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Pre-service Science Teachers' Views and Content Knowledge about Models and Modeling

Fen Öğretmen Adaylarının Modeller ve Modelleme Hakkındaki Görüşleri ve İçerik Bilgileri

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Abstract

The aim of this study was to investigate pre-service science teachers' views and knowledge of models and modeling. The data were collected from seven participants through semi-structured interviews and an open-ended questionnaire. The results indicated that variations and deficiencies existed among the participants' views and knowledge of models. The participants were unable to distinguish exclusive characteristics of scientific models. It was also found that the pre-service science teachers favored a teaching model according to model's aesthetic appeal, scientific context, and practicality. It is recommended that pre-service science teachers should engage in more modeling activities and gain more modeling experiences throughout their training programs to improve their content knowledge of models and modeling.

Keywords: Pre-service science teachers, models, modeling, content knowledge.

Öz

Bu çalışmanın amacı, fen öğretmen adaylarının modeller ve modelleme hakkındaki görüş ve bilgilerinin incelenmesidir. Çalışmanın verileri yarı-yapılandırılmış görüşmeler ve açık-uçlu anket kullanarak yedi katılımcıdan elde edilmiştir. Sonuçlar, katılımcıların modeller hakkındaki görüşlerinde farklılıklar ve yetersizlikler olduğunu ortaya koymuş ve katılımcıların bilimsel modellerin özgün karakterlerini belirleyemediklerini göstermiştir. Yine sonuçlar, öğretmen adaylarının bir öğretim modelini tercih ederken modelin estetik çekiciliğine, bilimsel içeriğine ve kullanılabilirliğine dikkat ettiklerini göstermektedir. Bulgular, fen öğretmen adaylarının eğitim programları sürecinde daha fazla modelleme aktivitelerine katılmasını ve daha fazla modelleme deneyimi kazanmasını ve böylece modeller ve modelleme hakkında sahip oldukları içerik bilgilerinin geliştirilmesini öngörmektedir.

Anahtar Sözcükler: Fen öğretmen adayları, modeller, modelleme, içerik bilgisi.

Introduction

One of the principal challenges facing model-based education today is the need to understand, enhance, and sustain teachers' content knowledge of models and modeling. To address this challenge, National Science Education Standards (NSES) emphasized the value of models and modeling by implementing it into the five unifying concepts of science for all grade levels (NRC, 1996). The Standards also suggested that models built by students can be used to asses and deduce students' performance and understanding of scientific knowledge. Despite the suggestions about models and the use of models as curricular materials (AAAS, 1990, 1993), it is reported that most science teachers have insufficient prior knowledge of models and modeling and inadequate understanding of the nature of models and modeling (Danusso, Testa, & Vicentini, 2010; Henze, Van Driel, & Verloop,

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2007a; Justi & Gilbert, 2002a, 2003; Justi & Van Driel, 2005a; Van Driel & Verloop, 1999).

Educating pre-service science teachers (PSTs) about models and modeling can be a challenging task for most science educators. This responsibility is complicated by the fact that what constitutes useful content knowledge on models and modeling for teaching science is not yet fully understood (Henze, Van Driel, & Verloop, 2007a; Justi & Gilbert, 2003). For instance, the term model has many different meanings and it can refer to a system, an object, or even an idea. Thus a range of definitions have been developed and commonly used in science education literature. A broader definition of the term model was suggested by the AAAS: "A model of something is a simplified imitation of it that we hope we can understand it better. A model may be a device, a plan, a drawing, an equation … their value lies in suggesting how things either do work or might work" (Science For All Americans, 1990, p. 168). We use models as they are being the essence of our understanding and doing science as well as learning and teaching scientific knowledge. We also use models, simply because in some cases, the object of interest could be too small for direct observation, or it could be too large to observe and inaccessible for researchers and teachers as would be the cases of galactic objects. In other cases certain phenomena could be understood and studied through their effects on nature but cannot be seen or observed directly as would be the cases of gravity and electricity. Similarly in science teaching and learning, models are used to make predictions, visualize, build, and test scientific concepts and simpler forms of objects. Because models make phenomena more accessible to both scientists and teachers, and they can be used in learning, teaching, and experimenting. Thus, understanding the nature of models and modeling should be vital for science teachers.

Nonetheless, enhancing science teacher's skills and knowledge on models and modeling is essential part of pedagogical content knowledge (Carlsen, 1991; Thorley & Stofflett, 1996). Pedagogical content knowledge, a way of combining content and pedagogy to comprehend how a certain topic is approached and represented to a diverse group of learners (Shulman, 1986, 1987), requires that teachers need to master two types of knowledge; content and pedagogic knowledge. Content knowledge is particularly vital for science teachers and deals with the organization and amount of subject knowledge. In this context, investigations on the growth of science teacher's content knowledge on the nature and use of models may help teachers to better address the curricular aspects of model-based teaching and learning in science education (Danusso et al., 2010; Gilbert, Boulter, & Rutherford, 1998; Gobert & Buckley, 2000; Henze et al., 2007a; Justi & Van Driel, 2005b).

Despite the significance of models and modeling in science education research, the number of studies on teachers' knowledge and understanding of models and modeling is small. An earlier study by Grosslight, Unger, Jay, and Smith (1991), though the study focused on Grade 7 and 11 students, did provide foundational grounds for investigating teachers' ideas about models and modeling. The researchers found that students often fail to distinguish models as being copies of reality rather than constructed representations. These findings also supported by Harrison (2001) study that students are observed to be often naïve believers and cannot distinguish between models and reality. Harrison argued that most students are dualists believing representations are either right or wrong.

One of the few studies that focused on PSTs was Smit and Finegold (1995) study. The researchers explored students' perception and knowledge of physics models. The authors reported that the PSTs believed that a model's main function is to help us understand complex or abstract things and explain how things might work. More than half of the participants (58%) considered models as representation of a target and they thought that a model should be identical to the real thing. Such perceptions and limited views of models for example viewing a model as a copy or an imitation of a target that exist in nature also reported among experienced teachers (Justi & Gilbert, 2002b, 2003; Van Driel & Verloop, 1999). Interestingly, 55% of the PSTs thought that a model is a copy, a replica, or an exemplar reproduction (Smit & Finegold, 1995), though in-service teachers defined models merely as "simpler, schematic representations of reality" (Van Driel & Verloop, 1999, p. 1146). According to Justi and Gilbert (2003) 21% of teachers thought that 'model cannot be changed' and 92% of teachers associated models with explanations.

Previous studies have also shown that teachers' modeling abilities, such as computer modeling and how they develop their modeling skills (Crawford & Cullin, 2004), the modeling abilities of teachers and textbook writes (Harrison, 2001), and teachers' perceptions about and use of models have considerable difficulties. Inadequate knowledge of models and modeling in science textbooks was also observed (Harrison & Treagust, 1998; Stern & Roseman, 2004). Studying ten experienced teachers' perceptions and use of models in classrooms, Harrison (2001) found that teachers depend on textbooks but textbooks do not provide adequate information on the nature of models and modeling and they do not even discuss modeling. Similar results on models and modeling in textbooks and lack of sufficient information on types, roles, and use of models in science were also reported (Aktan & Eichinger, 2004; Justi & Gilbert, 2000).

Justi and Gilbert (2002a) investigated teachers' understanding of the nature of modeling and found that even though teachers showed awareness and understood the value of models in science learning, many of them ignored or did not pay attention to their students' ideas on models and modeling. Most recently Justi and Van Driel (2005b) reported investigations on five Dutch science teachers' content and pedagogical content knowledge of models and modeling. The attention was given to understanding process and how science teachers develop their knowledge of models and modeling. Other studies found that understanding how science teachers develop their knowledge of models and modeling is central to constructing science teachers' pedagogical content knowledge of models (Henze, Van Driel, & Verloop, 2007b, 2008; Justi & Van Driel, 2005a; Van Driel & Verloop, 1999). For example, it was reported that even though most teachers have some prior knowledge of models and those teachers were more prone to stress the value of models and modeling, they all have difficulties and problems in content and subject knowledge of models and modeling (DeJong & Van Driel, 2001; Justi & Van Driel, 2005b). It was also reported that modeling activities and model-based teaching can make teachers more enthusiastic and provide valuable opportunities allowing them to modify and improve their subject knowledge of models and modeling (Danusso et al., 2010; Justi &Van Driel, 2005b; Ogan-Feral, 2007).

The Purpose and the Significance of the Study

Although much effort has been invested on students and in-service teachers, research on pre-service science teachers is strongly needed. This study aims to fill the gap in this area and helps to improve teacher education research about pre-service science teachers' knowledge and understanding of models and modeling. For this reason, the purpose of the study is to answer the following main research question: what knowledge do pre-service science teachers have about models and modeling in science?

The present study reports part of the results from a larger investigation on PSTs' knowledge, attitude, and understanding of models and modeling (Aktan, 2005). Thus, the study attempts to add to the limited body of research on model-based science teaching and learning from pre-service science teacher perspective and provides suggestions to improve teacher education research.

Method

The design of the study was influenced by qualitative approaches and it was structured as a descriptive study. This design can be used to describe a phenomenon without manipulation of treatments or participants or it can be used to correlate relationships of different phenomena (McMillan & Schumacher, 1997). The methodological framework of this study was established by grounded theory and implemented by document analysis and in-depth interpretative phenomenological interview analysis (Smith, Harrè, & Van Langenhove, 1995).

Participants

The participants in this study were seven volunteer pre-service science teachers at a large Midwestern university in the U.S. They all (six females and one male) were coded as S1 through S7. All participants were enrolled in a secondary biology teacher education program except S6, which was from the chemistry teacher education program. They were all Caucasians and their average age was 23.

Data Collection

At first, informed consent forms were distributed to all students and a description of the nature of the study was provided both verbally and in writing. Later, those who were willing to participate received the open-ended questionnaire to be answered individually at home. Additionally, specific dates and times were arranged for the pre-service science teachers who were also willing to participate in interviews (S1 through S5). Hence, in this research, the data were obtained through two main instruments, an open-ended questionnaire and in-depth semi-structured interview. Similar to the previous studies, the design of the questionnaire and the semi-structured interview were based on instruments developed by Grosslight et al. (1991) and were enhanced through later studies (Justi & Gilbert, 2002a, 2002b, 2003; Van Driel & Verloop, 1999, 2002).

The open-ended questionnaire was specifically designed for pre-service science teachers by Rosaria Justi and Jan Van Driel in the context of studying teachers' knowledge and views of models and modeling, VOMM (Justi & Gilbert, 2003). In original, the questionnaire contains five items with multiple parts; however, the modified version (TEKUM) is a 7-item questionnaire with two sub-questions. The instrument included two sections. The first section was designed to collect demographic data from the PSTs concerning their race, gender, teaching experience etc. The second section of the instrument asked questions about teacher's views and knowledge of scientific models.

Since the data come from what is written or chosen, the data obtained from questionnaires may lack of in-depth interpretations and the results can be incomplete or inappropriate (McMillan & Schumacher, 1997). In this research, however, to overcome such disadvantages, post-interview phase clarifications were used to clarify and collect any unclear and missing data from the open-ended questionnaires. Furthermore, this step helped to validate the teachers' responses through cross checking of the outcomes. This task was completed at the end of each interview.

In this study, a semi-structured in-depth interview designed and used to reveal possible themes and patters among the participants' knowledge and understanding of models. I interviewed each participant individually and only once. I conducted the interviews in a quiet room without any distraction or interruption. A typical interview lasted 50 minutes per participant and it was audio-recorded.

Data Analysis

The data from the open-ended questionnaire were analyzed based on qualitative coding techniques to seek emergent themes and trends from the participants' responses (Giles, 2002; Smith, 1995; Strauss & Corbin, 1998). Analyses of the semi-structured interviews were done following the interpretative phenomenological interview analysis (Smith, 1995). First, voice recordings were transcribed. Second, transcripts were read many times individually studying the individual cases (idiographic approach). Third, emerging themes and trends were captured and documented as theme titles. Fourth, a detailed analysis of emerging themes and trends was performed to reveal possible connections, clusters, and super ordinate concepts. Fifth, an ordered master list of themes and trends was produced to capture the most vivid concerns of the participants and an identifier was added to map the transcripts. Sixth, during the process of analyzing, participants' emerging explanations and arguments were captured through the respondents' explanations and opinions to see what classifications, connections can be made or related to the participants' knowledge, experiences, life histories, on the phenomenon, models. Finally, seventh, the write-up phases were completed by translating the master themes and trends into narrative accounts. All data analyses were carried out with the help of ATLAS.ti qualitative data analysis software (Version 5.0).

Results

Analyses of the data indicated that, the PSTs' knowledge of models and modeling in science fall within the following family of themes. The results for the themes model knowledge, model definition, and model characteristics are reported below.

Model Knowledge

The data clearly indicated variations among the PSTs' knowledge and views of scientific models. For instance, the term model was used to refer to a person, a scientific model, or an example. On the other hand, the participants typically used the concept of model as being a representation, an idea, or an image. There were, however, some unique characteristics among the PSTs' knowledge of models. The participants understood and used the word model as an example of something, an example of how something works, or a representation of how something should and does look. A summary of the PSTs' ideas and views of models in science and science teaching are listed in table 1.

S1 acknowledged the idea that a model is an example of something else or how it works as in a role model like a person or a car model like an object. Thus, S1's understanding is based on how the word model is used. S1 said that models could help students understand better, and in science models are abstract. However, she acknowledged that models are usually mathematical and scientific concepts, for example:

> In science, hmm, well then it's kinda an abstract thing, if you're talking about DNA or something that's little unusual, students, they can understand what it really looks like… [40:S1]

Table 1.
Pre-service Science Teacher's Views of Model

Examples from the PSTs' responses
Model is/can be a *person*, an *example*. An example of something some sort about, like almost like the role model … an example of something how it works. [6:S1] First thing that comes to mind is model cars … I think of models as in figures like people … that are looked up to whether it would be science or a fields someone has been successful… [3:S4] The person that wears clothes … model car… [3:S3]
Model is/can be a *picture*, an *example*. I imagine a model in the classroom like a like a model of DNA or, hmm I pretty much picture molecules… [3:S2]
Model is/can be an *idea*, a *process*. I think of the organic chemistry modeling kit … where you put different atoms together and you see the 3-D structure of a molecule … like Bohr's model and different people's different ideas about how the atom was put together … they [Models] don't necessarily represent what is real but it's just an idea of what is going on atoms so that we can think it more clearly. [3:S5]
Model is/can be a *representation*, an *image*. I think a scientific model is simply a representation of an idea or thing. [109:S6] An ideal, a type, a standard, or an illustration to illustrate scientific data or a scientific concept. [110:S7]

S1 was able to provide a very good explanation which shows her knowledge of models is well developed in some respect. She believed that the word model can be used in science in many ways. For instance, she suggested that one way that we can use the word is as an example like

"… the giant squid is often used as a model organism for looking at action potential propagation, because it has a giant axon that is excellent for studying" [79:S1]. The second way that models can be used is a reference to something, like analogies. For example, "… sometimes teachers will use the city model of a cell when explaining how cells work. Each cell structure is equated with a structure within a large city to help students understand how cells work" [79:S1]. According to S1 the third way of using the word model in science is by using theory and model interchangeably. For instance, "different types of theories are sometimes referred to as models … for example there are two major models of evolution: gradualism and punctuated equilibrium. Another example would be the Bohr model of the atom, or the 'Plum Pudding' model" [79:S1]. Lastly, S1 also suggested that the word model can be used to refer to "recreations or miniature examples to help illustrate a concept."

Similar to S1, S2 also focused on the exemplar aspects of the word model. However, it appears that her knowledge of model is very limited. According to S2, "It [model] helps people to visualize things that they normally might not be able to" [80:S2]. In addition, S2 emphasized the aspect of scale and she viewed models as scaled representations, for example:

> Hmm I would try to explain to them [students] it's [model] not the actual thing … it's not the same size but it's the scale and if they didn't understand I have to talk to them about what scale is. [5:S2]

It was evident that S3 demonstrated a certain level of knowledge and understanding about models. However, she was mostly thinking of models as objects and examples, and she was able to provide legitimate examples. S3's notion of model knowledge is based on the expressions of model's representational forms. Therefore, she found that representing how something should look or does look is the common aspects of models. She stated:

> Hmm I guess they [models] represent the way something should look or does look. Like a model, you think, is supposed to be the picture of beauty … a toy or a model airplane it's gonna look, it's gonna be a representation of a real airplane… [17:S3]

Therefore, S3's understanding of a model is related to similarities between a model and its target, for example:

> In science we can use models that represent some general things. A typical model of an animal cell does not show all different cells, but represents what a general animal cell will look like. [81:S3]

It was apparent that S4's model knowledge was diverse and he was able to provide various responses. His examples, however, focused on the use of the word as examples of objects or concepts, like "molecular models" or "modeling the inquiry process". Furthermore, S4 associated the term model primarily with physical models, scientific models, figures, and people, for example:

> … there is definitely objects but there is also like learning models for me or even you know the scientific method in my mind that's kinda a model to follow when you're writing a research paper … think about model as a system too. They can be used to make things more efficient more effective like with the learning model you know … [Models are] both physical and abstract things. [5:S4]

Though she provided good responses and examples, S5's model knowledge was limited and concise. She recognized that a model doesn't have to be a real representation of the phenomenon it represents. She mentioned that a model can be a drawing or an object that represents something complicated, for example:

> It could be a drawing or a 3-D object that is gonna help you understand hmm a process better, it might represent a theory often, I think it represents something that is complicated that has many parts to it and so you need to look at it to understand it, like reading about it in text isn't gonna give you enough information. [9:S5]

S6’s model knowledge revolved around a model being an idea. She was able to provide in-depth explanations and focused on the representative nature of models. Thus, similar to S2 and S3, S6’s knowledge of models is closely related to the word representation, for example:

> A model is just a representation for something else that is difficult to show on its own … Models help show what we would like to [emphasize] at a particular point in time. They have the benefit of making some things extremely understandable, but one must remember it is simply a representation and a model cannot follow all the rules for the original idea; if it did it would not be a model. [79:S6]

Although S5 partly mentioned the idea, S6 was the only PST to clearly state that a model cannot represent the target fully or “follow all the rules for the original idea.” Such understanding seems to be very rare among the PSTs.

S7 also accepted that the word model can be used in science similar to the statements, like ideal, form, and standards to follow. She stated that the word can be applied for an ideal ecosystem, for example:

> The interaction of wildlife, for example, wolves and moose, can be observed and monitored without the threat of habitat destruction or relationships with domesticated fauna. [87:S7]

Furthermore, S7 was able to provide many legitimate examples. What was common among them is that her range of thoughts revolved around the uses and functionality of the word model rather than its representational aspect. For example, she brought up an example from behavioral science, “Prochaska’s Transtheoretical Model of Change, an approach or type of vehicle for change concerning substance abuse treatment” [87:S7] underlying the functionality or “a certain wetland ecosystem could be used as a model for wetland restoration (or creation) at a different location” [87:S7], underlying the uses of the word model.

Table 2.
Pre-service Science Teacher’s Definitions of Model

Common Aspects Model is:	The PSTs’ Responses
A representation	It’s kinda of an example or representation of something that maybe it’s hard to understand or hard to get access to. [22:S1]
A simplified version of the real thing	… this [model] is a representation of … [model] is what we think it looks like… [17:S2]
An example	It’s a representation of the actual objects that you’re talking about … something that represents something else… [19:186:S3]
What goes on in the real world	… this [model] is simplified version of what goes on the real world so we can look at the parts and understand how it works… [13:S5]

Model Definition

From the data, I observed that the participants’ descriptions were shaped by their knowledge of models, their content knowledge, and how they experienced the term model over the course of their education. Table 2 summarizes the teachers’ general definitions of models. Even though the PSTs had various definitions of scientific models, they seemed to agree that scientific models are representations of ideas or things. The PSTs’ definitions of scientific models varied from a model is being a representation, an example, an idea, a process, a concept, a phenomenon, a drawing, a physical object, a form of analysis to a simplified version of what goes on in the real world or something that represents something else. For example:

I think a scientific model is simply a representation of an idea or thing. Models enhance certain parts of the original for the purposes of its use. [109:S6]

An ideal, a type, a standard, or an illustration to illustrate scientific data or a scientific concept. [110:S7]

A scientific model is anything that enables a person to explain, predict, or represent some concept. [114:S3]

Considering the level of participants, providing a sound definition of model in science education is especially complicated for science teachers. As one of the PSTs, S4, mentioned defining and explaining the concept of model in science classrooms are not easy. Once he realized the difficulty of defining models, instead of providing a description, S4 tried to deal with it by using examples:

… I mean a lot of things come to mind and it would be hard to directly explain to that student that a model is … a model is a fashion model … model cars … that's a smaller representation of an actual car… [102:S4]

For the PSTs, the representative nature of model was the most common way of defining models in science. Apparently, the PSTs defined the term model referencing the concept with an example, an object, or an idea, for example:

… this [model] is a representation of DNA, this is not DNA this is what we think it looks like … and make sure they [students] know that it's not really the size that is a lot smaller, they cannot really see it ... but this is what we think it looks like. [17:S2]

It's kinda of an example or representation of something that maybe it's hard to understand or hard to get access to. [22:S1]

Therefore, models can also be described as explanations or examples:

… something explains something to make it easier for you to understand without having the real thing. [186:S3]

… I looked up to my dad or even scientist … Einstein as a model of what to pursue to reach for some, that's been successful and they are model to follow. [9:S4]

Model Characteristics

With the exception of S6, all participants provided valuable data regarding the characteristics of models. Insufficient understanding on the nature of scientific models was also emerged. For example:

I don't think any characteristics of models are particularly exclusive to scientific models … The only thing that seems to distinguish scientific models is that they contain science. [91:S1]

I don't think that there are any characteristics exclusive to scientific models. I think models can be used everywhere. [93:S3]

Initially, S2 responded by saying that she had no idea. When further investigated during the post-interview phase, she responded that:

The only difference I could think of would be hmm if it something that you would study in science class hmmm I can't think of anything about the model itself that would be different… yeah I am not really sure if there is anything exclusive to scientific models. [194:S2]

However, participants S4, S5, and S7 identified certain characteristics such as being the result of experiments, being true under certain conditions, or being based on theories, for example:

Scientific models are scientific in nature and are therefore [they] are the result of experimental results which hold true in a given set of conditions. [93:S4]

Scientific models are based on theories. They are our best representation for a phenomenon

> in the real world. Each part of a model may represent a different part of the real object. [92:S5]

Furthermore when the characteristics of teaching models were being explored, interesting results emerged from the PSTs' views of models in science teaching. It was evident that the PSTs basically considered three main aspects to look for in a good teaching model. A teaching model can be chosen for its aesthetic appeal. When it's built, a teaching model should be neat and nice to look at. In other words it should be "pleasing to the eye." The following excerpt from the data shows, for example, how S2 expresses her attitudes with the aesthetic aspect of a teaching model.

> Researcher: What other characteristics could you tell?
>
> S2: Hmm to scale again, it's got to be scaled, it's a big one.
>
> Researcher: What else could it be?
>
> S2: Hmm probably something they can touch because a lot of students need the hands on I have a lot of students hands on right now, and so, it's kinda hard sometimes talking about genetics for the hands on students, yeah definitely hands on. Hmm, something it's nice to look at, it's not so it's not just when you look at, it doesn't confuse you, something that I guess pleasing to the eye, maybe colorful or hmm... yeah.
>
> Researcher: You said pleasing to the eye, interesting point.
>
> S2: Heh yeah.
>
> Researcher: You mean that looks nice?
>
> S2: Yeah it's neat it's not just thrown together and you can tell somebody took to time to think about it and made it.
>
> Researcher: So, you're also saying that, when we build a model or when a teacher is going to build a model he or she should also try to make the model looks good and nice?
>
> S2: She doesn't want some glue dripping off of it because students are gonna notice that instead of what she want[s] them to notice. [238:S2]

The second aspect of a good teaching model is its scientific context. Basically, a teaching model must be built to facilitate learning. Therefore, its context should be supported by scientific knowledge and the context could be modified in accordance with certain needs like clearing up misconceptions or enhancing scientific knowledge of students. Yet the scientific aspect of teaching models should offer certain challenges to students by promoting inquiry. That is, a good teaching model should be reproducible and, thus, its context must be suitable for interpretation, modification, and the knowledge and skills that are pertinent to science teaching. The following example demonstrates the PSTs' intentions and perceptions about the scientific aspect of a teaching model, for example:

> The model should make the concept easier to understand and clear up any misconceptions. There would be no use for the models if they didn't help with understanding the concept. [149:S3]

The third aspect of a good teaching model is its practicality. The practicality of a model refers to a wide range of thoughts and features. For example, a model can be practical just because it could be the most relevant model available for science teachers or it could be easier to manipulate or use in science class. Likewise, the practicality of a model maybe limited for science teachers due to the nature of the model like its size, the environment in which it exists, the complexity of representation, or even the type such as a physical versus a verbal model. Hence, the practicality aspect of a good teaching model can be approached from many directions.

> I believe a good model for use in teaching is again, relevant to the students. [159:S1]
>
> A good model for teaching is one that helps student learn from obvious reasons. There are no specific characteristics to place on a "good" model and a "bad" model. Different people

learn from different representations and a good teacher recognizes this and is able to come up with different models for students to work with. [163:S6]

Discussion

In this study, I specifically focused on pre-service science teachers' views and knowledge about models and modeling. The results of data analyses provided valuable perspectives about these PSTs' knowledge and perceptions of models. While variations exist on what the PSTs think of models, I found considerably dominant characteristics among their views. For instance, the PSTs mostly viewed models as examples and representations. Their views of model associated with a model is being 'an example of something', 'a representation of something' to how 'something should/does look or work'. Similar results such as viewing models as simplified or schematic representations of a target were also reported by Van Driel and Verloop (1999) among experienced science teachers. As a result, akin to experienced science teachers, these PSTs also saw scientific models as representations or imitations of phenomena rather than demonstrating a higher level of perception about the creative and innovative aspects of science in which scientific models are used for testing, observing new ideas, and developing new theories.

It appears that the participants tried to conceptualize the word model based on either their own experiences such as the use of the word model or the expressions of model's representational forms like physical objects. Consequently, two major ways emerged from the data on the PSTs' definitions of model. The first way is that when the PSTs tried to define the word, they were inferring likenesses. Using likenesses, resemblances of a model, between a model and its target, was a preferable way to define the word model. The second preferable way was defining the term as a simplified version of phenomena. In either case, there was a tendency towards to use of examples to define the word model. Although using various examples may seem to help, overemphasizing likenesses and simplifications could have serious consequences on students' understanding of models. That is because likenesses or resemblances can only apply at some level. Neither the target nor the model *per se* can imitate each other fully. Hence the focus, especially in science teaching should be on likenesses about the model's function and representation. Similarly, a model by itself is not the simplified version of a target. Rather, a model acts and represents certain functions or aspects of phenomena in a simplified way.

In general, the PSTs were not able to distinguish exclusive characteristics of scientific models. However, when the characteristics of teaching models were being explored, they identified three main aspects as aesthetic appeal, scientific context, and practicality in a good teaching model. Unlike these findings, Justi and Gilbert (2002a) reported that models accuracy and making ideas accessible to the students are the main characteristics observed among in-service science teachers. Yet, similar to the PSTs, inconsistencies in teachers' ideas were also common and even for expert modelers, developing a knowledge base on the nature of models and modeling is not easy (Crawford & Cullin, 2004; Danusso et al., 2010; Henze et al., 2007b; Justi & Gilbert, 2002a; Van Driel & Verloop, 1999, 2002). Evidently, the PSTs saw models as something that helps us to understand, represent, explain, or predict phenomena. This thinking is possibly due to their perceived understanding of a model as a tool. Consequently, the following general aspects of scientific models emerged from the PSTs' responses. Scientific models have (a) different ideas and concepts, (b) they represent natural processes, (c) they illustrate a phenomenon, (d) they help us understand concepts and processes, and finally, (e) they help us explain concepts and processes.

Conclusion and Suggestions

Earlier studies on in-service science teachers' understanding about the nature of models and modeling revealed variations among teachers' limited yet diverse understanding of scientific models, lack of knowledge, and inadequate use of models in teaching. It was also reported that some inexperienced teachers depend on textbooks in which the interpretation of models and modeling is unclear. The findings of this study also indicated that the PSTs' knowledge of models and modeling was also limited and they viewed models as examples and representations. The concept of model was commonly used as being a representation, an idea, or an image. This finding was also confirmed by the participants' definitions of models. Similar patterns also reported among experienced teachers, for instance teachers have a common definition of models as "simplified or schematic representation of reality" (Danusso et al., 2010; Henze et al., 2007b; Justi & Gilbert, 2002a, 2003; Van Driel & Verloop, 1999, p. 1146). However, the findings also revealed that the PSTs tend to define model either by using likenesses between model and its target or underlying model as a simplified version of a target. As previously discussed, such perceptions may affect teachers' views on the nature of models and their use of models in teaching. This finding is also supported by studying in-service teachers' use of models and deficiencies were found between teachers' teaching activities and their knowledge of models (Henze et al., 2008; Justi & Van Driel, 2006; Van Driel & Verloop, 2002).

Based on the results, it is important for PSTs to engage in more modeling activities. This was also reported in previous studies. Teachers should gain more modeling experience and know their students' prior knowledge before a final model is built for use in teaching science. Teachers should provide clear objectives for the use of models based on the level of the learners. Lastly, both pre-service and in-experienced teachers should collaborate with their colleagues for developing, implementing, and evaluating models used in their science classes. As previously discussed, many factors including content knowledge of models and modeling skills can influence science teacher's instruction. Therefore, it is vital for science teaching that both pre-service teacher education and professional development programs should emphasize the nature of models and modeling in science through implementing curricular activities about models. Certainly, a neat teaching model could attract both students and teachers and it can be easier to use, understand, and represent the main concepts behind the model. It may be suggested that for younger students, definition of model should focus on examples. Likewise, *Benchmarks for Science Literacy* (AAAS, 1993) recommends lower level students being able to distinguish model from its target through similarities.

References

AAAS (1990). *Science for All Americans*. New York, NY: Oxford University Press.

AAAS (1993). *Benchmarks for Science Literacy*. New York, NY: Oxford University Press.

Aktan, M. B., & Eichinger, D. C. (2004). An analysis of the uses and interpretations of science models in U. S. high school science textbooks. *Paper presented at the National Association for Research in Science Teaching,* Vancouver, Canada.

Aktan, M. B. (2005). *Investigation of prospective teachers' knowledge and understanding of models and modeling and their attitudes towards the use of models in science education*. Unpublished doctoral dissertation, Purdue University, IN.

Carlsen, W. S. (1991). Effects of new biology teachers' subject-matter knowledge on curricular planning. *Science Education, 75*(6), 631-647.

Crawford, B. A., & Cullin, M. J. (2004). Supporting prospective teachers' conceptions of modelling in science. *International Journal of Science Education, 26*(11), 1379-1401.

Danusso, L., Testa, I., & Vicentini, M. (2010). Improving Prospective Teachers' Knowledge about Scientific Models and Modelling: Design and evaluation of a teacher education intervention. *International Journal of Science Education, 32*(7), 871-905.

De Jong, O., & Van Driel, J. H. (2001). Developing preservice teachers' content knowledge and PCK of models and modeling. *Paper presented at the National Association for Research in Science Teaching*, St. Louis, MO.

Gilbert, J. K., Boulter, C., & Rutherford, M. (1998). Models in explanations, Part 2: Whose voice? Whose ears? *International Journal of Science Education, 20*(2), 187-203.

Giles, D. C. (2002). *Advanced research methods in psychology*. New York, NY: Routledge.

Gobert, J. D., & Buckley, B. C. (2000). Introduction to model-based teaching and learning in science education. *International Journal of Science Education, 22*(9), 891-894.

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: conceptions of middle and high school students and experts. *Journal of Research in Science Teaching, 28*(9), 799-822.

Harrison, A. G. (2001). How do Teachers and Textbook Writers Model Scientific Ideas for Students? *Research in Science Education, 31*, 401-435.

Harrison, A. G., & Treagust, D. F. (1998). Modelling in science lessons: Are there better ways to learn with models? *School Science & Mathematics, 98*(8), 420-429.

Henze, I., Van Driel, J. H., & Verloop, N. (2007a). The change of science teachers' personal knowledge about teaching models and modelling in the context of science education reform. *International Journal of Science Education, 29*(15), 1819-1846.

Henze, I., Van Driel, J. H., & Verloop, N. (2007b). Science teachers' knowledge about teaching models and modelling in the context of a new syllabus on public understanding of science. *Research in Science Education, 37*(2), 99-122.

Henze, I., Van Driel, J. H., & Verloop, N. (2008). Development of Experienced Science Teachers' Pedagogical Content Knowledge of Models of the Solar System and the Universe. *International Journal of Science Education, 30*(10), 1321-1342.

Justi, R. S., & Gilbert, J. K. (2000). History and philosophy of science through models: Some challenges in the case of 'the atom'. *International Journal of Science Education, 22*(9), 993-1009.

Justi, R. S., & Gilbert, J. K. (2002a). Science teachers' knowledge about and attitudes towards the use of models and modelling in learning science. *International Journal of Science Education, 24*(12), 1273-1292.

Justi, R. S., & Gilbert, J. K. (2002b). Modelling, teachers' views on the nature of modelling, and implications for the education of modellers. *International Journal of Science Education, 24*(4), 369-387.

Justi, R. S., & Gilbert, J. K. (2003). Teachers' views on the nature of models. *International Journal of Science Education, 25*(11), 1369-1386.

Justi, R. S., & Van Driel, J. H. (2005a). A case study of the development of a beginning chemistry teacher's knowledge about models and modelling. *Research in Science Education 35*(2-3), 197-219.

Justi, R. S., & Van Driel, J. H. (2005b). The development of science teachers' knowledge on models and modelling: promoting, characterizing, and understanding the process. *International Journal of Science Education, 27*(5), 549-573.

Justi, R. S., & Van Driel, J. H. (2006). The use of the Interconnected Model of Teacher Professional Growth for understanding the development of science teachers' knowledge on models and modelling. *Teaching and Teacher Education 22*(4), 437-450.

McMillan, J. H., & Schumacher, S. (1997). *Research in Education: A conceptual introduction*. New York, NY: Longman.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Ogan-Bekiroglu, F. (2007). Effects of model-based teaching on pre-service physics teachers' conceptions of the moon, moon phases, and other lunar phenomena. *International Journal* *of Science Education 29*(5), 555-593.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Smit, J. J. A., & Finegold, M. (1995). Models in physics: Perceptions held by final-year prospective physical science teachers studying at South African universities. *International Journal of Science Education, 17*(5), 621-634.

Smith, J. A. (1995). Semi-structured interviewing and qualitative analysis. In J. A. Smith, R. Harrè, and L. Van Langenhove (Eds.), *Rethinking Methods in Psychology* (pp. 9-26). Thousand Oaks, CA: SAGE Publications.

Smith, J. A., Harrè, R., & Van Langenhove, L. (1995). *Rethinking Methods in Psychology*. Thousand Oaks, CA: SAGE Publications.

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching, 41*(6), 538-568.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage Publications.

Thorley, N. R., & Stofflett, R. T. (1996). Representation of the conceptual change model in science teacher education. *Science Education, 80*(3), 317-339.

Van Driel, J. H., & Verloop, N. (1999). Teachers' knowledge of models and modelling in science. *International Journal of Science Education, 21*(11), 1141-1153.

Van Driel, J. H., & Verloop, V. (2002). Experienced teachers' knowledge of teaching and learning of models and modelling in science education. *International Journal of Science Education, 24*(12), 1255-1272.