can place too great a demand on a child’s ability to interpret, maintain, and integrate verbal and visual representations. Anggoro et al. found that children who were read a science text by a tutor showed greater learning gains than students who read the same text by themselves, especially younger children. The finding suggests that supporting the integration of verbal and visual information is a critical consideration when a science lesson is comprehensive and causally coherent. Another way to enhance students’
understanding of a science lesson is by leading the lesson with brief activities (Openers) that emphasize knowledge integration. Zertuche, Gerard, and Linn found that when students were given opportunities to make connections among ideas and reflect upon these ideas, they were more likely to form coherent hypotheses and explanations about chemical reactions. These articles offer some important guidelines in the design of the instructional conditions that support optimal learning of natural science.

The papers in this special issue highlight some of the many considerations relevant to children’s learning in the natural sciences. The articles also speak to the many contexts in which science learning takes place—from informal conversations in a museum, to searching through online texts, to formal technology-assisted instruction. Indeed, children develop their knowledge of natural science from many places. To engineer the educational systems of the future, educators must not only think beyond conventional modes of instruction, but also beyond the classroom.

References


