Educ. quím., **23**(4), 451-457, 2012

Publicado en línea el 7 de septiembre de 2012, ISSNE 1870-8404

Teaching about Scientific Models in a Science Content Course

Renée Schwartz,[1] *Brandy Skjold*[2]

ABSTRACT
Scientists construct and use models as part of scientific inquiry. Thus, learners should be knowledgeable about what scientific models are, how they are developed, and how they are used by scientists. This paper describes the instruction and effectiveness of teaching about the nature of scientific models in the context of an undergraduate science course for future elementary and middle school teachers. Multiple representations are used to teach biological phenomena while drawing explicit attention to the development and use of models in the scientific community and in science teaching. Results indicate participants initially considered models to be physical representations of objects to be visualized, the process scientists use to do an experiment, and a chart scientists use to record data. Posttests indicate increased recognition of models as representations of scientists' ideas and explanations of processes. Despite explicit instruction, few came to understand the role of models in making and testing predictions.

KEYWORDS: scientific models, nature of science, scientific inquiry, preservice teachers, multiple representations, biology

Resumen (La enseñanza sobre los modelos científicos en un curso con contenidos de ciencia)
Los científicos construyen y utilizan modelos como parte del proceso de la indagación científica. Por consiguiente, los aprendices deberían de conocer lo que son los modelos científicos, cómo son desarrollados y cómo son utilizados por los científicos. Este artículo describe una estrategia y qué tan efectiva es en la enseñanza sobre la naturaleza de los modelos científicos en el contexto de un curso de ciencias para estudiantes de la licenciatura en enseñanza elemental y secundaria. Múltiples representaciones son utilizadas en la enseñanza de fenómenos biológicos mientras se dibuja, se explicita la atención al desarrollo y uso de modelos en la comunidad científica y en la enseñanza de las ciencias. Los resultados muestran que los participantes al inicio consideran que los modelos son representaciones físicas de objetos materiales; el proceso científico implica un experimento y que los científicos utilizan tablas y gráficas para registrar sus datos. El posttest indica la existencia de un incremento en el reconocimiento de los modelos como representaciones de las ideas de los científicos y de las explicaciones de los procesos. A pesar de la instrucción explícita, muy pocos entendieron el papel de los modelos en el hacer y la prueba de predicciones.

Palabras clave: modelos científicos, naturaleza de la ciencia, indagación científica, profesores en formación, múltiples representaciones, biología

Introduction: The Problem and Purpose

> Inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. (NRC, 1996, p. 214)

Scientists use models in processes of scientific inquiry and develop models as products of inquiry (Gilbert, 1991, 2004). In order to "learn science in a way that reflects how science actually works" (NRC, 1996, p. 214), learners should be knowledgeable about what scientific models are, how they are developed, and how they are used by scientists. Yet, students and teachers typically hold narrow conceptions of models, generally considering them to be larger or smaller versions of the real thing and not recognizing their explanatory and predictive nature (e.g. Crawford & Cullin, 2004; Gilbert, 2004; Grosslight, Unger, Jay & Smith, 1991; Harrison, 2001; Justi & Gilbert, 2003; van Driel & Verloop, 1999, among others). If children are to learn science in a way that reflects real-world scientific inquiry, it is important for their teachers to have an understanding of how models are developed and used in the scientific community. An opportunity for teachers to learn about models is during their undergraduate science courses. Learning about models and modeling as a part of scientific inquiry can be embedded into science content courses and teacher education courses and addressed in an

[1] Department of Biological Sciences. Mallinson Institute for Science Education. Western Michigan University. 1903 W. Michigan Ave. Kalamazoo, MI USA 49008-5440.
E-mail: r.schwartz@wmich.edu
[2] Mallinson Institute for Science Education. Western Michigan University. 1903 W. Michigan Ave. Kalamazoo, MI USA 49008-5440.
E-mail: b.skjold@wmich.edu

explicit way that draws attention to relevant aspects of scientific models (e.g. Crawford & Cullin, 2004; Justi & van Driel, 2005). All science disciplines involve models; thus, all science courses can be appropriate contexts for teaching about models and modeling. This paper describes how the concept of scientific models can be explicitly taught within an undergraduate science course, in this case a biology course, and the conceptions future teachers hold before and after instruction. The research questions are:

1. What are preservice teachers' conceptions of scientific models before and after a science course that utilizes multiple models and explicit instruction about models and modeling?
2. Do preservice teachers distinguish between scientific models and teaching models?

What are Scientific Models?

Scientific models. Models have been described in a variety of ways, but consistent among them is that models are representations that serve to describe, explain, or predict (van Driel & Verloop, 1999). Gilbert (2004) describes models as "simplified depictions of a reality-as-observed, produced for specific purposes, to which the abstractions of theory are then applied" (p. 116), "idealizations of a possible reality" (p. 116), visualizations of abstract phenomena or of something too small or too big to see otherwise, simplifications of something complex, and "the basis for both scientific explanations of and predictions about phenomena" (p. 116). Models can represent myriad of phenomena including: objects, abstractions, systems and parts of systems, entities, relationships among entities, an event, a behavior, and a process (Gilbert, 2004). Further, models are used in science as products of investigations, frameworks for investigations, and tools for predictions and testing. In a study by Schwartz & Lederman (2005, 2008), experienced scientists described models as mathematical, physical, analogical, or mental constructs that (1) explain or organize observations that then enable prediction and testing through further observation; (2) simplify a complex phenomenon or renders an abstract concept visible; and (3) provide a framework for guiding further investigation. A model is not an exact replica of the actual phenomenon or process; but serves as a representation and/or explanation of the phenomenon (target system) with features that are deemed important and applicable to the structure and function of the target. Features of explaining, predicting, visualizing, simplifying, testing, and showing relationships can all apply to the concept of scientific models. Models allow for multiple representations including physical or structural (solar system, DNA), functional (moon phases, chemical reactions), and analogical (billiard ball model of a gas, liquid drop model of the nucleus).

Mental models. One complications of defining scientific models within a framework of science education is that they can become confused with teaching models or mental models. To make distinctions, we provide some general descriptions of teaching and mental models, as they compare to scientific models. This is not an exhaustive review, as both can be as complex as scientific models. Briefly, mental models are personal, or individual, representations of visual perception, discourse, or reasoning (Johnson-Laird, 1989). As Coll, France and Taylor (2005) suggest, mental modeling is an attempt to understand the world and then to find a way to express that understanding to others. There is little doubt that scientists use mental models in their work; however, they are not equivalent to scientific models because of the personal (individual) aspect of mental models in contrast to the expressed nature of scientific models as examined and critiqued by the scientific community.

Teaching models. Teaching models explain ideas to students. Models, of course, span the spectrum of disciplines, but in science classes teachers may use the same models that scientists use. They may use scientific models for the purpose of teaching, such as working process models or three-dimensional modes. In contrast, they may use other decidedly unscientific models, such as metaphor or analogy. Generally, teaching models are simple representations that form a bridge between reality and mental models and help students understand science ideas (Coll, France & Taylor, 2005).

Developing Learners' Conceptions of Models

Recent literature on learners' conceptions of models examines ideas of specific models from specific fields. Examples include redox models (Osterlund, Berg, & Ekborg, 2010), chemical models such as functional groups and acid/base reactions (Strickland, Kraft, & Bhattacharyya, 2010), and biopolymer (e.g. DNA and proteins) models (Jittivadhna, Ruenwongsa, & Panijpan, 2010). These studies highlight some of the problems associated with learning through models. For example, problems arise when textbooks use different representations of the same model without explanation of the form or purpose of the model (Osterlund et al., 2010). Research also demonstrates the benefits of models for teaching, such as providing students 3-D representations of molecules that are difficult to represent as 2-D structures (Jittivadhna et al., 2010). While models for teaching can be helpful for developing science concepts, these articles do not provide insight into students' conceptions of scientific models in general.

One study of middle and high school students' conceptions of models indicates that students have limited exposure to scientific models in their schooling, and they have a difficult time relating models to science and scientists' ideas (Grosslight et al., 1991). The students described models from a realist perspective, considering models as physical replicas of objects or phenomena. When asked to provide an example of a model, students tended to identify non-scientific models, such as clothing models or toy models. A study by Treagust, Chittleborough, and Mamiala (2002) found that secondary students considered models as tools for learning and held limited understanding of the role of scientific models in the scientific community.