Model-based learning applied to natural hazards
Aprendizaje basado en modelos aplicado a los riscos naturales

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Abstract

Model-Based Learning is a methodology that promotes the restructuring of students' mental models. It includes the construction of many types of models that recreate physical phenomena, to seek the development of their scientific knowledge and scientific literacy. This work aims to analyze the opinion of 20 graduation students about the use of different types of models (computational model, physical model and mixed model) in the teaching of subjects of Natural Hazards in a public university in the north of Portugal. Having this in mind, we applied a seismological model evaluation scale, consisting of ten items classified through a five-point scale, developed and validated for this purpose. The data analysis allows us to understand that, although all the models were considered important, students recognize the major importance of a mixed model in restructuring their mental models, and in helping their learning process. Thus, the authors argue that the use of models should be more explored in science education, because they are important in the learning process, and in the promotion of students' interest and motivation in science lessons.

Key words: *geosciences, mixed models, model-based learning, science education, seismology.*

Resumen

El aprendizaje basado en modelos es una metodología que promueve la reestructuración de los modelos mentales de los estudiantes, ya que incluye la construcción de diferentes tipos de modelos que recrean los fenómenos físicos, buscando el desarrollo de sus conocimientos científicos. El objetivo del estudio es analizar la opinión de 20 estudiantes de graduación sobre el uso de diferentes tipos de modelos (modelo computacional, físico y mixto) en las asignaturas de Riscos Naturales en una universidad pública del norte de Portugal. Se aplicó una escala de evaluación de modelos de sismología, compuesta por diez artículos, desarrollada y validada para el estudio. El análisis de los datos permitió comprender que los estudiantes reconocen la importancia de todos los modelos, pero ellos consideran que el modelo mixto es el mejor en la reestructuración de sus modelos mentales, y en el desarrollo de su proceso de aprendizaje. Los autores creen que el uso de modelos debe ser más explorado en la enseñanza de las ciencias, pues son importantes en el proceso de aprendizaje, y la promoción del interés y la motivación de los estudiantes.

Palabras clave: *aprendizaje basado en modelos, educación en ciencias, geociencias, modelos mixtos, sismología.*

INTRODUCTION

Nowadays, in science education, it is contended that students develop their knowledge through the construction of mental models, which help them to develop scientific reasoning and make decisions, being the basis of individual behaviors (Jones, Ross, Lynam, Perez & Leitch, 2011). Johnson-Laird (1983) argue that mental models are internal representations of the natural world (Orlik, 1996; Moreira, 2002) that students use to interact with the world around them. The Theory of Mental Models is based on three principles: (i) mental models represent what is common to a distinct set of possibilities; (ii) mental models are iconic, their structure, as far as possible, corresponds to the structure of what they represent; (iii) they are based on descriptions and represent what is true and observable. People develop mental models to explain, perceive, and understand real world behaviors (Kurnaz & Eksi, 2015), which means that mental models are personal and constructed by individuals (Moreira, 2002), based on their life experiences, perceptions, and understandings of the world (Jones *et al.*, 2011). In fact, they are related to perceptions acquired as a result of one's actions, and an external or conceptual model can be developed by generating codes about these perceptions (Kurnaz & Eksi, 2015).

In this context, model-based learning has an important role in science education because it involves the construction of models that aim to recreate a physical phenomenon, seeking to respond to problem situations. It leads students to develop many relationships between objects and variables which can represent the scientific phenomenon and recreate its behavior (Louca, Zacharia & Constantinou, 2011). According to this methodology, the behavior of a phenomenon and its variables arises from its objects and engages students in the process of building and testing models of scientific phenomenon, and helps them to develop many important skills, such as scientific reasoning, scientific communication and argumentation (Justi & Gilbert, 2002). According to Pirnay-Dummer and his collaborators (2012), model-based learning provides a useful spur for knowledge restructuring because it induces a cognitive conflict by carefully introducing contradictory facts to those which students believe. This cognitive conflict is necessary for construction of new knowledge over their prior existing mental models (Pirnay-Dummer, Ifenthaler & Seel, 2012). Thus, model-based learning is considered fundamental in the building of students' scientific knowledge and in the promotion of scientific literacy, assuming an important role in the development of meaningful learning (Gobert *et al.*, 2011). Johnson-Laird argues that there is not only one mental model to represent a particular phenomenon, which means that there may be several, even if only one of them is scientifically consistent with it (Moreira, 1996). In this context, it is assumed that there are also many types of models that can be constructed and applied through modeling (Vasconcelos *et al.*, 2015). Many authors accept the importance of establishing a typology of models, trying to help science teachers to distinguish them and to select the best models to apply in their classroom with their students. Boulter & Buckley (2000) consider that categorizations enable groupings according to their similarities and classifications are usually constructed to highlight these similarities between types, but also to facilitate description and to reduce complexity. In fact, categorization is a crucial personal process in making sense of the world and the human mind is set upon making sense of the big range and complexity of the impressions that we are able to experience (Bailey, 1994). Categorization should allow us: (i) to structure and give coherence to the world of models and to organize the diverse range of models into a usable form; (ii) to predict patterns as we seek to fit new models into the categories; (iii) and to ask useful questions about the progression of models in the learning process and within the development of science (Boulter & Buckley, 2000).

All categorization is valid if properly justified according to the purpose of the study, and providing that it is simple and clear to be easily understood, both by teachers and students. In this work the categories of models were delineated according to their functional characteristics and three types of models were defined: computational model, physical model and mixed model.

The first model that was used was the computational model, which consists in a computer software that contains a model of a process, and is typically used to create images of phenomena, to find and test relationships in complex systems, and to test multiple hypotheses (Gilbert & Ireton, 2003). This computational model is available in the internet (Earthquakes, Make-a-Quake: Earthquake Simulator), and its manipulation was accompanied by a M*odel Exploration Document*, developed by the authors.

According to De Jong and Van Joolingen (1998), computational models can be divided into two types: simulations containing conceptual models and simulations based on operational models. The first one holds principles, concepts, and facts related to the phenomenon being simulated, such as the seismic effects on soils and buildings, as was simulated in the computational model applied in this study. The operational models include sequences of cognitive and non-cognitive operations that can be applied to the simulated phenomenon.

The use of these types of model led teachers: (i) to save time in class, allowing them to devote more time to the students rather than to the set-up and supervision of experimental equipment; (ii) to allow the manipulation of experimental variables, help the students for stating and testing hypotheses; (iii) and to provide ways to support understanding of many representations, such as diagrams and graphs (Rutten, Van Joolingen & Van Der Veen, 2012).

It is well known that students of all ages like to play with the computer, so all kinds of computational software are very interesting and helpful for teaching (Orlik, Gil, Moreno & Hernández, 2005), because they increase the students' motivation. Moreover, these types of software create a friendly learning environment while introducing and explaining some important science concepts (Orlik *et al.*, 2005). In spite of its recognized importance in improving the educational standards of science teaching, because the variety of software makes it possible improved results in instruction compared with traditional methods of education (Orlik, 1997), there is no consensus about the advantages of computational simulations because, some authors noticed that students working with these models, were unable to deal with unexpected results and that they did not utilize all the experimenting possibilities that were available. This situation stems from the lack of preparation of teachers to explore such models sufficiently with students. Thus, it is argued that the approach to the models in the classroom should be accompanied by some instructional support that helps students on a guided manipulation of the model (De Jong & Van Joolingen, 1998), and therefore it is necessary that teachers develop abilities to use computers in their classes (Orlik, 1997).

In this study it was also applied another type of model – physical model, also named material model (Chamizo, 2010). Basically, these models consist of a type of simulation used to communicate some phenomena with other individuals. Physical models express mental models that are articulated through a specific language (Chamizo, 2010), and where students directly manipulate the variables, and correspond to the regular simulations that are usually used in science education.

Physical models provide operational descriptions of physical systems (Louca & Zacharia, 2012), allowing representation of phenomena in which one or more elements of a system is changing over time, and given the dynamic character it allows students to simulate and observe a certain natural phenomenon and which variables are involved in it. Therefore it summarizes the key aspects of the theory, so that students can more easily visualize their explanatory principles (Greca & Moreira, 2001).

These types of simulations are very useful because they allow the recreation of natural phenomena that cannot be reproduced in the classroom, and help students to understand the phenomena, because they consist in concrete representations of abstract ideas in science (Louca & Zacharia, 2012). As we know, there are many natural phenomena that cannot be reproduced in the science classroom because of time and scale constraints, for example geological phenomena. Consequently, physical models are accessible for students, and teachers know that they enjoy manipulating them (Harrison & Treagust, 2000), so the application of these models stimulates students' motivation. It is suggested that teachers should be sensitive to the familiarity, similarities and differences between the models that they use to explain scientific phenomena, so they can help students to understand it and to develop their knowledge. It is also argued that students could develop the ability to produce, test and evaluate these models, as well as their dynamics, through the manipulation of physical models. Therefore they could improve their interest and have a deeper understanding of the real changes that have occurred in the course of Earth history (Deus, Bolacha, Vasconcelos & Fonseca, 2011).

Finally, we applied a different type of model named mixed model. This model includes two components: a physical component (from the physical model) and a computational component (from the computational model), so it is basically richer than the previous one, because it covers some of the characteristics of the other two models that were applied. In this study, the mixed model applied consisted in a seismic shaking table, as the physical component, which let us to simulate the earthquake in the classroom. The seismic shaking table was connected to a seismograph that recorded the propagation of seismic waves, presenting the results, trough a computer software, as seismogram (computational component).

The use of mixed models is fundamental for presenting complex concepts, because each component of the model refers to different dimensions of the same concept (Gilbert & Ireton, 2003; Vasconcelos *et al.*, 2015).

Given the particularities of Geology as a science, and taking into account the difficulties inherent to the teaching of science, as the issue of temporal and geographic scale, or the behavior of materials existing in nature, it is easy to understand the need to improve the models generally used for simulating geological phenomena (Moutinho, Moura & Vasconcelos, in press).

Boulter and Buckley (2000) suggest that learning models often require multiple components to convey information about the phenomenon, such as *animations of structures to convey behaviors, plus narration to explain the causal mechanism* (p. 46). Having this in mind, mixed models are, in fact, a type of model that articulate all the components that were needed for simulating the natural phenomenon. Considering this characteristic of mixed models, they could be assumed as an important learning strategy to help students in the construction of their scientific knowledge, because they promote the development of skills that enable students to become informed citizens and to be able to solve everyday problems.

Despite the potential of model-based learning, it requires a specific knowledge, training, and an appropriate educational context to be successful. Then, the teachers' role remains essential in the whole learning process (Libarkin & Brick, 2002), but they need to be aware so that they can develop strategies to enable the restructuring of students' mental models.

METHODOLOGY APPLIED IN THE INVESTIGATION

The purpose of the study was to analyze the opinion of graduation students about the three types of models used during the lessons about the seismic effects on soils and buildings. Each one of the three models was applied in three different classes, using Problem-Based Learning as learning strategy, because, in all classes, students were confronted with problems related to (seismic) natural hazards, that they should solve through the manipulation of the models. Hence, a scale was developed and validated, named *Seismological Models' Evaluation Scale – SMES* (Moutinho, Moura & Vasconcelos, 2014), that contained ten items that evaluate each one of the three models (computational model, physical model and mixed model) that are manipulated during the classes. In the scale, each item should be classified according to a five points scale (from 1- *Totally disagree* to 5 - *Totally agree*).

After collecting the data, they were statistically analyzed trough the 23rd version of a statistical program SPSS. In this study we used a nonparametric test and its selection was made having in consideration the dimension of the sample, which was too small to assume the normality (McDonald, 2014). It was defined a confidence level of 95% which represents a significance level of 0.05.

In this study we selected a convenience sample, which included 20 graduation students from a curricular unit of Geological Hazards, ministered in a northern Portuguese public university. The study sample contained 10 females and 10 males, with an average age of 21.6 years old and ranged 20 to 24 years old.

The samples that are defined for the statistical test are also paired, because the purpose of the study is to compare values that are different measures of an individual. As so we applied the Wilcoxon Test, a nonparametric test recommended to paired and small samples, with a non-normally distribution (McDonald, 2014).

RESULTS AND DISCUSSION

After the analysis of the data with the statistical program SPSS, the results are presented in table 1.

Table 1. Statistical information about computational, physical and mixed model (n=20).

	Computational model	Physical model	Mixed model
Average	36.2	33.9	36.4
Standard Deviation	6.70	5.15	5.92
Minimum	21	24	26
Maximum	48	45	50

According to table 1, it is possible to understand that for the study sample (n = 20), the mixed model is the one with the highest average (36.4), followed by the computer model (36.2), although this model presents the largest standard deviation value (6.70). The mixed model has a standard deviation value of 5.92, but the model with the lowest standard deviation value is the physical model (5.15). Moreover, the analysis of the data from table 1 shows that the mixed model presents higher maximum and minimum values, 50 and 26, respectively; while the computational model has the lowest minimum value (21) and the physical model has the lowest maximum value (45).

For that reason, the data analysis led us to understand that the mixed model is the one that, besides having a higher average, also has one of the smallest standard deviation values between higher maximum and minimum values. Therefore, graduation students consider that the mixed model is the best model for helping in the construction and development of the students' learning process. The other two types of models (computational and physical) have also higher average values, however these models have higher standard deviation values, which led us to consider these values not to be so precise.

Nonparametric Test – Wilcoxon Test for paired samples

As we have already referred in the methodology section, as the study sample was small and didn't have a normal distribution, it was decided to use a nonparametric test, named Wilcoxon Test. For the application of this statistical test, three hypotheses were defined (HA, HB and HC):

H0: The average scores for the computational model importance in the learning process is equal to the average scores for the importance attributed to the physical model in the learning process.

HA: The average scores for the computational model importance in the learning process is different from the ordinations average of average scores for the importance attributed to the physical model in the learning process.

H0: The average scores for the computational model importance in the learning process is equal to the average scores for the importance attributed to the mixed model in the learning process.

HB: The average scores for the computational model importance in the learning process is different from the average scores for the importance attributed to the mixed model in the learning process.

H0: The average scores for the physical model importance in the learning process is equal to the average scores for the importance attributed to the mixed model in the learning process.

HC: The average scores for the physical model importance in the learning process is different from the average scores for the importance attributed to the mixed model in the learning process.

According to the hypotheses that have been established, the Wilcoxons' nonparametric test for paired samples was applied. In this case bilateral tests were used because the data only let us ascertain whether the hypotheses are different or not, but we could not determine what is the tendency of this difference (if it exists). The results of the Wilcoxon test are organized and presented in table 2.

Table 2. Results of Wilcoxon test for the three tested hypotheses (n=20).

	HA Computational-Physical	HB Computational-Mixed	HC Physical -Mixed
Z	-1.674	-0.379	-2.094
Significance (bilateral)	0.097	0.723	0.035

It was defined a confidence level of 95% and a significance level of 0.05. The results of the Wilcoxon test (table 2) show that only the difference between the physical and the mixed model is, in fact, significant, because of the value of $p<0.05$. There is no significant improvement in the students' learning with both other types of intervention. Thus, mixed models are the best type of models to promote the construction of knowledge, which includes the restructure of students' mental models to make them more congruent with school science models.

CONCLUSIONS

This study led us to understand that graduation students recognize some importance in the application of the three types of models in geosciences lessons, because all the three types of models obtained similar average values. However, graduation students consider that mixed models are the best type of models to promote the construction of scientific knowledge, and the restructure of students' mental models.

In fact, these results led the authors to consider that because of its characteristics, mixed models are the most complete models to apply in geosciences lessons. These models have two important characteristics: first of all they have a computational component that promote the interest and motivation of students, because 21st century is the technology century, and so students are familiarized with electronic devices, such as computers. On the other hand, this type of model also has a physical component, that allows students to observe directly the phenomenon occurrence These help them to understand what happens in nature, even knowing that what they observe is only a simulation of the natural phenomenon. Therefore, the authors consider that these types of models should be more explored in science education, because they are important not only in the learning process, but also in the promotion of students' interest and motivation in science lessons. Modeling and the manipulation of models help students to develop some attitudinal skills, because they allow students to analyze problem situations, to formulate questions and to observe and understand how natural phenomena occur, and at the same time, develop scientific reasoning and argumentation skills. During this process, students understand if their mental models are consistent with the curricular model of the phenomenon and, if they are not, they naturally restructure them to make their mental models congruent with the curricular model. This process is very important because it allows students to develop a meaningful learning.

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Development of the learning design ability in the vocational context for pre-service chemistry teachers

Desarrollo de la capacidad de diseño de aprendizaje en el contexto profesional para los profesores de química en formación

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Abstract

Differences in the nature and purpose of learning chemistry in general schools and vocational schools have implications on the need to prepare specific capabilities for pre-service chemistry teachers. This study aims to examine the basic ability of pre-service chemistry teachers to design learning through the development of pedagogical content knowledge (PCK) in the context of vocational training. This study was designed as a descriptive study. Participants (36) in this study were students of third level on chemistry education study programs of Yogyakarta State University in Indonesia who are taking the subject of vocational chemistry. Preparation of pre-service teacher's ability was conducted through collaborative learning in small groups, class discussions and ends with an independent assignment. There are three instruments used in this study. They are assessment sheet of the ability to analyse the chemistry content appropriate in vocational context, to construct content representation (CoRe) and to construct pre-pedagogical and professional experience repertoires (p-Pap-eRs). The results showed that pre-service chemistry teachers have a pretty good ability in designing chemistry learning in vocational context. The main implication of this research is the need for restructuring of the curriculum for pre-service chemistry teacher education programs that are more concerned with professional development in the context of vocational schools.

Key words: *learning design, Content Representation , Pedagogical and Professional experience Repertoires , vocational, chemistry teacher, Pedagogical Content Knowledge.*

Resumen

Las diferencias en la naturaleza y la finalidad del aprendizaje de la química en las escuelas, tienen implicaciones sobre la necesidad de preparar los profesores de química con las capacidades específicas. Este estudio tiene como objetivo examinar la capacidad básica de licenciados de química para diseñar el aprendizaje a través del desarrollo del conocimiento didáctico del contenido en el contexto de la formación profesional. Los participantes (36) de este estudio eran estudiantes de tercer nivel sobre programas de educación de la química de la Universidad Estatal de Yogyakarta en Indonesia. El trabajo se llevó a cabo a través del aprendizaje colaborativo en grupos pequeños, discusiones en clase y terminó con una asignación independiente. Los tres instrumentos fueron : la hoja de evaluación de la capacidad de analizar el contenido de la química apropiada en el contexto profesional, para la construcción de la representación del contenido y para la construcción de repertorios de experiencia pre-pedagógicos y profesional. El resultado mostró que los licenciados de química tienen una buena capacidad de aprendizaje en el diseño del curso de química en el contexto profesional. La implicación principal de esta investigación es la necesidad de una reestructuración del plan de estudios de licenciatura en la dirección del desarrollo profesional en el contexto de las escuelas de formación profesional.

Palabras clave: *diseño de aprendizaje, representación de contenido, experiencias pre-pedagógicas y profesionales , profesor de química, conocimiento didáctico del contenido .*

INTRODUCTION

One of the capabilities that are important for the teacher's role as controller of learning in the classroom is the ability to design learning. Learning design is very important because it is used as a guide for teachers in implementing the learning to achieve the expected goals. In particular, a pre-service chemistry teacher at a vocational school must have a good ability to develop learning chemistry in accordance with the vocational context. There are two things that are associated with the ability of pre-service teachers in designing learning. Both of these are a foundation of knowledge and thinking framework for teachers in designing learning in order to create a wide variety of learning conditions conducive to facilitate student learning.The development of foundation of knowledge and thinking framework forteachers in designing learning begins with constructing Pedagogical Content Knowledge (PCK) for pre-service chemistry teachers. PCK as a construct of teachers' knowledge is subject and domain-specific (Shulman, 1986; Shulman, 1987, Bucat, 2004). PCK is an amalgamation of content and pedagogy in a specific context (Gess-Newsome, 1999). In other words, it refers to knowledge about teaching and learning of particular subject matter that takes into account the particular