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Teaching about Scientific Models in a Science Content Course

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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 post-test 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.

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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 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.

Crawford and Cullin (2004) found that while preservice teachers also hold narrow conceptions of scientific models, they were able to broaden their ideas to include more explanatory functions through explicit instruction and experience with scientific modeling activities. Despite the improvements, the preservice teachers were still limited in the level of sophistication with which they were able to describe models as explanatory and predictive. The participants tended to separate the structure of models from their function. More research is necessary to understand the contexts in which learners can expand their understanding of scientific inquiry to include scientific models as products, processes, and predictive tools. The current study provides an example of teaching about models in a science classroom context and examines learners' descriptions of models in that context.

Context of the Study

Participants were 71 students enrolled in four sections of an undergraduate biology course designed for preservice elementary and middle school teachers at a large university in the United States. Each section of the course has approximately 24 students. The same instructor (first author) taught all four sections that pertain to the current study, and is an experienced teacher of the class. All sections follow a standard syllabus, use the same lessons, and use the same assessments. This course addresses topics of nature of science, scientific inquiry, cells, genetics, molecular processes, and biotechnology. During the introductory unit on nature of science and inquiry, the concept of models is explored through activities and discussions. Students experience model construction and testing with the nature of science "tube" activity (Lederman & Abd-El-Khalick, 1998; Schwartz & Skjold, 2009) and other introductory lessons. The "tube" is an example of a black box activity where students make observations of the tube and its function and then infer what is on the inside (unseen) of the tube that explains their observations. Students then construct models to test their hypotheses. A valid model is one that serves to explain the functioning of the "real tube" and enables predictions and testing of that function. There are multiple possible constructions for the tube model, and students are probed to consider what makes a valid model, how models might change, and the value of a model even though they may not know if their model is an exact replica of the real thing.

Models are then emphasized throughout the course as specific examples of products and processes in scientific inquiry, as well as teaching and learning tools (Schwartz & Skjold, 2009). Below, we describe how multiple models are embedded within the molecular unit. Similar focus on using multiple representations through models occurs during the other instructional units (cells, genetics, and biotechnology).

Explicit Teaching and Assessments about Models and Molecular Processes

The molecular unit focuses on the biochemical processes of DNA replication, transcription, and translation. Understanding the molecular structure of DNA is a foundation for the unit, from which students then consider how the molecule can be copied and serve as a code for protein synthesis. First, the students study historical cases that lead to the development of the DNA model. They study the work of Griffith, Avery, MacCleod, McCarty, Hershey, Chase, Franklin, Wilkins, Watson, and Crick. Emphasis is on the question "What is the genetic material?" and the specific questions asked, data sought, and assumptions made that lead to the construction, testing, and eventual acceptance of DNA modeled as a double helix. The development and critique of both faulty and accepted DNA models is compared to the student activity with the "tube" models in terms of inferring relationships, explaining observations and function, and enabling prediction and testing. Class discussion also focuses on relevant aspects of nature of science such as tentativeness, creativity, subjectivity, and the empirical nature of science (see Schwartz, 2009). In addition to the analogous tube model and depictions of the Watson and Crick 3D model, students explore other representations of DNA. Students construct a paper model of DNA and a 3D model with pipecleaners and candy. They discuss uses, assumptions, and limitations of each model as it represents different features of molecules and DNA structure. They use the models to predict how DNA replication could occur. As the unit progresses, students are exposed to online simulation models of DNA replication, transcription, and translation. Finally, students design and construct their own dynamic models of the process of translation. These functional models must demonstrate how proteins are made and enable students to predict and test the consequence of an error during the process.

Explicit and purposeful instruction and assessments draw students' attention to the nature of scientific models such as model development (through observation, inference, and testing) and model use (prediction, testing, and guides for further investigation) in the scientific community. The historical episodes provide the context for examining model development, critique, change, acceptance, and utility in guiding further investigations. Class discussions focus on these elements of models, using and comparing the models students construct as well as models scientists construct. Whereas the model of the tube has strong implications for both structural and functional models, DNA models are often only used to suggest structures, while ignoring important functional features. The models can be used to show structural features such as base pairing along with the sugar/phosphate backbone alignment. However, we emphasize that students can move beyond learning structural components of DNA to understanding how the structure of the molecule relates to its function. The two criteria the genetic information had to fulfill were (1) must hold information, and (2) must be faithfully copied. The historical episodes highlight the role of model development and critique, as well as structure/function relationships. Nobody had ever seen DNA, yet (like students did with the tube models) scientists were using a variety of data sources to develop models to show the structure and predict function. Specific questions prompt students to consider models in specific contexts as well as within the broader sense of the scientific community. For example, questions for discussion, short formative writing assignments, and summative assessments include:

- Nobody had ever seen DNA. What type of information did the scientists use to construct a model of DNA?
- What were they trying to explain with the model?
- Consider the first model the Watson and Crick built that Rosalind Franklin evaluated. What aspects of the model did Franklin criticize?
- How can a model be critiqued when nobody has seen the "real thing"? How does this relate to what you did with the tube models?
- Why was the revised DNA model eventually accepted, even though DNA was not directly seen?
- What other scientific models do you know about that explain something that people cannot directly observe? [ex: atom, earth structure, chemical bonding, etc]
- How does Francis Crick relate the pairing of the bases to the ability of the molecule to be faithfully replicated? [How does the structure of the DNA predict how it replicates?]

When the students design, construct, and present functional models of the process of translation, they are prompted to critique the models and discuss their strengths and weaknesses for explaining the process, enabling predictions, and as teaching tools. Good functional models not only appropriately represent the target system, but they also make sense intuitively. Students should be able to apply the model to new situations. Students come to realize that not all models are equal in their ability to explain and predict events. Some questions are:

- What are some of the limitations of these models for explaining and predicting?
- What would be the consequence to the amino acid sequence if a mistake happened at …? (The instructor uses the model to select a location and type of mistake/mutation. Students explain and demonstrate the effect.)

Beyond structure and function, models are also useful for addressing aspects of nature of science. For example, students are asked to consider the creative, tentative, subjective (or theoretical perspective), and empirical nature of science:

- How do scientists know when their model works? [Has evidence to support the structure and function; the model serves to explain the available observations and is consistent with existing knowledge]
- How can there be more than one acceptable model for the same phenomenon (like the tube)?
- What assumptions did scientists make in developing the model of DNA? [subjectivity/theoretical perspective: scientists made assumptions about symmetry, simplicity, and chemical properties]
- How does creativity play a role in the construction and acceptance of scientific models?
- What influences a scientist to change a model? [more information that must be explained by the model; a shift in perspective or different way of thinking about the existing information and how the model serves to explain it]

Finally, students reflect on the use of multiple models as learning tools. During discussion and on a quiz students are asked to explain how they used the various models during the molecular unit to better understand the structure and function of the molecules and processes. They were also asked, as future teachers, to describe how they think models are useful tools for teaching science. By prompting student reflection on the nature of models in the scientific community as well as for science teaching, instruction is explicitly and purposefully targeting the objectives of the lesson.

Data Collection and Analysis

We studied the effectiveness of the instruction on students' conceptions of scientific models. Four sections of the course comprised the sample for this study, with 71 students agreeing to participate. Students were administered the *Views of Nature of Science* questionnaire, version 270 [VNOS-270] (validated version of Lederman *et al.*, 2002, found in Schwartz, 2009) and the *Views of Scientific Inquiry* questionnaire, version 270 [VOSI-270] (Schwartz, 2008) in a pre/post format. One item on the VOSI-270 pertains specifically to models: *Models are widely used in science. What is a scientific model? Give an example of a model*. The second author interviewed approximately 30% of the students at the end of the semesters, following the recommended format of Lederman et al. (2002).

Data were analyzed through analytic induction, seeking emergent themes that described participants' views of scientific models. Each participant's pre responses and post responses + interview were analyzed separately and then compared to identify changes from pre to post in description as well as examples. In the first phase of analysis, codes emerged as descriptors of what students believe scientific models are and how they are used. The second phase used this data to further elucidate if students distinguish between scientific models or other types of models (e.g. Teaching Models). Data were analyzed independently by the two researchers and discussed until at least 90% consensus was reached. We acknowledged that there could be differences among the four class sections. Results were compared across sections and found to be similar enough to justify the combined results. For the current study, we are reporting the results relevant to students' conceptions of scientific models. Results of students' conceptions of nature of science and inquiry can be found elsewhere (Schwartz, 2009).

Results

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?

Table 1 presents the results for the pretest and posttest/interview responses. Some responses fell into more than one category. For example, a response could indicate a model is a physical representation meant to visualize an entity as well as explain a process. Such a response was coded as "physical representations" and "provides an explanation for a process or phenomenon." Thus, the total % for pretest and posttest can total over 100. Table 1 also includes the overall change from pre to post.

Models as physical representations. The preservice teachers began the course thinking of models primarily as physical representations that serve to visualize something that is otherwise too small or too big to see. Few were able to extend their ideas beyond "physical representation" at the beginning of the course. For example, one participant said at the beginning, "*models are a representation of something that is hard to see in its original state.*" She then gave the example of a model that shows the layers of the Earth. Other typical responses described models as 3D objects such as a cell model, solar system, DNA model, or an atom. By the end of the course, 65% of the participants were able to explain how models can be physical representations. Many were able to expand upon these descriptions and fell within more than one category.

Models provide an explanation for a process or phenomenon. There was a shift in ideas about models as simply physical representations to also include models as representations that serve a functional purpose that could provide an explanation for a process or how something works. Initially, only 7% of the students mentioned that models could represent a process or provide a means to understand a process, as compared to 52% of students at the end of the course (+45% gain). For example, in the pretest Maria stated, "*A model is a graph, chart, grid, etc that is organized data about the subject*." In the posttest, she stated, "*A model is an object that models a process.*" In the interview, Maria explained, "*The purpose of a model is to better understand it [a process]. We made translation models and I feel like the only way you're going to know something inside out is if you make it*." Another student stated in the posttest, "*A model is something that shows a process. It is not an exact replica*."

Models are findings or results from an investigation. At the start, 20% of the students described models as the results of an investigation. They considered models to be the actual data or a display of the data, such as a table or chart (as the quote above). Only 11% voiced this view by the end of the course. They shifted away from describing models as data to better understand models as inferred representations that explain data or show relationships. For example, Sara said on the prestest, "*A model is something that shows the findings for others to see.*" She gave the example of "*dinosaur fossils that are put back together so people can see their original structure.*" Sara's posttest showed a change in her ideas, indicating that she now considers models as representations of scientists' ideas.

Table 1. Descriptions of scientific models before and after instruction.

Description of model	Pretest (%)	Posttest (%)	Difference (%)
Physical representation to visualize a phenomenon	35	65	+30
Provides an explanation for a process or phenomenon	7	52	+45
The data or results from an investigation	20	11	–9
Tools for teaching	0	7	+7
Tools for predictions and testing	0	4	+4
The experimental procedure that scientists follow	11	1	–10
Miscellaneous; unclear response	20	9	–11

> *A model is something that is a scientific representation…like the DNA model that no one can see, but it's in a model that is accepted. It kinda represents… it's like a visual way for people to see what it is that scientists are talking about.* (Sara, posttest)

Models are the experimental procedure that scientists follow. A naïve view voiced by 11% of the students at the beginning of the course described models as procedures or steps that scientists follow to experiment. For example, Robert stated, "[a model is] *a diagram that shows how an experiment is done.*" He gave the example of a chart that shows how to plant seeds as an example of a model. Petra stated, "*A model is the scientific method scientists follow.*" Only one student still held onto this conception at the end of the course.

Models are tools for predictions and testing. Scientists use models to make and test predictions. The data indicate that none of the students understood this aspect of models at the beginning of the course. Despite this functional aspect being emphasized throughout the course with multiple model experiences with processes and reactions, only 4% of the students offered "prediction and testing" in their posttest descriptions. Ashley enhanced her understanding of the predictive nature of models, as demonstrated in her posttest response: "[Models] *make abstract ideas concrete… scientists should be able to make predictions from models.*"

Do Preservice Teachers Distinguish between Scientific Models and Teaching Models?

The results from the initial analysis revealed that although students broadened their ideas about models and they also showed a shift toward more abstract ideas about modeling, the results did not clearly indicate if students were more

Table 2. Participants' views of the context of model use.

Description of model	Pretest (%)	Posttest (%)	Difference (%)
Seeing/Visualizing/Scale (no target audience)	25	32	+7
Explaining/Describing a phenomenon (for learners)	34	45	+11
Research/Investigating (for scientists)	33	13	–20

accurately describing *scientific* models per se. There is some indication from the phase one results that despite a small increase in the number of students who understand that models can be used to predict and test (a currently accepted function of scientific models), students may be confusing scientific models with teaching models. To study this, we conducted a separate round of data analysis that looked at the intended audience for models. Who did the student think was going to use the models and why?

Table 2 presents results of phase two analysis. Participants described a model as "*visible*", "*to scale*", an "*appropriate size*", or "*blown up*," because something is "*too big or too small*", "*microscopic*", "*can't be seen with the naked eye*", or is "*not visible to everyone*." As Table 2 shows, the seeing/visualizing/scale model was frequently described with no clear attention to a target audience. The implication is that despite describing models in more abstract terms, students are still reliant on the idea that the purpose of a model is to make something that can't normally be seen, visible (a very concrete idea).

We found that the students had a greater tendency to describe the role of models as tools for teaching and learning, as opposed to tools that scientists use in their research. Thus, the target audience is the learner, not necessarily a scientist or the scientific community. Even though participants were specifically asked about scientific models, there is no indication that they clearly differentiated between scientific and teaching models. The implication is that to nearly half of the students, models are products of inquiry that "*explain processes*", "*show normal people*", "*level people's understanding*", or to "*help comprehend material studied*." The notion of using models for further research and testing, or as part of the process of inquiry, is missing from these responses. Students increased their understanding of models as teaching/learning tools (+11%), while they decreased their mention of models as scientific tools of inquiry (–20%). In the posttest, a few students used more sophisticated descriptions of scientific models as research tools. For example, in one pre-test a student said that models are "*Taking research and showing the results*." In the post-test, she continued with her science-based understanding of models, but had refined her response, saying that a model is a "*tool to observe and interpret*."

Discussion and Implications

The results suggest that students in the biology course were able to shift ideas from seeing models as merely representations of objects, either exact replicas or simplifications, to understanding that models have functions related to processes and explanations of ideas. Students' narrow conceptions at the beginning of the course were consistent with what others have found (Grosslight et al., 1991; Harrison & Treagust, 1996; Ingham & Gilbert, 1991; Treagust et al., 2002). By the end of the course, just over half the students were able to recognize the explanatory role of models, and this category showed the largest gain. Yet not all of these went so far as to say explanations were inferences or representations of scientists' ideas as well as data. The results suggest that the instruction was effective in helping many of the future teachers grow in their conceptions about models and come to understand the role of models in learning science. Some of the participants also recognized that models are more than products that help others understand a phenomenon. However, seeing models as tools for learning was still a predominant view among the participants, with limited understandings about how models are used by scientists to develop and test ideas. These results are consistent with others' findings (Grosslight et al., 1991; Smit & Finegold, 1995; Treagust et al., 2002, among others). According to Grosslight et al. (1991), an expert conception of models focuses on purpose: understanding a phenomenon, testing the model against the real world, model construction with purpose in mind, multiple models for the same thing, and modifications of models. When scientists' describe how models function in the scientific community, they include products of investigations as well as functioning in processes of investigations, especially in predicting and testing (Schwartz & Lederman, 2005; 2008). The findings here suggest that few students came to understand the role of models in making and testing predications. This is consistent with the struggles identified by others (De Jong & Van Driel, 2001; Treagust et al., 2002; Van Driel & Verloop, 1999). While the course was successful in advancing many students' ideas of models to include processes and explanations of ideas, it failed to sufficiently help learners understand the full function of models to the processes of scientific inquiry.

The learning experiences involving multiple representations and multiple models during the course may have contributed to advancing these students' conceptions of models. Treagust et al. (2002) suggested integrating models as teaching tools, with emphasis on how models are used by scientists. Although explicit instruction emphasized process elements of models and provided examples such as how the DNA model lead to predictions regarding DNA replication, the students were better at understanding the role of models in their own learning, as opposed to the role of models within the scientific community. It may be that this was the first time the students had experienced multiple representations of science phenomena as part of their learning. Also, given the prior coursework for these students, it is very likely that this biology course was the first explicit exposure these students had to the nature of science, scientific inquiry, and scientific models. As such, learning the biology concepts may have been viewed as the primary objective to the dismissal of learning about the nature of scientific models. It seems that students require additional or different type of instruction to help them continue developing adequate conceptions of scientific models as integral to processes of inquiry.

There is need to explore whether limited conceptions of the purpose and function of models affects student understanding and application of various scientific models, such as DNA, biochemical processes, atomic structure and behavior, chemical reactions, earth science systems, etc. In addition, future research should consider how instructors can more effectively present models, not only as tools for teaching and learning, but also as scientific tools for explaining, organizing, predicting, testing, simplifying, visualizing and guiding. It is clear that teacher education programs must include explicit instruction about the nature of scientific models.

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