Chapter 3
Argumentation and Modeling:
Integrating the Products and Practices of Science to Improve Science Education

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ABSTRACT

There is now growing consensus that K12 science education needs to focus on core epistemic and representational practices of scientific inquiry (Duschl, Schweingruber, & Shouse, 2007; Lehrer & Schauble, 2006). In this chapter, the authors focus on two such practices: argumentation and computational modeling. Novice science learners engaging in these activities often struggle without appropriate and extensive scaffolding (e.g., Klahr, Dunbar, & Fay, 1990; Schauble, Klopfer, & Raghavan, 1991; Sandoval & Millwood, 2005; Lizotte, Harris, McNeill, Marx, & Krajcik, 2003). This chapter proposes that (a) integrating argumentation and modeling can productively engage students in inquiry-based activities that support learning of complex scientific concepts as well as the core argumentation and modeling practices at the heart of scientific inquiry, and (b) each of these activities can productively scaffold the other. This in turn can lead to higher academic achievement in schools, increased self-efficacy in science, and an overall increased interest in science that is absent in most traditional classrooms. This chapter provides a theoretical framework for engaging students in argumentation and a particular genre of computer modeling (i.e., agent-based modeling), illustrates the framework with examples of the authors' own research and development, and introduces readers to freely available technologies and resources to adopt in classrooms to engage students in the practices discussed in the chapter.

INTRODUCTION

Science education has historically attempted "to cultivate students' scientific habits of mind, develop their capability to engage in scientific inquiry, and teach them how to reason in a scientific context" (NRC, 2011). These three foci have often been treated separately in traditional approaches to science education; however, with the result that science is often treated as isolated

DOI: 10.4018/978-1-4666-7363-2.ch003

rote facts or artificial and arbitrary five-step methods (Driver, Leach, Miller, & Scott, 1996; Lemke, 1990). There is now growing agreement that students need to understand science and the processes of science as functions of argumentation and modeling (Duschl, 2008; Kelly, 2005; Lehrer & Schauble, 2006). The framework for the new science standards in the United States therefore "stresses the importance of developing students' knowledge of how science and engineering achieve their ends while also strengthening their competency with related practices" (NRC, 2011, p. 3.1). The new standards use the term "practices" rather than "skills" to "stress that engaging in scientific inquiry requires coordination both of knowledge and skill simultaneously" (NRC, 2011, p. 3.1). This chapter discusses the practices of argumentation and modeling in terms of their roles in the scientific disciplines and in terms of practices appropriate for students in the classroom.

WHAT ARE ARGUMENTATION AND MODELING?

True scientific literacy involves understanding how knowledge is generated, analyzed, justified, and evaluated by scientists and how to use such knowledge to engage in inquiry in ways that reflect the practices of the scientific community (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002). Scientific inquiry is often described as a knowledge building process in which explanations are developed to make sense of data and then presented to a community of peers so they can be critiqued, debated, and revised (Driver, et al., 2000; Duschl, 2000; Sandoval & Reiser, 2004; Vellom & Anderson, 1999). Argumentation and modeling are at the heart of the scientific enterprise. As Lehrer and Scahuable (2012) point out, in the world of science, inquiry may take on various forms. Inquiry may be observational, theoretical, or computational. Inquiry may be carried out on a theorist's desk, in a physics lab, or a biological field station. However, despite these variations, all scientists engage in constructing, revising, applying, and defending models of the natural world (Giere, 1999; Hesse, 1966). Modeling has been described as the signature of research in the sciences (Nersessian, 2009), and argumentation is the process through which communities of scientists test, refine, and tentatively accept or reject models as a community. The ability to engage in scientific argumentation (i.e., the ability to examine and then either accept or reject the relationships or connections between and among the evidence and the theoretical ideas invoked in an explanation or the ability to make connections between and among evidence and theory in an argument) is, therefore, viewed by many as an important aspect of scientific literacy (Driver, et al., 2000; Duschl & Osborne, 2002; Kuhn, 1993; Siegel, 1989). Thus scientific theories, modeling, and argumentation are not separate decontextualized entities. Scientific theories, modeling, and argumentation are dynamically interwoven and interdependent.

Learning to engage in scientific modeling and argumentation is challenging for students. Furthermore, opportunities for students to learn how to engage in scientific argumentation in a productive manner as part of the teaching and learning of science are rare (Newton, Driver, & Osborne, 1999; Simon, Erduran, & Osborne, 2006) as are opportunities to engage in authentic modeling. Traditional science curricula portray scientific theories as fixed and immutable facts to be memorized and accepted. Argumentation, when included at all, tends to either be a decontextualized game of creating rebuttals or an unreflective statement of "evidence" for theories that are treated as foregone conclusions. Similarly, models and modeling tend not to be integrated in school science in authentic forms. To the extent that they do appear in school, models usually play an illustrative, rather than scientific theory building role (Windschitl & Thompson, 2006).