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RESEARCH REPORT

# Students' understanding of the role of scientific models in learning science

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Scientific models are used routinely in science not only as learning tools, but also as representations of abstract concepts and as consensus models of scientific theories. Students' experiences with scientific models help them to develop their own mental models of scientific concepts. This paper discusses the development and evaluation of an instrument to measure secondary students' understanding of scientific models. The results of a study with 228 secondary science students identify five themes about students' understanding of scientific models: scientific models as multiple representations; models as exact replicas; models as explanatory tools; how scientific models are used; and the changing nature of scientific models. The results highlight the need for greater emphasis on the teaching of the role and purpose of the concept of scientific models in science.

## Introduction

As an integral part of the scientific process, models are used in a variety of ways within the science classroom. Teachers use models as aids to help explain scientific phenomena and students often make their own models of scientific phenomena to display their understanding. Indeed, scientific models are often the only way to explain an abstract scientific theory and scientists' consensus models are taught as fact as a result of being the accepted model of a scientific theory, for example, the model of the atom. Personal mental models are constructed from all the information assimilated and understanding is conveyed via each person's expressed model (Gilbert *et al.* 1998a). This diversity in the way in which scientific models are used and perceived is significant.

Scientific models are an important part of the scientific process and although the role of the model and the scientific process are not always taught directly, the concepts are shown through examples in many different topics across the science curriculum. Scientific models have long been used and appreciated as useful tools that enhance learning; however, most elementary and junior high school students regard scientific models as concrete replicas of the real thing, with few students regarding scientific models as representations of ideas or abstract entities (Grosslight *et al.* 1991, Ingham and Gilbert 1991). Grosslight *et al.* (1991) found that students have 'conceptions of scientific models that are basically consistent with a naïve realist epistemology. They are more likely to think of scientific models as physical copies of reality that embody different spatio-temporal

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perspective than as constructed representations that may embody different theoretical perspectives' (p. 799).

Learning is an active process and requires students to construct their own personal schema to assimilate new concepts (Yager 1991). To assist in this constructivist process, scientific models are valuable tools because they can be used to 'make sense of abstract, difficult and non-observable science concepts to accommodate the explainer, the audience, the content and the context' (Treagust and Harrison 1999: 4). However, scientific models used superficially without understanding have been shown to hinder understanding (Cosgrove and Schaverien 1997). Two primary functions of scientific models in teaching are the predictive power of the model and the ability to provide insight into the fundamental nature of the phenomenon (Bhushan and Rosenfeld 1995). Scientific models are tools for prediction and correlation, although their potential is not always fully utilized in the classroom. Nevertheless, recent technological advancements have brought computer modelling and simulations into the realm of everyday life so many students experience simulation games, test their own ideas in strategy games, and drive cars or fly planes by means of computer simulation. These new experiences, including extensive exposure to visual stimuli, will impact on a student's conceptual understanding of what models are and the way models work in learning science.

The objective of this study was to gain some insight into students' understanding of the role of scientific models in learning science. The instrument Students' Understanding of Models in Science (SUMS) has been designed to achieve this. Students have their own personal and unique understanding of the role of scientific models in science built up through their life experiences. These understandings may not always be scientifically correct and may lead to alternative conceptions; teachers' assumptions about the degree of students' understandings of scientific models also may not always be correct. Consequently, a more accurate picture may be obtained through the administration of a pencil-and-paper instrument so that science teachers can be more aware of the range and variety of students' understandings of the role of models in learning science.

## Instrument analysis

### *Subjects*

This study with 228 students from two government, non-selective, co-educational high schools in Perth, Western Australia, involved 69 (30.3%) Year 8 students (age 13 years), 44 (19.3%) Year 9 students (age 14 years), and 115 (50.4%) Year 10 students (age 15 years). The students had received no special teaching about scientific models in science, so the responses reflect their understanding based on the general science curriculum they have experienced.

### *Instrumentation*

The items in the instrument Students' Understanding of Models in Science (SUMS) have been written based on data from a study into the use of chemical models in teaching organic chemistry (Treagust *et al.* 2001) and from Grosslight *et al.*'s (1991) study into students' understanding of models and their use in science. The instrument was designed to gain some insight into students' understanding of what a model is, the role of models in science, including how and why models are used and what causes models to be changed. The SUMS instrument is a 27-item pencil-and-paper questionnaire which requires students to respond on a five-point Likert-type scale, with a choice of responses: strongly disagree (1), disagree (2), not sure (3), agree (4) and strongly agree (5). The Statistical Package for Social Scientists (SPSS) (Coakes and Steed 1996) was used to analyse the quantitative data.

### *Factor Structure*

Factor analysis using a varimax rotation identified five distinct factors in the items of the SUMS instrument which are described as five scales in the instrument: the 'Models as multiple representations' (MR) scale (factor 1); the 'Models as exact replicas' (ER) scale (factor 2); the 'Models as explanatory tools' (ET) scale (factor 3); the 'Uses of scientific models' (USM) scale (factor 4); and 'The changing nature of models' (CNM) scale (factor 5) (see table 1).

The MR scale explores students' acceptance of using a variety of representations simultaneously, and their understanding of the need for this variety. Examples of items from this scale are: 'Many models may be used to express features of a science phenomenon by showing different perspectives to view an object' (item 1); and 'Many models represent different versions of the phenomenon' (item 2).

The ER scale refers to students' perceptions of how close a model is to the real thing. Examples of items in this scale are: 'A model needs to be close to the real thing by being very exact in every way except for size' (item 13); and 'A model should be an exact replica' (item 9).

The ET scale refers to what a model does to help the students understand an idea. This scale includes providing visual enhancement, generating a mental model or providing a concrete representation. Examples of items in this scale include: 'Models help create a picture in your mind of the scientific happening' (item 18); and 'Models are used to physically or visually represent something' (item 17).

The USM scale explores students' understanding of how models can be used in science, beyond their descriptive and explanatory purposes. Examples of items in this scale are: 'Models are used to help formulate ideas and theories about scientific events' (item 22); and 'Models are used to make and test predictions about a scientific event' (item 24).

Finally, the CNM scale addresses the permanency of models. Examples of items include: 'A model can change if new theories or evidence prove otherwise' (item 25); and 'A model can change if there are new findings' (item 26).

The range of items in the SUMS instrument attempts to identify the breadth of students' understanding of particular aspects of models. Each item attempts to identify the details of students' understanding by asking about particular aspects of models that are categorized as scales of the SUMS instrument. A number of items for each scale help ensure consistency of results. Three items load into two factors: item 5, 'Many models may be used to show different sides or shapes of an object' is loaded into the MR and the ET categories. This is not surprising as the models take on these complementary roles simultaneously. Item 14, 'A model needs to be

**Table 1. Factor analysis of the 27-item instrument Students' Understanding of Models in Science (SUMS) (n = 228).**

| | *Factor Loadings* | | | | |
|---|---|---|---|---|---|
| *Item number* | *Factor 1: Models as multiple representations (MR)* | *Factor 2: Models as exact replicas (ER)* | *Factor 3: Models as explanatory tools (ET)* | *Factor 4: Uses of scientific models (USM)* | *Factor 5: Changing nature of models (CNM)* |
| 1 | 0.75 | | | | |
| 2 | 0.62 | | | | |
| 3 | 0.61 | | | | |
| 4 | 0.60 | | | | |
| 5 | 0.59 | | 0.48 | | |
| 6 | 0.57 | | | | |
| 7 | 0.52 | | | | |
| 8 | 0.50 | | | | |
| 9 | | 0.80 | | | |
| 10 | | 0.67 | | | |
| 11 | | 0.65 | | | |
| 12 | | 0.64 | | | |
| 13 | | 0.60 | | | |
| 14 | | 0.55 | 0.51 | | |
| 15 | | 0.50 | 0.45 | | |
| 16 | | 0.47 | | | |
| 17 | | | 0.66 | | |
| 18 | | | 0.66 | | |
| 19 | | | 0.61 | | |
| 20 | | | 0.45 | | |
| 21 | | | 0.41 | | |
| 22 | | | | 0.83 | |
| 23 | | | | 0.70 | |
| 24 | | | | 0.69 | |
| 25 | | | | | 0.70 |
| 26 | | | | | 0.67 |
| 27 | | | | | 0.47 |
| % variance | 33.2 | 8.6 | 5.2 | 4.8 | 4.1 |
| Eigenvalue | 8.97 | 2.32 | 1.40 | 1.28 | 1.11 |

Factor loadings less than 0.4 omitted.

close to the real thing by giving the correct information and showing what the object/thing looks like', and item 15, 'A model shows what the real thing does and what it looks like', are loaded into the ER and ET scales. These items reflect both of these aspects of models. These three items are discussed for each of the two scales that they represent.

### *Data Analysis*

The reliability of each scale ranged from 0.71 to 0.84 (see table 2) showing that the instrument has high internal consistency for each scale; item-to-total correlations were above 0.45 except for item 16. A bi-variate correlation of the five scales (see

**Table 2. Descriptive statistics and reliability of the five scales of the SUMS instrument (n = 228).**

| *Scale* | *Number of items* | *Mean* | *Standard deviation* | *Cronbach alpha reliability** |
|---|---|---|---|---|
| Models as multiple representations (MR) | 8 | 3.52 | 0.63 | 0.81 |
| Models as exact replicas (MR) | 8 | 3.58 | 0.71 | 0.84 |
| Models as explanatory tools (ET) | 5 | 3.58 | 0.71 | 0.71 |
| The uses of scientific models (USM) | 3 | 3.41 | 0.73 | 0.72 |
| The changing nature of models (CNM) | 3 | 3.73 | 0.74 | 0.73 |

* a measure of the internal consistency of each scale.

**Table 3. Bi-variate correlation of the five scales in the SUMS instrument (n = 228).**

| *Scale* | *2 (ER)* | *3 (ET)* | *4 (USM)* | *5 (CNM)* |
|---|---|---|---|---|
| (1) Models as multiple representations (MR) | 0.61** | 0.63** | 0.47** | 0.58** |
| (2) Models as exact replicas (ER) | | 0.49** | 0.30** | 0.52** |
| (3) Models as explanatory tools (ET) | | | 0.46** | 0.52** |
| (4) The uses of scientific models (USM) | | | | 0.30** |
| (5) The changing nature of models (CNM) | | | | |

** Correlation is significant at the 0.01 level (2-tailed).

table 3) shows a high level of correlation indicating that students' responses to each scale are related and consistent.

The distribution of scores for each scale of the SUMS instrument is concentrated closest to the 'agree' elective (table 4). The CNM scale has the most highly agreed upon response while the USM scale has an even distribution between the 'not sure' and 'agree' responses. The use of the word 'phenomenon' in three items of the SUMS instrument corresponded to a high 'not sure' response indicating that students were not familiar with the word; consequently, results involving items using this word are considered guardedly. A one-way ANOVA (Coakes and Steed 1996) showed no statistically significant differences for any of the scales between year levels. An independent *t*-test identified a significant difference in gender for the ET scale only, with the results indicating that females responded more positively than males to the items in this scale.

## Discussion of the five themes

Through the analysis of the data from the instrument, a number of themes concerning scientific models that related to the five scales identified in the factor analysis of the SUMS instrument consistently emerged:

(1) Scientific models as multiple representations
(2) Models as exact replicas
(3) Models as explanatory tools
(4) How scientific models are used
(5) The changing nature of scientific models

**Table 4. Results of students' understanding of models (SUMS) (n = 228).**

| *Factor†/ Item Number* | *Item* | *Mean (sd)* | % *Disagree** | *Not sure* | *Agree*** |
|---|---|---|---|---|---|
| MR/1 | Many models may be used to express features of a science phenomenon by showing different perspectives to view an object. | 3.56 (0.96) | 12 | 27 | 61 |
| MR/2 | Many models represent different versions of the phenomenon. | 3.33 (0.97) | 15 | 41 | 44 |
| MR/3 | Models can show the relationship of ideas clearly. | 3.67 (0.97) | 11 | 27 | 62 |
| MR/4 | Many models are used to show how it depends on individual's different ideas on what things look like or how they work. | 3.56 (0.91) | 10 | 34 | 56 |
| MR/5 | Many models may be used to show different sides or shapes of an object. | 3.60 (0.86) | 11 | 25 | 64 |
| MR/6 | Many models show different parts of an object or show the objects differently. | 3.44 (0.93) | 14 | 34 | 52 |
| MR/7 | Many models show how different information is used. | 3.51 (0.93) | 11 | 34 | 55 |
| MR/8 | A model has what is needed to show or explain a scientific phenomenon. | 3.52 (0.93) | 13 | 30 | 57 |
| ER/9 | A model should be an exact replica. | 3.14 (1.17) | 36 | 21 | 43 |
| ER/10 | A model needs to be close to the real thing. | 3.74 (1.10) | 13 | 18 | 69 |
| ER/11 | A model needs to be close to the real thing by being very exact, so nobody can disprove it. | 3.35 (1.09) | 23 | 28 | 49 |
| ER/12 | Everything about a model should be able to tell what it represents. | 3.61 (0.94) | 14 | 23 | 63 |
| ER/13 | A model needs to be close to the real thing by being very exact in every way except for size. | 3.57 (1.11) | 18 | 20 | 62 |
| ER/14 | A model needs to be close to the real thing by giving the correct information and showing what the object/thing looks like. | 3.83 (0.99) | 9 | 16 | 75 |
| ER/15 | A model shows what the real thing does and what it looks like. | 3.69 (0.91) | 9 | 26 | 65 |
| ER/16 | Models show a smaller scale size of something. | 3.77 (1.06) | 15 | 15 | 71 |
| ET/17 | Models are used to physically or visually represent something. | 3.85 (0.95) | 9 | 17 | 74 |
| ET/18 | Models help create a picture in your mind of the scientific happening. | 3.55 (1.06) | 16 | 19 | 65 |
| ET/19 | Models are used to explain scientific phenomena. | 3.36 (0.88) | 12 | 43 | 45 |
| ET/20 | Models are used to show an idea. | 3.80 (1.02) | 12 | 9 | 79 |
| ET/21 | A model can be a diagram or a picture, a map, graph or a photo. | 3.46 (1.11) | 20 | 22 | 58 |
| USM/22 | Models are used to help formulate ideas and theories about scientific events. | 3.41 (0.87) | 14 | 37 | 49 |
| USM/23 | Models are used to show how they are used in scientific investigations. | 3.46 (0.95) | 15 | 32 | 53 |
| USM/24 | Models are used to make and test predictions about a scientific event. | 3.35 (0.90) | 14 | 42 | 44 |
| CNM/25 | A model can change if new theories or evidence prove otherwise. | 3.82 (0.90) | 6 | 23 | 71 |
| CNM/26 | A model can change if there are new findings. | 3.79 (0.90) | 7 | 22 | 71 |
| CNM/27 | A model can change if there are changes in data or belief. | 3.62 (0.90) | 10 | 26 | 64 |

† MR (Models as multiple representations); ER (Models as exact replicas); ET(Models as explanatory tools); USM (The uses of scientific models); and CNM (The changing nature of models).
* Disagree = Strongly Disagree and Disagree. ** Agree = Strongly Agree and Agree.

Selected data that support each theme are analysed, presented and discussed. The consistent and contradictory examples of the data are examined and implications from the results discussed.

### *Theme 1: Scientific models as multiple representations*

Alternative scientific models can provide a variety of perspectives and appearances and most students show an appreciation of these (table 4, factor 1, items 1–8). Consistently, approximately 60% of students agreed that the use of multiple models is useful to show different perspectives, different views and different versions of an object. More than half of the students recognized that a variety of scientific models are useful in catering for individual differences (table 4, item 4). These consistent results show that more than half of the respondents recognized the need for multiple scientific models to cater for particular aspects of the item as well as catering for individual needs of the learner. By recognizing the value of multiple scientific models we can infer that students have an understanding that a model is just one representation of an entity and that each representation displays a particular perspective or emphasis. These results contrast with those of Grosslight *et al.* (1991: 816) where 'very few of the mixed ability 7th and the honors 11th graders even hinted at the sense of multiple modeling'. Considering the extensive use of multiple representations in science, the need to recognize multiple representations and be able to transfer from one representation is important.

### *Theme 2: Scientific models as exact replicas*

The SUMS instrument showed that 43% of students agreed that a model was an exact replica (table 4, factor 2, item 9). The responses consistently confirm that models need to be 'close to the real thing' (items 14, 10, 11 and 13). These results indicate that there is a significant group of students with a narrow and naïve understanding of the concept of a model as an exact replica. This corresponds to scale scientific models that are usually representative of more familiar and better-understood objects, for example, a model ear or a globe of the earth, for which accuracy and detail are crucial. Despite this, as many as 20% of the students realize that there is more to scientific models than just being a copy of the original. When scientists model abstract and unknown entities, often the actual appearance is not known or is irrelevant and the representation – which does not have accuracy or detail – can provide insight into why and how something works the way it does.

In considering the need for scientific models to be accurate and closely represent the real thing, 75% of students agree that a model needs to be close to the real thing by giving the correct information and showing what the object looks like (table 4, factor 2, item 14); 62% agree that a model should be exact in every way except for size; and 49% agree that the model must be very exact, so nobody can disprove it (table 4, items 11 and 13). The data consistently confirm that some students continue to regard scientific models as exact duplicates of reality. Similar results have been obtained in other studies (Grosslight *et al.* 1991, Ingham and Gilbert 1991, Harrison and Treagust 1996). This stumbling block associated with models is recognized by Hardwicke (1995) who emphasized the role of the teacher in 'distinguishing the positive and negative analogies as clearly as possible' (p. 64) so that students realize the limitations of the model. Students seem to be faced with a dilemma of trading off the accuracy of the model (exact replica) with the concept of a model providing insight into specific aspects of the entity, even though this could mean that the model is not totally accurate. These results distinguish two types of models: the scale replica, a precise representation, which has accuracy and detail; and the imprecise representation, which doesn't have the accuracy or detail, and may be nothing like the object, but can provide insight into why and how something works the way it does. Students' experiences with everyday models are usually associated with the first type, whereas scientific models, especially of the more abstract concepts, would more commonly fall into the latter scale. Students' awareness of the type of model being used is a most important issue when considering their understanding of the role of scientific models in learning.

### *Theme 3: Models as explanatory tools*

Models are often used to represent things that are too small or too big to be seen with the eye, so, in this way, models are the only visual representation that the learner sees. The visual aspect of scientific models applies to many forms of scientific models and is described by Gilbert *et al.* (1998b) as providing a form of visual explanation, which helps students link the known and the unknown, familiar and the unfamiliar (Collins and Gentner 1987). The responses to the SUMS instrument revealed that most students valued this descriptive aspect of models with the majority agreeing to statements such as 'models are used to physically or visually represent something' (table 4, factor 3, item 17, 74%) and that 'many models show different sides or shapes of an object' (factors 1 and 3, item 5, 64%) and 'a model shows what the real thing does and what it looks like' (factors 2 and 3, item 15, 65%).

The results suggest that most students are aware of the value of the visual representation that many scientific models provide. The ability of the student to take advantage of the features of a model must be taken into consideration when assessing the value of a particular model; consequently, with visual representations and three-dimensional representations, a student's spatial ability is a significant factor in the success of using the model. In a study investigating the effects of visually stimulating computer-generated representations, Barnea and Dori (1999) showed that there is a strong correlation between spatial ability and achievement in science, which is not surprising considering the dependence on scientific models in the form of diagrams, graphs, tables and three-dimensional scientific models. The close relationship between models and explanations identified by students in their responses is significant. Students use models to make a connection between the observed phenomena and the scientific explanation. Through this process, students generate a mental model as explained by Gilbert *et al.* (1998a). Many topics in science require students to generate their own mental models and students are aware that physical representations can help them to generate their own mental models and understand new concepts. Teachers routinely make use of models and representations to assist students to construct their own mental model. This is particularly relevant and useful for abstract ideas. Students have indicated a good understanding of this role of models as explanatory tools in their responses to the SUMS instrument with the majority agreeing that 'Models are used to show an idea' (table 4, factor 3, item 20, 79%), and that 'Models help create a picture in your mind of the scientific happening' (item 18, 65%). It is interesting that students are able to recognize this quality of models that enables them to develop mental models and conceptual models for new concepts (Tiberghein 1994, Duit and Glynn 1996). Modelling is an instinctive behaviour and the explanatory role the model adopts is most useful in learning science (Gilbert and Boulter 1998).

The diverse forms that a model may take may include an idea, an object, event, system or process (Gilbert and Boulter 1998). The variety of forms that can be represented were appreciated by the majority of students with 58% agreeing that a model can be a diagram, picture, map, graph or photo (table 4, factor 3, item 21). However, the remaining 42% of students 'disagreed' or responded with 'not sure' to this description of a model, indicating that they do not regard all of these particular items to be models. With respect to scientific models, the implied meaning of the term model is broad and includes many representations compatible with the variety of representations used in explaining science; however, the meaning of the term 'model' in general everyday use is narrower and hence may lead to misunderstandings. The contextually relevant dictionary meaning of the term 'model' is '(1) a standard or example for copying or comparison; (2) a representation, usually on a small scale; (3) an image in clay or wax' (The Macquarie Essential Dictionary 2000: 508). The discrepancy between the definition, understanding, and use of the term model could explain the students' lack of understanding of the concepts of models and model building in science (Gilbert 1991).

### *Theme 4: How scientific models are used*

Approximately 50% of students agreed that scientific models are used for making predictions, formulating theories and showing how information is used (table 4, factor 4, items 22, 23 and 24); approximately 50% of students either were not sure or disagreed with this view. In this instance, there is evidence that many students do not understand how scientific models are used in the development of scientific ideas and theories. In Grosslight *et al.'s* (1991) study into students' understanding of the role of models in science, similar results were found and it was recommended that students

> be provided with some experiences using models to solve intellectual problems. In this way students would have an opportunity to learn that a model can be used as a tool of inquiry and that it is not simply a package of facts about the world that needs to be memorized. (Grosslight *et al.* 1991: 820)

The application of models beyond a descriptive nature, as described in theme 3, seems to be beyond the understanding of many of these student respondents. If the results reflect students' experiences, then it would be suggested that students have had experience with scale models and descriptive models but have not used models in a quantitative or interpretive fashion. Stephens *et al.* (1999) reported that model-based reasoning is not practiced in school science and consequently students have no experience with models being used in a scientific way. Similarly, Gilbert *et al.* (1998a) report on the value of mathematical and symbolic representations which allow predictive, interpretive and causative varieties compared to the more descriptive explanations of visual, verbal and physical models. Obviously, the descriptive models are most valuable for teaching and are used extensively; however, there is a need to make more use of interpretive and predictive models in the teaching process.

### *Theme 5: The changing nature of scientific models*

Over two-thirds of students showed an appreciation that models are constructs to support scientific theories and that they will change according to changes in scientific thinking. This is supported by strong agreement for statements in the SUMS instrument, such as 'A model can change if there are new findings' (table 4, factor 5, item 26, 71%), or 'A model can change if new theories or evidence prove otherwise' (table 4, item 25, 71%). The consistency of these results confirms that more than two-thirds of those students have a clear understanding of the changing nature of scientific models in response to changes in scientific thinking. This aspect of models introduces students to the important feature of the uncertainty of scientific knowledge and the nature of science, which has been shown to be lacking even in Grade 12 chemistry students (Boo 1998). Students' understanding of the nature of science has been shown to influence their learning in science (Songer and Linn 1991), so it is a most important aspect of their learning to foster.

## Conclusion

This analysis has focused on the difficulties associated with understanding the model concept, but this should not detract from the results that have shown that many students have a good understanding of the role of scientific models in learning science. Students' interpretation of the term 'scientific model' will depend on their experiences and personal understanding. Models as multiple representations (factor 1) were recognized as being necessary and useful by the majority students, and they appreciated the visual value of scientific models in helping to generate their own mental models. Students showed a good appreciation for the changing nature of scientific models (factor 5), which was linked to the changing nature of scientific knowledge.

However, there are inconsistencies in the percentage of students' responses, in that some students clung to the understanding that a model is an exact replica (factor 2) supporting the descriptive concept of a model. The categorization of a model as a precise representation or an imprecise representation helps to explain some of the conflicting ideas that students have about scientific models. When dealing with more abstract concepts it is assumed that students would adopt a more abstract nature of scientific models, but this is not necessarily true. While this study has specifically focused on scientific models, students' experience with general models is the starting point in their understanding of scientific models. General models more commonly fit into the category of scale replica, whereas scientific models assume many forms and are used more analytically (Hardwicke 1995). By highlighting these subtle differences between different types of models, they may be used more effectively in teaching and learning science.

The results of this instrument showed that the majority of students understood that scientific knowledge can change (factor 5), with new ideas and theories resulting in changes to the accepted scientific models. We also can conclude that a large majority of these students understood the descriptive role of models (factor 3), but there is scope to expand the applicable role of models in scientific ways such as making predictions and testing ideas (factor 4). The evaluation and use of scientific models in this way could improve students' understanding of the use of scientific models in the development of scientific ideas as well as developing a better understanding of the particular content area.

Under a constructivist philosophy, learning in science requires students to take ownership of an idea or concept, reconstruct it, internalize it and be able to explain or communicate it to others. Models serve as invaluable tools in this process. The links between models and learning are indisputable; however, there is evidence in these results that many students do not fully appreciate scientific models. The reason for this could be lack of opportunity to use models effectively and applicably, or teachers may fail to emphasize the strengths and limitations of particular models and thereby create misunderstandings in students' perceptions. The vast extent to which models are used in the scientific field provides inspiration to further the use of models in the science classroom to enhance learning in a scientific manner.

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