

# PRE-SERVICE SCIENCE TEACHERS' PERCEPTIONS AND ATTITUDES ABOUT THE USE OF MODELS

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## Introduction

In recent years we have witnessed a growing interest in model-based science teaching and learning. Researchers in this area are interested in how models and modeling can play a role in science teaching and learning (Gobert & Buckley, 2000). In science, because the forging of new scientific knowledge and ideas depend on the development of models, almost all scientists today use models to build, represent, replicate, observe, and test their ideas, hypotheses, and theories. Although the methodologies of science teaching and learning are different than doing science, teachers also use models and modeling steps to help students make sense of natural phenomena and visualize scientific concepts to advance students' understanding of scientific knowledge. If a science teacher is familiar with the concept of model and needs to develop a model, he/she will quickly realize that models can be used in everyday conversations, learning, experimenting, and making predictions. Therefore, understanding the nature of models, building and using models in science teaching and learning is the core of science curriculum (Gilbert & Ireton, 2003; Oh & Oh, 2011).

On the other hand, formation of a teacher's attitude towards the use of models could be affected by the teacher's beliefs about the nature of models and modeling and the amount and type of information the teacher has about the object of attitude (Henze, Van Driel, & Verloop, 2008; Justi & Van Driel, 2005b, 2006). Therefore, a science teacher's attitude may be attributed to positive or negative tendencies towards the use of models in science teaching. The ways that a teacher judges and evaluates the object, define teacher's perceptions. These can also influence his/her teaching and attach meanings to the teacher's experiences. Because the teacher's attitude, consistent tendencies to respond in a particular way, and perception influence his or her teaching efficacy, teaching style, and instructional methods; consequently, they are also associated with developing students' beliefs and attitudes as well as increase in students' academic achievements. Therefore, it is important for teacher educators to understand and study science teachers' perception and attitudes towards the use of models.

The concepts of model, modeling and how we define these concepts are also fundamental parts of science and technology curriculum (AAAS, 1993;



JOURNAL  
OF BALTIC  
SCIENCE  
EDUCATION

ISSN 1648-3898

**Abstract.** *Models are central constructs of science teaching and learning. This research aims to report on seven pre-service science teachers' perceptions and attitudes towards models and the rationale for using models in science teaching. Semi-structured in-depth interviewing, an open-item questionnaire, and a five-point Likert scale questionnaire were used to obtain data from the participants. No evidence of negative attitude towards the use of models was observed among the participants. Although the pre-service science teachers (PSTs) valued the idea that scientific models are important aspects of science teaching and learning, they were hesitant to use and build models as teaching tools. Four categories related to the perceptions about the rationale for using models were identified from the data namely, promoting interest and attention, promoting understanding due to illustrative and representative nature of models, promote concretization as instrumental tool and promoting theoretical understanding in science. The findings indicated that the PSTs showed positive attitudes towards the use of models in their teaching, but certain factors like level of learner, time, lack of modeling experience, and limited knowledge of models appeared to be affecting their perceptions and attitudes negatively.*

**Key words:** *modeling experience, pre-service teacher, science teacher, use of models.*

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Danusso, Testa, & Vicentini, 2010; Oh & Oh, 2011). A model can be defined as "a representation of an idea, an object, an event, a process or a system" (Gilbert & Boulter, 1998, p. 53). Such representations are the expressions of ideas, systems, or natural phenomena by means of variety of forms. These forms can be constructed by texts, drawings, verbal expressions, etc. In the science classroom for instance, forms of models can be used to teach about galactic objects, gravity, or molecular structures that are inaccessible and invisible to us. Hence, in all these and similar cases, science teachers can construct or use models to assist their students. Undeniably, the emphases on the nature of models and modeling in science teaching and learning have been increased by the reforms in science education (AAAS, 1990, 1993; NRC, 1996; Oh & Oh, 2011). General suggestions, recommendations about models and the use of models as curriculum materials have improved the need for better understanding the role of models in teaching. More specifically, Magnani and Nersessian (2002) suggested that use of models can influence our cognitive functions; resulting a new form of reasoning known as 'model based reasoning'.

An earlier study by Smit and Finegold (1995) surveyed prospective science teachers' perceptions of models and found that most prospective science teachers believed the main function of a model is to explain complex or abstract targets. The researchers also reported that more than half of the participants thought that a model is a copy or an example of real, natural phenomena. In another study, Van Driel and Verloop (1999) lucidly showed that experienced teachers' understanding of models is highly diverse and inconsistent. According to Gilbert and Ireton (2003), variations and inconsistencies among teachers' views and perceptions of models are especially evident on the use of models in science teaching.

Harrison's (2001) study focused on the modeling abilities of teachers. The researcher interviewed ten experienced science teachers and found that individually teachers' perceptions about models and their use of models in science classroom are all showed variations. Harrison's study also showed that the disagreements among the teachers were also common and at least six of them disagreed with various assertions (models are main products of science, models are major tools of science, models are important learning tools, and models are important teaching tools) on models. The results from Van Driel and Verloop's (2002) study on the other hand focused on experienced teachers' use of models. The interview outcomes from seven biology and chemistry teachers revealed discrepancies in the teachers' use of teaching activities about models and modeling in science. It is suggested by Van Driel and Verloop (2002) that teachers should be practicing with concrete examples before teaching activities. Justi and Gilbert's (2002a) study investigated teachers' perceptions on the use of models and modeling in science teaching. Based on the interview data from 39 science teachers' perceptions and ideas, the participants were grouped into three classes; "the status and value of models in science education, translation of teachers' beliefs into the classroom context, and teachers' responses to the outcomes of students' modeling activities" (p. 1279). Overall, all these studies provided valuable implications about promoting and changing science teachers' attitudes towards model-based conceptual science teaching and learning.

Today, models and modeling are essential parts of the field science education. Models are in use by means of providing tools, promoting learning, and developing conceptual understanding. However, there are still big questions on how we use and develop models, their efficacy, and what is necessary for a successful model-based teaching and learning.

#### *Problem of Research*

Despite the increasing emphases on models and the use of models in the science curriculum, it appears that science teachers', specifically pre-service science teachers' attitudes, knowledge and their perceptions of scientific models and the rationale for using modeling have not been researched well. Only a small number of studies have addressed the PSTs' knowledge and attitudes of models (Crawford & Cullin, 2004; Danusso, Testa, & Vicentini, 2010; Henze, Van Driel, & Verloop, 2007a, 2007b; Justi & Gilbert, 2002a; Justi & Van Driel, 2005a; Van Driel & Verloop, 1999). Common results from the literature indicated that most science teachers' use of models is either limited or insufficient (Justi & Gilbert, 2003; Oh & Oh, 2011; Van Driel & Verloop, 1999, 2002). The findings also revealed that both in-service and PSTs have inadequate knowledge of models and modeling. Likewise, although they mainly investigated experienced or in-service teachers, there are only few studies that have been published on teachers' use and understanding of models and modeling (Justi & Gilbert, 2002a, 2002b, 2003; Smit & Finegold, 1995; Van Driel & Verloop, 1999, 2002). Yet none of these studies specifically addressed the PSTs' perceptions and attitudes towards the use of models and modeling in science teaching.



### *Statement of Purpose*

The purpose of this research was to explore pre-service science teachers' perceptions and attitudes towards the use of models in science teaching. Given this position, the following main research question was guiding the study: What perceptions and attitudes do these pre-service science teachers hold about models and the rationale for using models in science teaching?

### **Methodology of Research**

This research is established by the qualitative inquiry traditions. The data systematically gathered and analyzed through research process to observe the PSTs' experiences and perceptions about using scientific models.

### *The Participants*

The participants were teacher learners from a large Midwestern university in the United States. Seven PSTs (six females and a male) voluntarily participated in the study. The participants were coded S1 through S7 for data analysis. Except S6, who was from chemistry teacher education program, all participants were enrolled in biology teacher education program. As a result of their educational training, they all have engaged in student teaching and they all had taken methods classes.

### *Instruments and Data Collection*

Two main instruments, a semi-structured in-depth interviewing and an open-item questionnaire, were used to obtain data from the participants. At first, the participants received the open-ended questionnaire to be answered individually at home. Later, they (S1 through S5) were interviewed on their knowledge, attitudes, and perceptions about the nature of models, modeling, and use of scientific models. The participants S6 and S7 however, did not want to be interviewed. All interviews were audio-recorded and each session lasted about 50 minutes. The interview and the questionnaire were designed based on the instruments from the studies of Grosslight, Unger, Jay, and Smith, (1991) and Justi and Gilbert (2003). The instrument contained seven open-ended questions with a number of guiding questions to obtain more information regarding participants' mental processes.

After the interviews, the subjects also responded to a seven-item Likert-type scale questionnaire as third data gathering instrument in order to obtain clearer picture of their perceptions and attitudes about scientific models. The Likert-type scale questionnaire, on a five point scale of strongly agree to strongly disagree was administered to only interview participants. Because the number of participants was small, the interpretation and analysis of the data from the Likert-type scale questionnaire were done only qualitatively. Following the PSTs' responses to each item, the researcher asked for an explanation of their rationale and why they selected the particular scale. Thus, the Likert-type scale questionnaire also produced valuable qualitative data.

### *Data Analysis*

Qualitative inquiry methods were used in this research. The data obtained from the questionnaires and the interviews were processed based on qualitative coding techniques. A cluster of data coded as [149:S3:] indicates the line number within the interview data from the participant S3. All the data including audio-taped recordings were transcribed and read many times in order to capture the emerging themes and trends. The data were analyzed by using an interpretative phenomenological perspective (Smith, 1995), following the techniques and procedures as described in Smith, Harrè, and Van Langenhove (1995), and Strauss and Corbin (1998). Further detailed analyses were performed to reveal possible connections, clusters, and concepts. Lastly, the emerging master themes and trends were translated into narrative accounts. The ATLAS.ti (Ver. 5.0) qualitative data analysis software was used to explore data and offered many advantages to the researcher such as coding, indexing of the text, processing and reprocessing large data sets, and producing reports for each of the categories and major themes.



## Results of Research

### *Perceptions and Attitudes about Models*

Analyses of the data provided valuable findings about the PSTs' perceptions and attitudes about models. The first four items in the Likert-type scale questionnaire, known as Gilbert's assertions, focused on the participants' views and perceptions about models. The last three items provided information about the PSTs' attitudes and levels of agreement on models in science teaching. The assertions provided information about the participants' understanding of the role of models in science teaching as well as doing science. It was observed that all participants agreed with the first assertion and thought that *models are main products of science* (item 1), for example:

They're products of science because we wouldn't have models if nobody studied science. People make the models because they studied something in science and then decided they make the model. I mean that's how models originated and then it's to help people understand... [118:S2:]

Hmm, well any time you put any research you're gonna have graphs and data and you're explaining something more thoroughly that would be a model ... so I think most of the time it would be a product. [149:S3:]

Unlike the results for the first assertion, only three participants (S1, S2, and S3) strongly agreed with the second assertion that *models are major tools of science* (item 2); while the remaining two participants agreed with the statement. How the PSTs made distinctions between the first and the second statement, however, was not obvious, for example:

Hmm, I guess scientists will use the existing models hmm to do work and they may change it but I think that's part of what they do you know. They, they may be really working on them but they're using them at the same time. [107:S5:]

It has been found that four of the participants strongly agreed with the third assertion, *models are important learning tools* (item 3). However, S4 agreed with the assertion implying that scientific models are reliable and they can be effective examples for people, for example:

Hmm, because they've [scientific models] been researched, they've been supported, they've been used in the past and are effective. [107:S4:]

S3: I mean like I would always try to do hands on stuff. I think hmm I think you have to, to be able to learn something you have to have a model I think you have to.

Researcher: So you're saying you can't learn anything without having a model.

S3: ... try to read a book but [it] doesn't have any pictures or anything and you didn't know what things were like. How can you explain like the color red to someone?

Researcher: Huh huh.

S3: And you would never know, you could have your own thought but unless you had a model of what red was you would never know what red was. So, I think that's very important. [151:S3:]

For the fourth assertion, three PSTs (S2, S4, and S5) agreed that *models are important teaching tools* (item 4), while S1 and S3 strongly agreed with this statement.

Hmm because I guess not all concepts we need to use the models for, but in general they're important to use in the classroom. [125:S2:]

... I'm not strongly agree because I think they [students] really need to internalize the information on their own. They [students] need to do a lot of the work. The teacher can only do so much, so you may use this model as, you know, part of a unit or you know other aspects of teaching but the students needed to do a lot of the work I think. [110:S5:]



Overall, in this study all five participants either agreed or strongly agreed with Gilbert's assertions. In addition, all participants, except S4, were unsure about the item 5; *models should be designed by students rather than given to them*. The PSTs' perception about allowing students to build their own models was also evident in the interview data. Moreover, this item also evidences the PSTs' neutral attitudes towards allowing their students to build models in science classes. Although the participants believed that it could be useful for students to build and design their own models, nonetheless they were unsure about it. The participants thought that because of certain factors such as the level of students, students' prior knowledge of the topic, students' modeling experience, and time, it could be difficult to let students design their own models. Thus, the PSTs were doubtful about the item, for example:

That's a tough one, I'd think that would be great for students to make their own models it really helps them learn for themselves ... but also if they don't understand it, the model might not be entirely accurate and that can make things worse so, let's see, I'm kinda neutral on that I can see both ways. [143:S1:!] ]

I guess I would may be have to say neutral because I can say that in some circumstances it would be useful to give students a model they're just beginning to learn about the topic you can't just expect them to come up with a model on their own. Hmm but may be for more advanced students or more advanced class you could have them come up with their own ideas. [115:S5:!] ]

Among the PSTs responses to items 6 (*science teachers do always use models in their teaching*) and 7 (*models used in science teaching should be different than models used in science*), similar levels of agreement were observed from the same participants. Overall, two of the five teachers (S2 and S4) disagreed with item 6; indicating that teachers do not always use models in science teaching, for example:

Because I've had some biology professors just completely, just lecture and not showed us any pictures or just gave notes the entire time. So, not all science teachers do and they should, I think they should but they don't. [129:S2:!] ]

In my experience science teachers don't always use models. Sometimes like, I wanna be a teacher [that] always uses models as much as I can because I find that's connecting. So I wanna be a teacher that effectively uses models because they're very effective inquiry and learning tools. Unfortunately I've had experiences in college and both high schools where teachers rely on one form of teaching ... models are not effectively used in all cases ... So in my experience no, science teachers [do] not use [models always] but for me personally I wanna be a teacher that uses models. [113:S4:!] ]

Interestingly, the same participants, S2 and S4, also disagreed with item 7 indicating that models used in science teaching and science should not be different. However, S2 also responded that for high school level she agreed, because models used in science teaching should be different or relevant to students. Conversely, S1, S3, and S5 agreed with the statement indicating that models used in science teaching should be different than the ones used in science. For example:

Hmm if it's the college level teaching, at the college level it should be the same. But thinking about the high school and below, I would say disagree because I would say in high school it probably should be a little more simple than what scientist use ... In high school, I would say agree, they should be little more simple. At the college level, teaching at the college level it should be same there should be no difference. [133:S2:!] ]

I guess it comes back to the level of the student you know. If the model that you used in science or gonna be with scientists who are experts on the topic you'll have perhaps much more detailed model and science teaching it would be very basic course on the topic. You may use the same model but take out some of the extra details it might be too complicated but I think you should use the same general idea ... I guess I would agree ... so in science teaching it's probably be less complex than a model ... scientists would use but it's gonna be the same general information. [122:S5:!] ]

Generally, given their responses to the last three items, the PSTs' level of agreement was variable yet showed certain patterns about science teachers and models in science teaching. One clear instance emerged from the



item 5, suggesting that the PSTs have neutral attitudes towards the idea that suggests models to be designed by students rather than teachers. Moreover, early in the study, one of the questions in the open-ended questionnaire specifically asked for the PSTs' opinion, whether models used in teaching should be different from those used in science. Generally, the PSTs thought that models should not be different but in some cases, due to the complexity of the model, they thought, models used in science teaching could be modified to the level of learner, for example:

In teaching, the models should be kept simpler. In science, the models can be more complex because scientists will be able to understand the details. [156:S2:Q]

No. Any model used in science should be used in teaching science so the students get a real world experience with learning science. Scientists use graphs and other such things to model data. It is important for students to be able to produce graphs and read them so they can understand the process at hand. [145:S3:Q]

Only when absolutely necessary. For the full understanding of the audience, jargon that is too specialized may have to be simplified if clarification, explanation is insufficient at the time the model is presented. [142:S7]

The findings showed no clear evidence of negative attitude towards the use of models among the PSTs. Overall, the participants believed that models are important aspects of science teaching and learning. Even though the PSTs showed positive attitude towards the use of models and modeling in their teaching, it was apparent that their lack of experience, knowledge, and certain factors such as the level of learner were causing challenges in model-based science teaching, for example:

Researcher: Do you think are you going to teach about models?

S1: Hmm, I think at some level yes but it's gonna depend again on student level, what exposure they have. We did, do a lesson and part of the lesson was about mnemonics of the model of memorization that, learning again better term for it, hmm which would [be] helpful. I don't know if I make it a central part of my curriculum ... May be not, I don't know, to say it. But I can see the advantages of pointing it out though. [200:S1:Q]

Similar attitudes and concerns were also common among the other PSTs. For instance, the following quotes show S2's attitudes and perceptions about the use of models in her classes, as well as how she could use models, including the factors that influence her teaching such as the cognitive level of students and the model's complexity, for example:

... like for example if there was a molecule I'd show them this color represents this element, this color this element and to show you know how things are connected or how not necessarily, exactly how they look but this is how we study it. [6:S2:I]

Yeah, you can't just you can't just give it to them and say this is DNA you have to explain to them what different parts are, hmm how they work with each other or if I were to draw something, you know I'd draw and explain to them as I was drawing and point things out. Yeah and sometimes I draw pictures on the overhead and explain that, I would consider that to be a model. [14:S2:I]

If I want them to learn more about hmm the different molecules ... I can make it complex or simple ... I have to think about what level I wanted to teach it to them at because I know a lot of the students if something is way too complex they'll just give up. So I need to keep it, nothing extra just what I want them to learn nothing extra and I could have another one on hand more complex see if students ask more questions and more interested in the complexities of it and I don't have to think about scale because I wanna keep it scaled, definitely. [92:S2:I]

Overall, given the PSTs' perceptions and attitudes about models concerning Gilbert's assertions, all five participants either agreed or strongly agreed with the assertions. The PSTs had not shown any negative attitude about models and modeling. Instead, they exhibited neutral attitudes towards the use of models, allowing students to build their own models. It seems that factors such as students' knowledge of models, time, curricular restrictions, level of students, etc. were making the PSTs hesitant towards using models.



*Perceptions about the Rationale for Using Models*

In this section, the main idea is to focus more on the perceived rationales for why the PSTs would use models are presented. The data revealed more about the PSTs' perceptions and their intentions to use models during their teaching activities. Some common perceptions were apparent in the data such as influence of teachers' learning and teaching experiences, their students, etc. Overall, the data showed that the PSTs hold diverse understandings about the use of models both in science and in science teaching. Besides variations among the PSTs' perception of model use, four categories were identified that seemed particularly evident from the PSTs' views. These categories are *promoting interest and attention*, *promoting understanding* due to illustrative and representative nature of models, *promote concretization* as instrumental tool, and *promote theoretical understanding* in science.

The first category (*promoting interest and attention*) is about the use of models in a way that could increase student's attention to the topic. The PSTs believed that models can be used as examples to make learning more interesting, to make topics more efficient and effective, and to make learning hands on. Hence for them, models can be used in science teaching to draw students' interests into the subject. The second category (*promoting understanding* due to illustrative and representative nature of models) is more about using a model's representative nature as a visual tool. The PSTs thought that, in science teaching, models can be used to demonstrate, display, and represent scientific knowledge allowing science teachers to use more concrete explanations and arguments. The third category of model use (*promote concretization* as instrumental tool) is the utilization of models as concrete teaching tools. This form of use seemed to be highly preferable among the PSTs. The fourth category (*promote theoretical understanding* in science) is the theoretical uses of models by scientists. The PSTs believed that models can be used by scientists to make scientific concepts accessible, more concrete, and to increase our understanding.

It seems that these four categories influenced the PSTs' understanding of and attitudes towards scientific models. More specific investigations of these categories may provide valuable insights about possible practical applications of model-based science teaching. Furthermore, it was evident from the categories of model use that the PSTs usually considered the direct use of models such as an example, a display, a tool, etc. or what I call materialistic use of models. Besides from materialistic use, the participants did not think much about a model's theoretical and conceptual uses such as testing ideas, experiments, or modifying existing theories. These categories alluded to, became apparent from the data as presented in Table 1.

**Table 1. Pre-service science teacher's perceptions about the uses of models.**

	PST Categories of Model Use	PSTs' Opinions
S1	Promoting interest and attention Promoting understanding due to illustrative and representative nature of models	I think that models can be used in science teaching to help illustrate and explain what might be difficult or abstract concepts. I believe that having a physical, visual, model can be very beneficial to students, especially visual or even kinesthetic learners. Finally, I believe that models can help information seem more relevant and more accessible to students. [146:S1:Q]
S2	Promoting understanding due to illustrative and representative nature of models	Many concepts in science deal at the molecular level and are hard to understand. By visualizing the concepts, more people should be able to learn. [143:S2:Q]
S3	Promote concretization as instrumental tool Promoting interest and attention	Models can be used every day. The pictures in the text are models, equations, charts, specimens, etc. are all models and needed to explain science. [133:S3:Q]
S4	Promoting interest and attention Promoting understanding due to illustrative and representative nature of models Promote concretization as instrumental tool	For development of effective lesson plans which promote inquiry by effectively connecting with the way in which students learn. Also, physical models in science are critical in order to connect with learners on a more visual level. [134:S4:Q]
S5	Promoting interest and attention Promoting understanding due to illustrative and representative nature of models	Models can be used to explain difficult and complex topics to students. [131:S5:Q]
S6	Promoting understanding due to illustrative and representative nature of models Promote theoretical understanding in science	Models are all we really have in science teaching. We cannot see an atom or a single molecule. We have to use models to show these things and how they interact with each other. It's not ethical in biology to dissect a human being so we use models to teach students about their bodies. It's not feasible to take students all over the world to teach them about different animals, trees, cultures, and ecosystems. Instead, we use models. [138:S6]



	PST Categories of Model Use	PSTs' Opinions
S7	Promoting interest and attention Promoting understanding due to illustrative and representative nature of models Promote theoretical understanding in science	The possibilities are endless. Charts and graphs to display trends in weather, evolution, migration, reproduction, chemical reactions. Hands on experiments/activities as models of behavior, reactions, tendencies, etc. Models created by teachers and also by students. [131:S7]

The following quotes are given as more examples of the PSTs' perceptions about the rationale for using models. Models can be used to make scientific concepts or natural phenomena more accessible to us. Hence for these teachers, models promote concretization as instrumental tools. Additionally models' illustrative and representative nature can also help promoting students' understanding. For example:

I think you can give give'em an access to somewhat they wouldn't normally have, creating a greater understanding of things, you could do a lot of the exposing them to things that they wouldn't see otherwise ... you know you might not get to see the real thing or ever have the real thing but you got a little piece of it ... I mean especially helps things that you can't really manipulate otherwise kinda lets you work it out. May be you can't really go to the lab and work with the real thing but you can plan it out kinda in the first place. [42:S1:1]

Materialistic use of models is also rationalized by these teachers indicating that model can be used as an example or a tool to help students' visualization. Thus, models can be used for promoting interest and attention, for example:

... like I said you can introduce a concept like when you're hmm like in any chemistry class you're introducing the hmm different shapes of the molecules. Have students build them themselves or just show them to them they can visualize it. Because when they describe it in the book, it does make no sense. Hmm some students need hands on ... and also for review, it's it's good to review with models and then for evaluation like you can have students build a model. [25:S2:1]

The PSTs' perceptions obviously indicated that the most common categories within the data are promoting interest and attention, promoting understanding due to illustrative and representative nature of models and promote concretization as instrumental tool. This became apparent from the following responses below:

... I have constructed hmm type of learning models because the students were doing independent research projects, projects so I, you know borrow from the scientific method and use that a model to the give a format a good way for them to effectively get started on their research project you know, what're the different steps, what is an abstract? So you know, I make an example or model for them to follow. [19:S4:1]

Hmm well I guess with teaching we talked so much about the standards. You might wanna look at the standards, for the grade level or something hmm you might want to find out what previous experiences these students have had with the topic ... if you're going to be using the information in the future may be you want to teach it in that context so that they understand hmm if you're teaching about a car if you're you know speaking with students who are going to be driving a car in the future you'll teach them differently about it than if they're going to be repairing cars in the future I think there is there is a purpose to learn and to use a model is the best way for that type of learning. [92:S5:1]

Overall, given the PSTs' perceptions about the rationale for using models, the four categories of model use in science teaching (*promoting interest and attention*, *promoting understanding due to illustrative and representative nature of models*, *promote concretization as instrumental tool*, and *promote theoretical understanding in science*) appear to be mutual among these participants.





## Discussion

Analyses of the PSTs' responses to the specific statements, particularly Gilbert's assertions provided valuable findings about these teachers' perceptions and attitudes towards the use of scientific models. The five PSTs (S1 through S5) who had responded to the Likert-type scale questionnaire found that Gilbert's first assertion agreeable and they thought that models are main products of science. In the case of second assertion, models are major tools of science, three participants, S1, S2, and S3 strongly agreed though the remaining two found the assertion agreeable. Surprisingly, four of the PSTs, except S4, strongly believed that models are important learning tools. While three PSTs, S2, S4, and S5, agreed with the assertion, models are important teaching tools, S1 and S3 found the assertion strongly agreeable. Although no specific pattern or evident distinction were observed about the PSTs' understanding of Gilbert's assertions, all five participants either agreed or strongly agreed with the assertions. Unlike these findings, Harrison's (2001) study however found different results among ten experienced science teachers. Even though those teachers in Harrison's (2001) study, all agreed with Gilbert's second assertion (models are major tools of science), three of them disagreed with the first assertion indicating that models are not main products of science. Additionally, Harrison (2001) reported that six of those teachers were either uncertain or disagreeing with at least one of Gilbert's assertions. Overall, this research shows that these PSTs' perceptions and attitudes diverge greatly from Harrison's (2001) experienced teachers' attitudes. At large, the findings of this research indicated that the PSTs have positive attitude towards scientific models and they emphasize the value of models in science teaching.

Furthermore, the data indicated that almost all participants, except S4, were unsure about allowing students to build their own models. Clearly, the PSTs demonstrated neutral attitudes towards the use of models as well as allowing their students to build models in science classes. Even though the participants assumed that it could be useful for students to build and design their own models, they were unsure about it. It appears that the underlying cause for this perception is that the PSTs believe factors like level of students, students' knowledge of models, their modeling experience, time, etc. could restrain possibility of allowing students to design their own models. These results on the possible factors that may influence PSTs' attitudes negatively confirmed the findings that were previously reported by Crawford and Cullin (2004). The authors indicated that obstacles about the use of models like being time consuming, curricular restrictions, and technological limitations could influence PST's perceptions and attitudes negatively towards using models and teaching about models.

As for the last two statements (science teachers do always use models in their teaching and models used in science teaching should be different than models used in science), surprisingly same level of agreement from the same participants were observed. Only two participants, S2 and S4, disagreed with item 6 while indicating science teachers do not always use models in science teaching. Interestingly, the same PSTs, S2 and S4, also disagreed with item 7 indicating that models used in science teaching and science should not be different. The others thought that models used in science teaching should be different than the ones used in science. This perception confirmed the results previously obtained when asked specifically whether models used in teaching could/should be different from those used in science. Nonetheless, the PSTs thought that models should be same in science and in education. Though in some cases, they consider the complexity of model should be relevant to students and models used in science teaching could be modified accordingly.

Generally, no evidence of negative attitude towards the use of models were found among the PSTs. Though there were many incidences that point out the PSTs' perceptions and positive attitudes towards the use of models in their teaching. It appears these PSTs valued the idea that models are important aspects of science teaching and learning and showed positive attitudes towards the use of models and modeling in their teaching. Nonetheless, their lack of modeling experience, limited knowledge of models, diverse understanding of the nature of model and modeling, and factors like level of learner, time constraints are causing certain challenges to their positive attitudes towards model-based science teaching.

On the other hand, there were clear variations among the PSTs' understanding and perception about the use of models in science and in science teaching. Four categories (*promoting interest and attention*, *promoting understanding* due to illustrative and representative nature of models, *promote concretization* as instrumental tool, and *promote theoretical understanding* in science) emerged from the data that describe the participants' views and perceptions about the uses of models. According to the PSTs, models can be used as examples to promote learning by making the subject more interesting, efficient, and as well as hands on. Thus, in science teaching models can be used to draw students' interests into the subject. Secondly, a model can be used as a visual tool to illustrate,



display, and represent scientific knowledge. This use of models in science teaching assists science teachers to use more concrete explanations and arguments in their teaching. Thirdly, models can be used as instruments, concrete teaching tools, to facilitate teaching. The fourth category of model use, however, is about promoting theoretical understanding by using models. The PSTs thought that theoretical use of models in science could be helpful for solving scientific problems, making scientific concepts accessible or more concrete, and increasing our understanding of natural phenomena.

## Conclusions

It appears that these four categorical uses of scientific models (*promoting interest and attention, promoting understanding, promote concretization, and promote theoretical understanding*) have substantial influence on the PSTs' understanding of models and modeling and their attitudes towards the use of scientific models. Hence, more research on these categories may provide valuable insights about the practical applications of model-based science teaching. As expected, the PSTs showed tendency towards certain categories such as promoting interest and attention, promoting understanding due to illustrative and representative nature of models, and promote concretization as instrumental tool in science teaching. Besides, the PSTs usually regarded materialistic, direct use of models like an example, a display, a tool, etc. Despite materialistic use, they did not think much about using models to promote theoretical understanding in science like testing ideas, experiments, or modifying existing theories.

It is important to note that in this research, although the participants represent a pool of PSTs, it could be argued that their personal experience and knowledge of scientific models may be different than from each other. Thus, there is a possibility of factors regarding their knowledge and practical experience of models and modeling. Such factors might affect the PSTs' attitudes and understanding of the phenomenon and they might cause variations within the data. Therefore, the findings should not be generalized to a wider population and their interpretation should be done accordingly.

Conclusively, the findings of the present study can have important implications for teaching practices and pre-service science teacher education programs. Based on the results, certain premises emerged from the data regarding PSTs' uses of scientific models. First, pre-service science teacher education programs should be designed to ensure that PSTs understand both the nature and role of models in science. This is an important aspect of acquiring scientific knowledge. Second, PSTs need guidance in developing positive attitudes towards the use of models and model-based teaching. It is suggested that teacher training programs should be designed accordingly to help them. Lastly, it is also important for PSTs to collaborate with their colleagues and learn more about their past experiences in models and modeling.

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Received: November 20, 2015

Accepted: February 05, 2016

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