Chapter 11
Pre-Service Teachers Critical Thinking and Developing and Using Models in Science

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ABSTRACT

The new science and engineering practice of developing and using models is needed to achieve the vision of three-dimensional teaching and learning and should be an important new component of teacher preparation programs. This chapter examined critical thinking and preservice teachers' preconceptions about critical thinking and the practice of developing and using models. The results of the study indicated that when preservice teachers initially described how this practice might look in the classroom, only two of the six categories outlined in A Science Framework for K-12 Science Education for this practice were described by most participants. Of those two categories described by most participants, the majority were at a novice level. These results emphasize the necessity for elementary teacher education to provide opportunities for preservice teachers to better understand the practice of developing and using models, and how critical thinking can help teachers use models.

INTRODUCTION

The development of critical thinking has been a widely accepted goal in education for many years with varying definitions across fields (Halpern, 2003; Hitchcock, 2018; Horvath & Forte, 2011). Hitchcock (2018) asserts there is a basic concept that anchors differing conceptions of critical thinking: careful thinking directed to a goal. Critical thinking skills encompass the need to retrieve information so that it will be available when needed to test hypotheses, predict or control environments, evaluate evidence, assess claims, monitor comprehension, solve problems, estimate likelihoods, and make decisions (Halpern, 2003). Some of these critical thinking skills are used more often than others in different academic

DOI: 10.4018/978-1-5225-7829-1.ch011

disciplines (Halpern, 2003). Conceptions differ depending on the type of goal, criteria or norms for thinking, and the thinking components that are the focus (Hitchcock, 2018).

Critical thinking can be improved in the science classroom by embedding strategies asking students to develop a deep understanding of concepts and competencies required to succeed in science by basing them upon evidence (Halpern, 2003; The Critical Thinking Consortium, 2015). To be competitive in the 21st century, American students are competing with students from across the globe. In 2010 Achieve completed an international benchmarking study of ten countries' science standards, identified through international assessments (Programme for International Student Assessment) and studies (Trends in International Mathematics and Science Study). The study noted a prominent shortcoming from studying leading nations, a call for students to consistently focus on evidence (Achieve, 2010). There is a need to "consistently incorporate science practices that focus on establishing lines of evidence, using evidence to substantiate claims, to develop and refine testable explanations, and to make predictions about natural phenomena" (Achieve, 2010, p. 5). The success of these high performing countries (including Singapore, Finland, Korea, Canada, and Japan) gave guidance to the National Research Council *Framework* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013) (Achieve, 2010). A primary successful feature noted after studying leading nations in the report was developing students' capacity to understand, design and apply physical, conceptual, and mathematical models as a key ability that should be interwoven in the new U.S. standards. "Scientific model-building is an important tool of science conceptualization and theorizing" (Achieve, 2010. p. 57). Developing and using models can improve critical thinking in science education because models are based on evidence (NRC, 2012). Modeling lies at the core of modern science and engineering providing a way to mediate or negotiate our ideas with empirical data and can help learners better advance their understanding of concepts (Schwarz et al., 2017).

In science, models are used to represent a system (or parts of a system) understudy, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others. Students can be expected to evaluate and refine models through an iterative cycle of comparing their predictions with real world and then adjusting them to gain insights into the phenomenon being modeled. As such, models are based upon evidence. When new evidence is uncovered that models can't explain, models are modified. (NGSS Lead States, 2013, Appendix F p. 6)

This chapter focuses on the critical thinking elicited through the practices of the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States, 2013) and seeks to study first steps in translating this critical thinking strategy through teacher education. Since the release of the NGSS, researchers have noted current classroom practices of using models in science as end products of learning instead of using them for explanatory purposes grounded in evidence when making sense of phenomena in a systematic way (Gouvea & Passmore, 2017). Modeling can aid in supporting learners advance their ideas based on evidence and help teachers teach more effectively when used appropriately (Schwarz et al., 2017). The study included here focused on preservice elementary teachers' preconceptions of the *NGSS* science and engineering practice of developing and using models. The study examined preservice teachers' initial views of models and preservice teachers' preconceptions of the role of student-student and student-teacher discourse in the development of modeling instruction in the classroom.

In a review of research, Davis et al. (2006) described how preservice elementary teachers have little sophisticated understandings of science inquiry in general or related skills due to their limited exposure to environments where true science inquiry is used. Previous to the Next Generation Standards, state