PRESERVICE ELEMENTARY TEACHERS' UNDERSTANDINGS ABOUT SCIENTIFIC MODELS AND MODELLING

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Abstract

Scientific models are important thinking tools, which are used to generate explanations and predications. Despite the relevance of scientific models and modelling in science education, several studies reveal that students and teachers do not possess adequate views regarding these topics.

This study investigated preservice elementary teachers' views about scientific models and modelling. Research questions included: (1) what do preservice elementary teachers understand about models and modelling in science?; (2) is there a relationship between preservice teachers' views about scientific models and modelling and their scientific background in high school or year of course attendance?

A questionnaire adopted form the literature was applied to a sample of preservice elementary teachers of one Portuguese institution of higher education at 1st, 2nd and 3th years of the course. This questionnaire comprised five aspects of students' understanding of models and modelling: nature of models, multiple models, purpose of models, testing models, and changing models.

Descriptive analysis showed that a high percentage of preservice elementary teachers hold naive or uninformed understandings of models and modelling. From this we can infer that this lack of understanding would hamper their pedagogical practice related to scientific issues in a fundamental way as well their teaching and learning in their initial formation.

Moreover, students' understanding of models and modelling didn't became more elaborated with increasing university years and no difference was found taking in account the area chosen in high school.

Keywords: Preservice teacher training, scientific models, Nature of Science.

1 INTRODUCTION

According to the new guidelines and international recommendations, science education must include at least three essential elements. The first, to learn science, corresponds to the development of conceptual and theoretical knowledge. The second, learning about science, is related to the development of an understanding about the nature of scientific knowledge and scientific methodologies, an appreciation of its history, its development, and the complex interactions between science technology and society and also a reflection on the personal, social and ethical implications of certain technologies. The third element, doing science, emphasizes the importance of students developing research and problem solving skills [1], [2]. Scientific models can be regarded according with these three elements. Indeed, students should learn relevant scientific models, develop knowledge about models (learn the nature of scientific models and modelling), and embraced practices of modelling. In this study, we focus our attention in the second element – knowledge about scientific models and modelling.

Different authors, with whom we agree, defend that students' understanding of scientific models is a component of their understanding of the nature of science [3], [4]. In other words, students "need to understand how models are used, why they are used, and what their strengths and limitations are, in order to appreciate how science works and the dynamic nature of knowledge that science produces" [4, pp. 634–635].

Despite the relevance of scientific models and modelling in science education, several studies reveal that students and teachers do not possess adequate views regarding this topic. Moreover, the concept of knowledge about models and modelling is conceptualized and assessed through different approaches. Therefore, we will proceed by describing students and teachers' understandings about models and we summarize the main approaches used in this area.

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1.1 Students' understandings about models

The work developed by [5] was pioneer in analyzing students' understandings about models. They interviewed seventh-grade and eleventh-grade students and experts (adults with specialized knowledge in models) about their conceptions about models in five categories: kinds of models, purpose of models, designing and creating models, multiple models for the same phenomena thing, and changing models. From the interviews analysis, three general levels of models and modelling understandings emerged. Students in level 1 thought of models either as toys or as copies of reality, which corresponds to a naïve realist epistemology of models and modelling. Students in level 2 realize that the model is created for a purpose and that the modeler makes conscious decisions about how to achieve that purpose. Although for these students the model does not need to exactly reflect reality, the main focus is still on the reality modeled, not in the ideas represented. Therefore, the model is tested in terms of its fitness for the predetermined purpose and not for the underlying ideas. In level 3, three ideas are present: the model is created to develop and test ideas, not to replicate reality; the modeler has an active role constructing the model; models can be tested and changed in order to inform the development of ideas. The authors found that students "are more likely to think of scientific models as physical copies of reality that embody different spatio-temporal perspective than as constructed representations that may embody different theoretical perspectives" [5, p. 779].

Using the Students' Understanding of Models in Science (SUMS) instrument, which includes decontextualized questions about models in science, [6] conducted a study with 228 students (13-15 years old). This instrument analyzed five different ideas: i) scientific models as multiple representations; ii) models as exact replicas; iii) models as explanatory tools; iv) how scientific models are used; v) the changing nature of scientific models. Most of the students understood that scientific knowledge can change, with new ideas and theories resulting in changes to the accepted scientific models and also understood the descriptive role of models. However, they didn´t understand the role of models in making predictions and testing ideas.

Another author [7], developed a study in order to analyze students' understanding of models and modeling as expressed in contextualized assessment tasks (refer explicitly to biology, chemistry, and physics scientific disciplines). Students' understanding of models was assessed by means of forced choice-tasks. The findings suggest that models may be used in a rather descriptive way in biology classes but in a predictive way in chemistry and physics classes. Moreover, they only detected small differences in students' understanding of models and modeling between the different grade levels 7/8 and 9/10.

1.2 Teachers' understandings about models

One study [8] researched on experienced secondary science teachers' (biology, chemistry and physics teachers) notions of models in the context of an innovative Dutch curriculum project in which the role and the nature of models and modelling in science was emphasized. Data collection was made through the application of a questionnaire. The authors conclude that "the knowledge of the majority of the teachers of models and modelling in science was not very pronounced" [8, p. 1151]. For instance, teachers hold the view that a model is a simplified or schematic representation of reality and rarely mentioned the fact that models are used by scientists to make predictions. They also reported that teachers used various criteria to decide whether or not a giving example is qualified as scientific models.

Other authors [9] conducted semi-structured interviews to enquire into the notion of model held by 39 Brazilians (10 science teachers of students between 6–14 years; 10 serving teachers for students aged 15–17 years; 10 undergraduate pre-service science teachers for aged 15-17 years; 9 university teachers of chemistry). According to the data analysis, the authors believe that the notion of models held by the teachers, can be represented by seven "aspects": the nature of a model; the use to which it can be put; the entities of which it consists; its relative uniqueness; the time span over which it is used; its status in respect of the making of prediction; and the basis of accreditation for its existence and use. Moreover, it was not possible to establish a relationship between teachers' views about the nature of model and the level they teach. However, to some extent, the understandings shown by the teacher's interviewed tend to be related to their educational background. Teachers with degrees in chemistry or physics had different views about the notion of model when compare with those with degrees in biology or with teacher training certificates.

One of the few studies related specifically to prospective teachers [10] explored 196 novice physical science teachers' perceptions of models in general, and of models specifically related to optical phenomena through a questionnaire. Most participants' level of knowledge of models was limited. They viewed the primary function of a model as a tool to help someone understand a phenomenon, explain complex and abstract things, and to demonstrate how something works, which represents a limited view of scientific models (models having basically a function of explaining to others).

1.3 Approaches to the concept of understanding models and modelling

Different approaches to the concept of understanding models and modelling are evident in science education literature. A comparative analysis of these approaches reveals similarities and differences. First, all approaches include different aspects as part of knowledge about models and modelling in science, although the term used to designate those aspects vary across the approaches. For example, [6] adopted the term *themes*, [9] the designation *aspects* and [11] the name *dimensions*. Even so, the nature of the aspects isn't always significantly different [11].

Second, the number of aspects addressed in each approach can range: [9] identified seven aspects of the notion of models (the nature of a model; the use to which it can be put; the entities of which it consists; its relative uniqueness; the time span over which it is used; its status in respect with the making of prediction; and the basis of accreditation for its existence and use); [6] identify five aspects about students' understanding of scientific models (scientific models as multiple representations; models as exact replicas; models as explanatory tools; how scientific models are used; and the changing nature of scientific models); and [12] used five aspects of modelling understandings (purpose of models, designing and creating models; changing a model, multiple models and validating and testing models).

In the present study, and like in the work of [7] and [13], we consider five different aspects: nature of models, multiple models, purpose of models, testing models and changing models. The aspect nature of models comprises the relation of a model to the phenomena it intends to represent. The aspect multiple models includes the reasons for the existence of different models for the same scientific object/phenomena. The aspect purpose of models encompasses the ideas regarding the finality of the model. The aspect testing models focuses on how a model can be tested, while the changing models aspect refers to the reasons why a model can be changed.

Third, regarding models' knowledge assessment, while most studies created different levels/categories of understanding, the number and the way those levels/categories were used differ: in study [5] three global levels were generated for each student evaluated; in research [11] three to four levels (limited, pre-scientific, emerging scientific and scientific) were constructed for each of the 5 aspects of models knowledge adopted; in the investigation [9] three to four categories of meaning emerged for each of the seven aspects analysed; and in [13] three aspect-dependent levels were used. This raises the question of whether we can regard models' knowledge as global or aspect-dependent.

2 METHODOLOGY

A questionnaire adopted form the literature [7] was applied to a sample of preservice elementary teachers of one Portuguese institution of higher education at 1st (40 students), 2nd (13 students) and 3rd (31 students) years of the course.

This questionnaire comprised five questions, related to five different aspects regarding models' knowledge (nature of models, multiple models, purpose of models, testing models and changing models). In each question, three statements were provided which represent three levels of understanding about the respective aspect (Table 1).

Table 1. Levels of models and modelling knowledge.

	Level I	Level II	Level III
Nature of models	Replication of the original	Idealized representation of the original	Theoretical reconstruction of the original
Multiple models	Different models objects	Different foci on the original	Different hypotheses about the original
Purpose of models	Describing the original	Explaining the original	Predicting something about the original
Testing models	Testing the model object	Compare the model and the original	Testing something about the original
Changing models	Correcting defects of the model object	Revise due to new insights	Revise due to the falsification of hypothesis about the original

Students were asked to order the statements by order of preference ('I agree more', 'I agree so-so', and 'I agree less'). However, in this study we only score the level that students ranked first, namely: zero, when they ranked level I as "I agree more"; one, when they preferred level II; and two, when they choose level III. Therefore, each student was graded as Level I, Level II, or Level III in relation to the five different aspects about models and modelling.

The internal consistency of this questionnaire was assessed in order to understand if the students' understanding about models could be expressed in a single score (as the mean of five sub scores). To test relationships between students' understanding about each model knowledge aspect and the year of the course, as well, their scientific background in the high school, we performed a chi-square test.

3 RESULTS AND DISCUSSION

Figure 1 shows the percentage of students' responses in each level by each aspect.

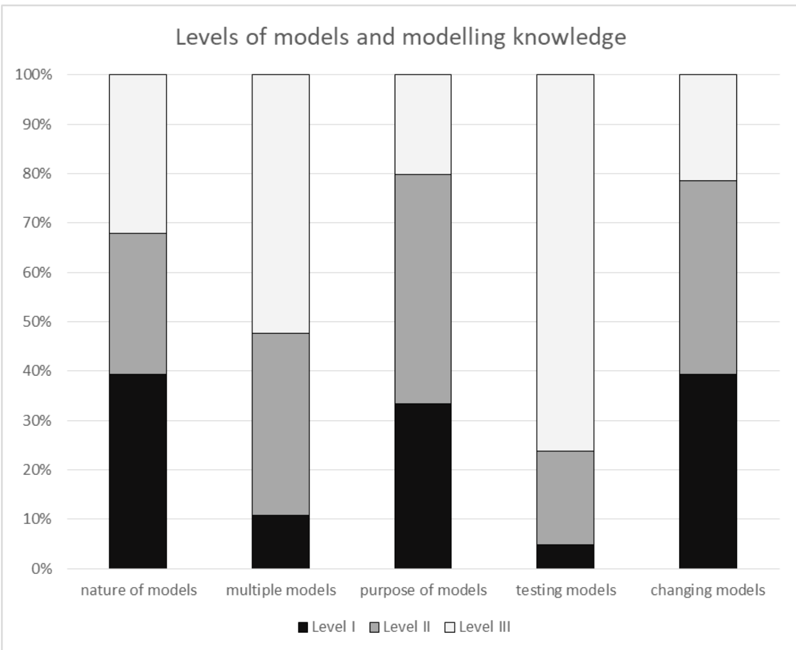

Figure 1. Levels of models and modelling knowledge.

As we mentioned earlier, the aspect-dependent understanding of models is one of the findings of several studies [9], [12], [13]. Students exhibit apparently contradictory knowledge of models. For instance, in [6, p. 366] students "showed a good appreciation for the changing nature of scientific models" but fail in address the nature of models, with a good percentage of them resting at the naive level of understanding. This aspect-dependent nature of the knowledge of the models is translated in this study by a poor Cronbach-alfa (α = 0.239). As this measure gives a hint about the dimensionality of the questionnaire, its value is another factor that allow us to adopt the aspect-dependent (multidimensionality) of students' knowledge of models. Like referred by [13] "students seem to have a complex and at least partly inconsistent pattern of understanding models" [13, p. 109].

In our study, *multiple models* and *testing models* were the aspects where students revealed a more informed knowledge – more than one-half reached level III. In addition, fewer than 11% of students were classified as level I (Figure 1). This result is in accordance with research [7], since these aspects were the ones where level III reached the higher percentage of preference (around 40% of the students choose level III in these two aspects). Although with a different methodology (deep interviews) the research [5] also explored students views regarding the aspect multiple models. These authors analyzed the answers, given by 7^{th} and 11^{th} grade students, to the question "can a scientist have more than one model for the something" and conclude that the majority of the students believe that the scientist could have different views of the same identity and one third of the 11^{th} grade students indicate that the scientist could emphasize different aspects of the identity. The authors also stated that "No student spoke of using different models to test rival hypotheses" [5, p. 810]. Using as reference the description of our levels of models and modelling knowledge (Table 1), we can say that the students who participate in study [5] hold ideas more in line with level II (Different foci on the original) than with level III (Different hypotheses about the original). However, is important to highlight that students interviewed were 7^{th} and 11^{th} grade students, a different population than the one used in the current work.

Analysing figure 1 is also possible to indicate that the aspect *nature of models*, *changing models* and *purpose of models* were the ones where level I reached higher preferences (39.3%, 39.3% and 33.3% respectively). In study [7] almost 40% and 50% of the students were also graded in level I in the aspect nature of models and purpose of models, respectively. However, in the aspect changing models, only 10% of the students were graded in level I.

In other study [5] a significant proportion of students: "described models as being just like the real thing but different in scale" [804]; indicated that models would be change "if it "wasn't right" or something was "wrong"" (…) [or] in light of new information that showed the model to be wrong" [p. 810]; and believed that the purpose of models "was to give you an example or demonstration of what something is or does (…) [or] help someone understand and to teach, as well as to make things more accessible or convenient to see and/or use" [804]. Our results can compare to the ones of study [5], since these descriptions are in accordance with our level I or II.

In the light of these results, it seems that not only students may have aspect-dependent understandings of models, but also that, in some aspects, is easier for some students to reach a scientific level of understanding than others. However, we only used a written questionnaire in this study and the sample is somehow limited comparing with for instance [6]. According to [12] "the use of a single assessment instrument may give an inaccurate or an incomplete picture of a teacher's knowledge structure" [12, p. 320] and, therefore, it will be important to conduct in depth interviews with students in order to further elaborated our comprehension about this topic.

The analyses of crosstabs to check if the students were distributed evenly over the three levels of models understanding with respect to their scientific background in high school and year of course attendance showed no significant differences between observed and expected frequencies (p>0,1). Therefore, students' understanding of models and modelling didn't become more elaborated with increasing university years. This also reinforce the need to explore this aspect in the initial formation of preservice elementary teachers by incrementing the number of moments and diversifying the teaching strategies about scientific models in science.

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