Pre-service Physics Teachers’ Knowledge of Models and Perceptions of Modelling

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Abstract

One of the purposes of this study was to examine the differences between knowledge of pre-service physics teachers those who experienced model-based teaching and those who did not. Moreover, it was aimed to determine pre-service physics teachers’ perceptions of modelling. Results indicated that implementation of the model-based teaching in the pre-service teacher education program did not make too much difference in the pre-service physics teachers’ general knowledge of models. However, detailed examination showed that type of the model constructed and used, and phenomenon for which the model was constructed to represent in the model-based teaching might generate some differences between the knowledge of pre-service teachers in the experimental group and the knowledge of pre-service teachers in the control group in terms of characteristics, roles and functions of models. Moreover, promoting model-based teaching in the pre-service teacher education program might affect the pre-service physics teachers’ perceptions of modelling positively and lead them to use models in their teaching.

Introduction

Models play a central role in science education. To introduce modelling successfully in teaching science requires that teachers have an appropriate understanding of models and modelling.

Science Teachers’ Knowledge and Views of Models and Modelling

According to Boulter and Gilbert (2000), the modelling and models are important for three major reasons: “first, modelling and models are explicitly recognized in science and science education; second, they play a major role in the nature of science and its achievements; and third, they play a major role in technology" (p. 344). Harrison and Treagust (2000) recommend that when analogical models (physical objects, pictures, equations and graphs) are presented in a systematic way and capable students are given ample opportunity to explore model meaning and use, their understanding of abstract concepts can be enhanced. Furthermore, Justi and Gilbert (2002b) advocate that in order to help students in learning science, teacher should have comprehensive understanding of the nature of a model in general, and know when, how and why the general idea of models and specific or historical models should be introduced in their classes.

Therefore, researchers have developed interest in teachers' knowledge of models and modelling. Van Driel and Verloop (1999) conducted a research in the Netherlands to map the experienced science teachers' practical knowledge with respect to models and modelling in science, in terms of the common characteristics, roles and functions of models. Their results showed that the participants shared the same general definition of models; however, their content knowledge of models and modelling proved to be limited and diverse. Van Driel and Verloop (2002) also aimed to find teachers' knowledge of teaching and learning of models and modelling in science education. Seventy-four science teachers in the Netherlands completed the questionnaire. They indicated the following results: The teachers differed in the extent to which they use teaching activities focusing on models and modelling in science. And, the teachers' knowledge of students' conceptions and abilities in this domain was either limited or not very well integrated with their knowledge of teaching activities.

Justi and Gilbert (2002b) interviewed 39 Brazilian science teachers to ascertain their perceptions of the role of models in science teaching. The teachers presented an awareness of the value of models in the learning of science but not of their value in learning about science. In the same research, Justi and Gilbert (2002a) also analyzed the questions around the theme

“What are the knowledge and skills that a person should have in order to produce a scientific model successfully?”. Their results illustrated that the interviewees were not aware of the ‘model of modelling’ framework, and they seemed to be thinking of modelling as something done primarily by scientists, or by other people who were less effective at this than scientists. Harrison (2001) interviewed 10 experienced science teachers about their understanding of the analogical models that they used to explain science to their students. Unlike other results, he found that these teachers had rich, comprehensive and creative view of modelling.

Based on their findings, Summers and Mant (1995) suggest that essential prerequisites for primary teachers if they are to teach astronomy are: knowledge of accurate, scientific, structural models and being able to use these models to explain and predict simple phenomena.

Reviewing of the literature indicates that teachers may have general idea of models but their knowledge of using models in teaching and learning science is limited.

The Purposes of the Study

Pre-service science teachers’ knowledge of models and modelling is crucial because it may influence the way they implement modelling in their classrooms. Therefore, providing opportunities for teacher candidates to improve their knowledge of models and skills in modelling should be the subject of pre-service education.

One of the purposes of this study was to examine the differences between knowledge of pre-service physics teachers those who experienced model-based teaching in pre-service education and those who did not. Moreover, it was aimed to determine the pre-service physics teachers’ perceptions of modelling.

Methodology

Posttest-only control group experimental design was used for the study (Krathwohl, 1998). Model-based teaching was implemented in the experimental group.

Participants

Participants of this research were 35 Turkish pre-service physics teachers taking the teaching methods course. The methods course is one of the courses in science teacher education program in Turkey. The class was divided into two groups. While there were 16 pre-service physics teachers in the control group, the population of the experimental group was 19. The participants were randomly assigned to the groups.

Model-Based Teaching Context

Boulter, Buckley and Walkington (2001) reveal that a model-building sequence begins with students expressing initial models. Then, students face challenges to their existing models in the field along with the need to negotiate new group models, and finally, they report models in their presentations and endure more challenges (Boulter et al., 2001). This sequence was provided in modelling context of the study by assigning a Moon project to the experimental group. The project was composed of observation, sharing the findings, expression of the ideas, and construction of a model. In other words, the pre-service teachers in the experimental group had to construct their own models and use them to explain some lunar phenomena in the context of model-based teaching.

Instruments and Data Collection

The Likert-type questionnaire consisting of 57 items was administered to both control and experimental groups at the end of the course. This questionnaire was developed by Justi and Gilbert (2003) to identify teachers' content knowledge about models and modelling. In addition, one open-ended question was asked to the pre-service teachers in the experimental group to determine their ideas about modelling. The question was: "How do you perceive modelling with regards to teaching and student learning?"

Data Analysis

Descriptive statistics were used to analyze the data gathered from the questionnaire. Mean response was based on a three-point Likert scale, with 0 = "I don’t agree", 1 = "I partially agree" and 2 = "I agree". If an item was not understood, it was requested to circle the question mark. Factor analysis was conducted to confirm that the questionnaire measured pre-service teachers’ knowledge of models and modelling. The reliability estimate for the questionnaire was calculated by using the Cronbach’s alpha formula. Independent t-test analysis was performed to examine the difference between two groups.

Qualitative analysis involved verbatim transcripts of the written responses for the open-ended question. The transcripts were analyzed inductively to identify themes that described the pre-service physics teachers’ perceptions of modelling.

Results and Discussion

The questionnaire was subjected to principal component analysis by using Varimax rotation. The explanatory factor analysis generated 20 factors with an Eigen value of one or greater than one, which explained the 89 % of the total variance in the data. Cronbach’s alpha reliability for two groups was found as .70. Cronbach’s alpha value for the control group was .81 whereas the value was .58 for the experimental group. These results illustrated that the questionnaire had internal consistency.

The independent t-test analysis of the data showed that there was not much difference between the knowledge of the pre-service teachers in the control group (mean = 1.28) and the knowledge of their peers in the experimental group (mean = 1.31) ($t = 2.578$, $df = 33$, $p = 0.025$, one-tailed). The pre-service physics teachers in both groups had moderate content knowledge of models and modelling.

The analysis of means showed the differences in the pre-service physics teachers' knowledge about some of the items. The items whose mean difference between the control and experimental groups was equal to 0.2 or greater than 0.2 were given in Table 1.

Table 1. *Mean values for some of the items in the questionnaire*

Items	Group	N	Mean
*A model can represent an object	Control	16	1.12
	Experimental	18	1.61
A model can represent an idea or ideas	Control	15	1.26
	Experimental	17	0.94
A model is used as a reference or standard to the followed	Control	14	1.21
	Experimental	17	0.94
A model is used to visualize something that is abstract	Control	16	1.56
	Experimental	19	1.16
A model is used to explain something	Control	16	1.37
	Experimental	19	1.68
A model can exist because an individual person wants it	Control	15	1.00
	Experimental	19	1.37
*A model can exist because a group in society wants it	Control	14	1.00
	Experimental	18	1.50
A model can exist because scientists want it	Control	16	1.06
	Experimental	19	1.42
A model is useful when it is as close to what is being represented as possible	Control	16	0.75
	Experimental	19	0.42
A model is useful when it does not need an excessive amount of prior knowledge	Control	14	0.78
	Experimental	18	0.44
A model is useful when it can be handled	Control	16	1.06
	Experimental	19	1.37
A model can be represented as a graph	Control	13	1.23
	Experimental	19	0.89
A model can be represented as a diagram	Control	14	1.50
	Experimental	15	1.06
The production of a model is a process that depends on its aims	Control	16	1.50
	Experimental	19	1.73

* significant at $p \leq 0.05$

According to Table 1, the pre-service physics teachers in the experimental group had better understanding of the following items: A model can represent an object; a model can exist because an individual person, a group in society or a scientist wants it; a model is used to explain something; and the production of a model is a process that depends on its aims. They agreed that a model was useful when it could be handled. On the other hand, the pre-service teachers' in the control group had better understanding of the following items: A model can represent ideas; a model can be represented as a graph and a diagram; a model is used as a reference or standard to the followed and to visualize something abstract. Neither the pre-service teachers in the experimental group nor the pre-service teachers in the control group completely agreed that a model was useful when it was as close to what was being represented as possible and when it did not need an excessive amount of prior knowledge.

The type of the model constructed and used in the model-based teaching might cause the differences in the pre-service teachers' knowledge of these items. Because the pre-service teachers in the experimental group were required to construct and use a concrete model to show lunar events, they might have come up with the ideas that a model could represent an object and was useful when it could be handled. Besides, observation of lunar events and explanation of these events on their three-dimensional models might have restricted their thoughts because the pre-service teachers in the experimental group partially agreed that a model could represent ideas, was used to visualize something abstract and could be represented as a graph or a diagram.

The results gathered by analyzing the open-ended question showed that the pre-service teachers in the experimental group had positive views about modelling. Some vignettes from 19 participants are given below.

> P1: It is easy to explain an event on a model. I am definitely going to use this technique in my teaching practice.
>
> P2: Construction of a model is a very effective way to provide thinking. It can resolve many problems in the instruction because students can find the solution by seeing and doing. Many difficult things can be explained by using a model.
>
> P3: Construction and use of a model have positive effects on conceptual learning because they provide an opportunity to turn abstract events into concrete. But construction of a model is difficult and the model may not provide all the answers.

P4: Construction and use of a model helped me to look at the universe with different perspectives. I tried to construct a logical but not costly model…..Use of modelling in teaching has advantages because it can provide meaningful learning, draw attention, motivate students, prevent recitation and help teachers to teach. However, if a model does not represent the phenomena exactly, it may cause misconceptions.

P5: I developed hypotheses during the Moon observations and I tested them on our model. Models make abstract events concrete and provide easy explanations. Construction and use of models can facilitate meaningful learning and develop students' psychomotor skills.

P6: I have learned many new things. Textbooks are not the only source of knowledge. Students can achieve the knowledge by constructing models.

P7: Modelling helps us to understand the events that are difficult to visualize in the mind. It also helps to keep the information in the long-term memory. Modelling can be a good teaching strategy because it gets students' attention and increases their interest.

P8: Construction and use of models have benefits of explaining concepts and events visually. I tested my hypotheses that I had developed during my observations on the model.

P 9: Modelling helps us to understand the events like the solar system that we cannot examine directly. Visualization of these events can enhance the retention of learning.

P10: Construction of a model requires group working. I really had fun when we were working on our model. Working on the model helped me to understand some lunar phenomena better. Furthermore, modelling can be a very effective strategy to motivate students.

P11: Models help us to explain the events that are difficult to explain. Modelling has increased our interest. As students, we are happy to create something. My motivation

> has increased, too. I could not construct in my mind that why we always saw the same face of the Moon. I have learned it very well because of modelling.
>
> P12: As a group, we did brainstorming about how we were going to design and construct our model. We tried to construct our model as similar as possible to the real situation. The constructed model may not explain all the reality. The more the model represents the reality the more it facilitates learning. We need to emphasize the difference between the model and the reality as we did during our presentation, otherwise modelling may cause misconceptions. To illustrate the lunar eclipse, the phases of the Moon and the relationship between the Moon's orbit and the Earth's orbit on the model were very helpful for me.

Results indicated that the pre-service teachers in the experimental group conceived modelling as an effective teaching strategy. They believed that use of models in teaching would make their practice easier since models could provide visualization for some events that were difficult to explain. Regarding student learning, the pre-service physics teachers thought that modelling might be very helpful because it could increase student's motivation and facilitate learning. Furthermore, the pre-service physics teachers were aware that use of models had limitations and if these limitations were not elicited during teaching, they might create misconceptions for students. They also believed that a model had to be close to the real situation it represented.

Conclusions and Suggestions

The following conclusions can be drawn from the study. Implementation of the model-based teaching in the pre-service teacher education program did not make too much difference in the pre-service physics teachers' general knowledge of models. However, detailed examination showed that type of the model constructed and used in the model-based teaching might generate some differences between the knowledge of pre-service teachers in the experimental group and the knowledge of pre-service teachers in the control group in terms of characteristics, roles and functions of models. Phenomenon for which the model was constructed to represent in the model-building sequence might also affect the pre-service teachers' knowledge of models. Moreover, the pre-service physics teachers in the experimental group considered modelling as an important teaching strategy.

This study suggests that promoting model-based teaching in pre-service teacher education program would affect pre-service teachers' perceptions of modelling positively and lead them to use models in their teaching. However, model-based teaching should be implemented in different contexts. In this way, pre-service teachers would understand that a model can be a representation of an idea, object, event, process, or system and models have different types of modes, such as visual, verbal, mathematical and, concrete.

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