Prospective science teachers’ views about models and modelling

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Abstract. Educators agree about importance of models and modelling in teaching and learning science and other disciplines. Models provide representations of scientific concepts that can make the ideas more understandable to learners. They serve to describe, explain, or predict objects, interactions, systems, and processes. Models as a methods and products of science provide non-linguistic representation of its target. Modelling is the essence of thinking and working scientifically. Models and modelling can bridge the gap and support a natural link between STEM disciplines. Some textbooks use different representations of the same model without explanation of the form and purpose of the model. The aim of this study is to determine prospective science teachers’ views about models and modelling. Prospective science teachers’ perception of models are complex, sometimes inconsistent and dissimilar depending of subject of study. Science teacher educators must devote more time on this topic. They also need strong literature basis for supporting complex issue about models and modelling.

1. Introduction

Models and modelling are necessary in many scientific contexts. Examples of models that are significant in different areas of science are: model of ideal gas, models of atom, Gaussian chain model of polymers, Lorenz atmospheric circulation model, Lotka-Volterra model used to describe dynamics of ecological systems, DNA double helix model etc. As an important tool, models are part of scientific investigation, teaching and learning processes, simulation processes, and prediction in social sciences. We make to ourselves pictures of facts. In this way, starting with facts, the human mind constructs images as models of reality [1]. Indeed, we acquire knowledge in term of models. The whole process of model construction and the use or application of models we characterise as modelling. Models and the process of modelling are fundamental aspects of science. According to Schwarz and White, knowledge about models and modelling can be called meta-modelling knowledge [2]. Scientists dedicate a lot of time in building, checking, comparing and correcting models, and a significant place in scientific journals is devoted to publications related to the presentation, application, and analysis of these important tools.

Models are essentially representations or purposeful abstractions of reality. Scientist build models of systems to understand their structures and behaviors using computer simulation [3]. Many phases of research in science rely on computer technology and computer simulations as a process of mathematical modelling. In short, models are one of the most important tools in science. Besides using models as an integral part of the scientific process, teachers use models in a variety of ways within the science classroom [4].
2. Theoretical background
Models are one of the main products of science, modelling is an element in scientific methodology, and models are a major learning and teaching tool in science education [5]. Models provide representations of scientific concepts that can make the ideas more understandable to learners [6]. Along this line of thinking, representations are the specific human way of learning. It seems that everything can be represented in some suitable form. Models can be represented in many ways, including words, mathematical functions, graphs, pictures, and model-specific representations such as motion diagrams, free-body diagrams, energy bar charts, ray diagrams, and so forth [7]. In a modelling process, we represent abstract concepts or certain properties of the objects and the real world. In fact, the model is a construction in which we arrange the symbols of our experience or thinking in such a way that as a result we get a systematic representation of this experience or thinking as a means of understanding or explaining to other people.

Science education shares this interest in models and modelling. While many scientific phenomena cannot be reproduced in the classroom because of time and safety constraints, models of these objects and processes are available. Models are accessible and teachers know that students enjoy playing with them and that modelling is an important constructivist teaching strategy. It is, therefore, important to explore the ways students construct, manipulate, and interpret the scientific models in school science lessons [8,9].

3. Methods

3.1. Research question
The goals of this study are to determine the Macedonian prospective science teachers’ views about models and modelling. For this purpose, we conduct simple descriptive survey based on two research questions:

1. To what extent do the prospective science teachers understand models and modelling?
2. What are the prospective science teachers’ views about models and modelling?

Students’ responses to items constructed according to theoretical framework described in Table 1 give the answer to the first research question. Other items in research instrument offer the opportunity to answer the second research question.

We used theoretical framework based on the five aspects about models and modelling: the nature of models, multiple models, the purpose of models, testing models and changing models (Table 1). For each of these five aspects, there are three levels reflected different perspective of students’ understanding.

| Table 1. The theoretical framework for students’ understanding of models and modelling. |
|-------------------------------------|---------------------|---------------------|---------------------|
| Nature of models | Replication of the original | Idealized representation of the original | Theoretical reconstruction of the original |
| Multiple models | Differences between different model object | The original allows the creation of different models | Different hypotheses about the original |
| Purpose of models | Describing the original | Explaining the original | Predicting connections between variables |
| Testing models | Testing the model object itself | Comparing the model with the original | Testing hypotheses about the original with the model |
| Changing models | Correcting errors in the model object | Revising the model due to new findings about the original | Revising the model due to falsification of hypotheses about the original with the model |
These three levels are closely tied to students’ epistemological views of models and modelling, ranging from a naive-realistic view (level I) to constructivist understanding (level III).

3.2. Sample and data collection

The central research problem in this study is to determine the status of prospective science teachers’ views about models and modelling and to investigate their views about models. In this study, we use survey research design to investigate research questions. We used purposeful sampling method to determine the selection from the population. The participants were prospective science teachers who had not been taught explicitly in models and modelling. The sample of the study involved 36 prospective science teachers (7 male and 29 female), students at the Faculty of natural sciences and mathematics in Skopje, capital city of North Macedonia.

3.3. Research instrument

The data were collected by administering a questionnaire during winter semester 2020. Students participated voluntary without any special teaching about models and modelling before administering the questionnaire. The items in the questionnaire have been adopted from previous research [10,11], modified in accordance with the aims of the study, translated in Macedonian language by the author and revised by two independent experts. The questionnaire was administered to a sample of 12 physics students, 12 chemistry students and 12 biology students at the beginning of the winter semester 2020/2021.

The instrument includes four parts: Part A (6 items, My Views of Models in Science, VOMMS), Part B (5 ranking, forced choice-task based on theoretical framework), Part C (3 open-ended questions) and Part D (11 dichotomous items). The questionnaire can be found in the Appendix section.

4. Results

In the process of data coding all students’ answers of the items in parts A, B and D marked as correct according to expert opinion are coded with one point. Figure 1 shows overall student results for all twelve students (physics, chemistry and biology study group). Out of possible 264 point, physics students get 211, chemistry students 205 and biology student 165 points. This graph indicate difference between physics and chemistry students on the one hand and biology students on the other hand.

![Figure 1. Overall students’ results.](image-url)
Most of the students have achieved better results in Part A rather than in Part B. It seems that VOMSS as an instrument consists of dichotomous questions is not suitable by itself to survey views and understanding of models and modelling. Findings revealed that the majority of the prospective science teachers’ responses to questions in Part B in all the five aspect are naïve, especially concerning to biology students. Figure 2 shows that only a few students achieved model competences at level III.

![Figure 2](image1.png)

**Figure 2.** Number of students’ responses correspond to model competence at level I, II and III.

![Figure 3](image2.png)

**Figure 3.** Number of physics students’ answers in part D.

The part D has theoretical background in the literature [8,9]. Many models are used in science and mathematics, and the school modelling spectrum includes both implicit and explicit models. The implicit iconic symbols used each day in mathematics and science (e.g. $y = x^2$, NaCl) are models, because they represent functions, variables, particles, and processes. Indeed, some mathematical process symbols and chemical formulae (e.g. H$_2$O) have been used so frequently for so long that they have become part of the language of mathematics and science. At the explicit level, science often uses
concept-building analogical models like scale models, pedagogical analogical models, maps and diagrams, mathematical and theoretical models, and simulations to represent objects, ideas, and processes. Analogical models comprise the scaled and exaggerated objects; symbols, equations and graphs; diagrams and maps; and simulations that facilitate scientific communication. They can be concrete, abstract or theoretical depending on the needs of their author and audience, but above all models must enhance investigation, understanding and communication and this makes them key tools in thinking and working scientifically.

All eleven items in part D are some kind of model, whether it is a physical law, mathematical expression, graph, chemical equation, periodic table, or a skeleton model. This means that the all answers to all eleven questions are YES. Results of all three groups are presented in figure 3, figure 4 and figure 5.

**Figure 4.** Number of chemistry students’ answers in part D.

**Figure 5.** Number of biology students’ answers in part D.

These graphs show that the majority of students in all three groups believe that mathematical expressions, chemical equations, formulas, the mathematical form of physical laws, and chemical formulas are not models. They are also unsure whether the periodic table of elements is a model or not. For example, only one-half of chemistry students answered correctly (YES), the same number as the physics students. Results and analysis of results from Part C are not included in this study.

5. **Conclusions**
In general, prospective science teachers hold narrow and limited conceptions of models, typically considering models as a representation of object. Many students do not recognize the explanatory and predictive nature of models in the development of scientific ideas and theories. The evident absence of students’ profiles attaining level III in understanding models and modelling suggests that students probably do not hold coherent ontological and epistemological views. Results indicate that biology students primarily think about scale and functional models related to biology. In contrast, many physics and chemistry students refer to theoretical and mathematical models of abstract concepts, maps, diagrams, tables and simulations. Findings from this study reveal differences in students’ understanding of models and modelling between physics and chemistry students on the one hand and biology student on the other hand.

It is worth pointing out some general implications to teaching and learning. Prospective science teachers should recognize the importance of models in teaching and learning. A coherent process in understanding of models has the potential to improve learners’ epistemological perspective. In this process, teachers can play a significant role.

Science teachers’ educators must devote more time on this topic. They also need a strong literature basis for supporting complex issues about models and modelling. Explicit aspect of university courses should be focused on teaching and learning meta-modelling knowledge with stronger emphasis on modelling as a scientific practice. Direct teaching in some form about models and modelling can be productive.

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Appendix
Part A
For each item in the following six questions, a statement is given and two answers are offered. Please choose between two alternative statements about scientific models. For each of these six questions, circle only one answer that you think is correct.
1. Models and modelling in science are important in understanding science. Models are:
   a) Representations of ideas or how things work.
   b) Accurate duplicates of reality.

2. Scientific ideas can be explained by:
   a) One model only, — any other model would simply be wrong.
   b) One model, — but there could be many other models to explain the ideas.

3. When scientists use models and modelling in science to investigate a phenomenon, they may:
   a) Use only one model to explain scientific phenomena.
   b) Use many models to explain scientific phenomena.

4. When a new model is proposed for a new scientific theory, scientists must decide whether or not to accept it. Their decision is:
   a) Based on the facts that support the model and the theory.
   b) Influenced by their personal feelings or motives.

5. The acceptance of a new scientific model:
   a) Requires support by a large majority of scientists.
   b) Occurs when it can be used successfully to explain results.

6. Scientific models are built up over a long period through the work of many scientists, in their attempts to understand scientific phenomenon. Because of these, scientific models:
   a) Will not change in future years.
   b) May change in future years.

Part B
For each of the following five items a short statement or title related to the answers is given. Three answers are offered for each statement/title. Circle one of the letters near to the three answers as you agree, namely, A - most agree with the answer, B - median agree with the answer, C - least agree with the answer. You should circle a different letter for each of the offered answers.

1. Nature of the models.
   A B C Model is a copy of the original.
   A B C Model is an idealized representation of the original.
   A B C Model is a theoretical reconstruction of the original.

2. One or more models (multiple models).
   A B C We use more models because we often have different objects (originals).
   A B C We use more models because we focus on it differently.
   A B C We use several models because we have different hypotheses about the object (original).

3. Purpose of models and modelling.
   A B C Purpose of the model is to describe the original.
   A B C Purpose of the model is to explain the original.
   A B C Purpose of the model is to make a prediction about the original.

4. Checking the models.
   A B C We check the model for possible omissions in making the model.
   A B C We check the model to determine similarity or identity with the original.
   A B C We check the model to test hypotheses related to the original.
5. Modify the model or replace it with another model.
   A  B  C We make correction or replacement of the model due to perceived flaws that have occurred.
   A  B  C We make a correction or replacement of the model based on new knowledge (discoveries).
   A  B  C We make a correction or replacement of the model due to disagreement with the set hypothesis.

Part C
1. What is a model? How do you understand the concept of model?

2. List some example of models (at least three) that you have encountered or used in lectures and exercises during the study at the faculty.

3. Do you receive adequate and sufficient professional knowledge and pedagogical content knowledge about models during your studies at the faculty (about the concept of model, meaning, purpose of models, application, testing models, importance of models, etc.)?

Part D
Does what is given from a) to k) represent a model?
If you think it is a model, circle YES. If you think it is not a model, circle NO.

   a) Velocity versus time diagram                  YES   NO
   b) \( y = 2x + 3 \) (mathematic equation of a given line)  YES   NO
   c) Map of Europe                                    YES   NO
   d) Free body diagram                                 YES   NO
   e) Structural formula of ammonia                   YES   NO
   f) \( 2H_2 + O_2 = 2H_2O \) (chemical equation)     YES   NO
   g) \( P_{t+1} = \lambda P_t \) (Populations growth rate formula)  YES   NO
   h) \( \vec{F} = m\vec{a} \) (Newton’s second law of motion formula)  YES   NO
   i) Skeleton used in biology teaching               YES   NO
   j) Periodic table of the elements                   YES   NO
   k) \( \text{NH}_3 \) (chemical formula)              YES   NO