

# Learning how to model in science classroom: key teacher's role in supporting the development of students' modelling skills

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## ABSTRACT

Modelling is a key process in the development of scientific knowledge. In order to conduct a more authentic science education, i.e., to make the processes it entails successively approximate to those of science per se, it is advocated that it should be conducted from a modelling-based perspective. From an analysis of how modelling is generally conducted in science, a scheme to represent such a process was previously proposed: the 'Model of Modelling' diagram. It has been used as a framework for the development and use of teaching strategies for some abstract concepts in chemistry. In this paper, a modelling-based teaching of chemical bonding occurred in a regular classroom in Brazil is analysed. In particular, the following research question is discussed: What must teachers do to support the development of modelling skills by students in lessons based on the 'Model of Modelling'? From such a discussion, relevant implications and recommendations for science teachers interested in based their practice in a modelling approach are also presented.

**KEY WORDS:** modelling-based teaching; teacher's role; students' modeling skills

## Introduction

Documents about science education published all over the world (for instance, American Association for the Advanced of Science - AAAS, 1990; Millar and Osborne, 1998; Teaching and Learning Research Programme, 2006) have been presenting guidelines for the teaching in this area that point out the need of engaging students in their learning process, defending the need of the development of skills, mainly those associated with the process of scientific investigation. This aims at contributing to the development of a wider vision of science and knowledge as it is built and used. The ultimate outcome would be science education becoming a significant part of the 21st century citizens' education.

Modelling is one of the essential processes in producing, validating, and disseminating scientific knowledge (Gilbert, Boulter, and Elmer, 2000). Therefore, from the science education view expressed previously, some researchers (e.g., Boulter and Gilbert, 2000; Clement and Rea-Ramirez, 2008; Erduran, 2001; Halloun, 2004) have emphasised the importance of model-based teaching and learning as a way to stimulate scientific understanding. That is because the constructive modelling process requires that students (i) sort out and build explanations of scientific phenomena, rather than merely memorising facts and definitions; (ii) define and revise problems over time; (iii) search for information and data sources.

Moreover, the process of establishing relationships between data to build a model can give students a reason to determine the quality of different information sources. Therefore, model building can provide a context for students to build scientific arguments, to state a position and then justify the claim, or position, with evidence. It can also provide students a context to think about the purpose of science, and the purpose of tools of science (like models and theories), thus becoming a powerful activity for engaging students in doing and thinking about science (Maia and Justi, in print). From such a perspective, we advocate that the involvement of students in modelling-based activities contributes to the development of a series of skills that are meaningful to all citizens' general education. Such a view can be justified by assuming that, although scientific knowledge is provisional, the scientific skills and process are not, that is, they can be transferred to other contexts (American Association for the Advanced of Science - AAAS, 1990).

In an attempt to synthesise the main stages that comprise the modelling process, Justi and Gilbert (2002a), from an analysis of how models are produced in science, proposed the 'Model of Modelling' diagram (Figure 1). It represents modelling as a non-linear creative process comprised of multiple and complexes stages mainly concerning with: acquiring information about the entity that is being modelled (from empirical observations and/or from previous knowledge), producing a mental model of it, expressing that model in an adequate mode of representation, testing it (through mental and empirical experimentation) and evaluating its scope and limitations.

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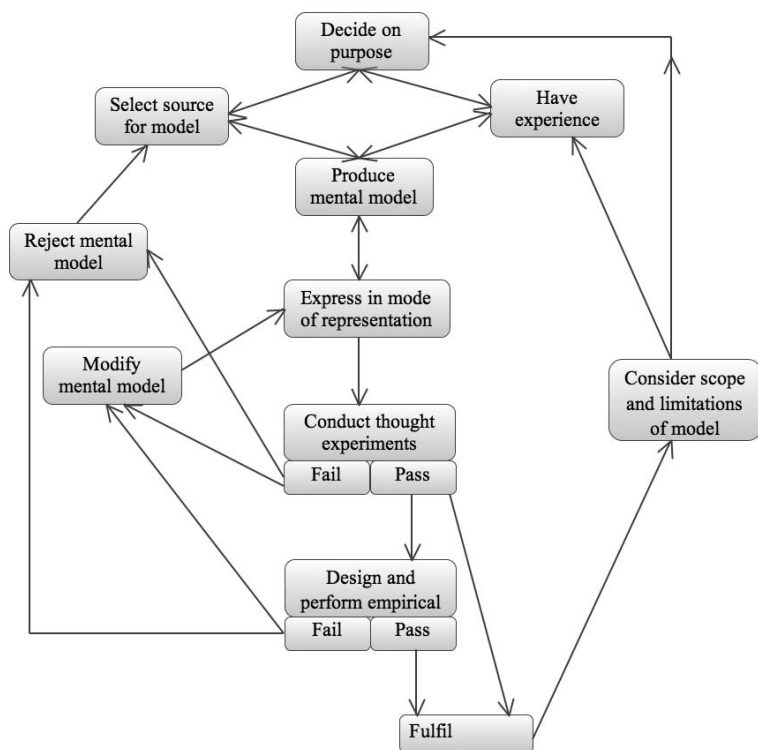


Figure 1. 'Model of Modelling' diagram (Justi and Gilbert, 2002a, p. 371).

In the last years, teaching strategies for some chemical concepts based on the view expressed in the 'Model of Modelling' diagram have been developed in our research group and used in medium level classes (15-18 years old students). For further information about the principles that guide the use of the diagram in the elaboration of the teaching activities, see Justi (2006). For information about teaching strategies produced for specific chemical themes, see, for instance, Maia and Justi (in print) and Mendonça and Justi (in print-a, in print-b). In all studies, we investigated how the modelling activities contributed to students' chemical theme learning in regular teaching situations. In general, our results showed that most of the students developed a comprehensive understanding not only about the themes (chemical equilibrium and ionic bond, respectively), but also about the nature of models and their role in the elaboration of scientific knowledge.

Part of the teaching strategies success in contributing to students' learning was credited to the structure of the strategies themselves. However, another significant part was identified as resulting from the way the teachers conducted the activities – which is a consequence of their knowledge on models and modelling. Previous attempts to characterise such knowledge (Harrison, 2001; Justi and Gilbert, 2002a, 2002b; van Driel and Verloop, 1999) showed that, in general, (i) teachers were not competent in this area, (ii) their practices rarely included modelling activities.

Teachers' knowledge is one of the most investigated themes in education. In his classical paper, Shulman (1987)

proposed seven categories that would describe teachers' basic knowledge. From this classical paper, other researchers (e.g., Magnusson, Krajcik, and Borko, 1999) discussed a more specific view of teachers' knowledge for science teachers. Analysing such works, we assume that two types of knowledge are of pivotal importance for science teachers using models and modelling: the content knowledge, and the pedagogical content knowledge (PCK). According to Shulman (1987), *content knowledge* is the understanding of the subject matter per se. In model and modelling context, it includes the understanding of the scientific models to be taught, as well as a comprehensive view about models (what a model is, the use to which it can be put, the entities of which it consists, its stability over time), and about the modelling process (the steps to be followed in the process and factors on which it depends) (Justi and Gilbert, 2002a; Justi and van Driel, 2005).

Shulman also proposed that teachers' PCK includes two core elements: "the way of representing and formulating the subject that make it comprehensible to others" and "the understanding of what makes the learning of specific topics easy or difficult" (Shulman, 1986, p. 9). This means that PCK is an integration of knowledge from several domains and it is focused explicitly on specific knowledge and skills that are unique to the teaching profession.

From these ideas, science teachers' PCK on models and modelling was previously identified as comprised of teachers' ability to conduct modelling activities in their classes, as well as their understanding of both how their students elaborate their own mental models and how the resulting expressed models should be dealt with in classes (Gilbert, Boulter, and Rutherford, 1998). Like the general definition of PCK, this specific one is also very comprehensive and complex. In order to help teachers interested in working from the modelling perspective, it is necessary to better characterise each of these general elements.

In a current research project, we are investigating which modelling skills students develop when they are participating in such teaching activities. This research project was proposed exactly because, during the previous studies focused on students' content learning, we realised that they learnt more than the chemical theme. Moreover, we realised that the teacher's role is essential in order (i) to turn the classes into inquiry environments, (ii) to help students to perform the stages of the modelling diagram, and (iii) to help students to develop relevant modelling skills – elements that could be included in their PCK concerning with the conduction of

modelling activities in classes. In our view, in order to really contribute to students' learning, the teacher has not only to understand the theoretical framework of the teaching activities and know the chemical theme, but also be able to play his/her role in the way briefly described above. This means that the teachers' roles in conducting modelling-based activities are different from those they play in ordinary traditional teaching situations. Therefore, in order to support teachers' education from this perspective, we decided to deeply investigate teacher's PCK concerning with the conduction of modelling-based activities.

In this paper, part of the results of this investigation is discussed. In particular, it focuses on the following research question: What must teachers do to support the development of modelling skills by students in lessons based on the 'Model of Modelling'?

### Context

This study was conducted in one 15-16 year old students' Brazilian public school class. The teacher had good previous experiences with modelling-based teaching. The students were learning chemical bonding for the first time, but had studied electrostatic forces in their physics classes. They worked in fixed friendship groups of 4-6 students. The teacher tried to support their discussion with the proposition of *generative questions*, those that "cannot be answered on the basis of stored information but require the genuine solution of a new problem" (Vosniadou, 2002, p. 358). Sometimes, after they had discussed the questions in their groups, the teacher promoted a class discussion in order to help students reach a consensus about a specific aspect that would be important for the next activity.

In elaborating the teaching activities that are briefly presented next, the principles of the modelling-based teaching, from the perspective described in the last section, were taken into account. Therefore, when doing the activities, students should create models – from the interrelationship between their previous knowledge concerning with Bohr's atomic model and new information presented in the teaching activities — to explain how bonds between atoms are established, thus forming a substance. Moreover, they should be able to express and test their models from the discussions between them and with the teacher. Next, students' models should be used to solve new problem-situations in which some macroscopic properties of ionic compounds could be explained. So, they could realise the explanation power of their models, as well as their limitations. The test and discussion stages did not intend to make all students express the same ideas/models. Rather, their main aim was to support students in changing their own models in a way to provide explanations which they judge adequate. At this stage, if it were necessary, the teacher should introduce some of the elements of the curricular model that might not have been proposed by students in their models, and establish a relationship between such elements and the consensus model in discussion, making clear

which aspects of the problem-situation each element of the model can explain. Table 1 presents a brief description of each activity of the modelling-based teaching, as well as its relationships with the 'Model of Modelling' framework.

In all activities in which students produced or changed their models, they had to present and justify them to the whole class. Such moments were very important because they favoured students' own idea organisation and communication. Therefore, they always resulted in great discussions among the students, each one trying to justify his/her ideas and to understand the difference between his/her ideas and their colleagues' ones.

After Activity 6, the teacher helped the students to reach a consensus about the nature of the ionic bonding electrostatic model. She also presented concrete models representing lattice structures of several ionic compounds and gave students some pieces of information about the scientific model (for instance, that in the NaCl lattice, each ion has six others of opposite charge at the same distance). However, even without this kind of information, the students were able to explain all the properties of the ionic compounds, and to calculate the lattice energy for the NaCl by using their own models.

### Methodology

After the approval of the Ethical Research Committee of the university where this study had been conducted, all the lessons were video-recorded. The videos focused on the discussion between the students in their original groups and those between the students and the teacher, as well as the moments when students presented and justified their models to their fellow students. All the moments when the teacher interacted with students (from a given group or the whole class) were transcribed verbatim.

As this investigation was conducted simultaneously with the one about students' development of modelling skills, the initial task in analysing the data was the identification of modelling skills. In order to do so, we analysed papers concerning with the development of students' skills in inquiry-based learning environments (for instance, Kuhn, Amsel, and O'Loughlin, 1988; Wu and Hsieh, 2006), as well as documents about international tests that aims at assessing the development of students' skills (for instance, Programme for International Students Assessment, 2006). This helped us in producing a long list of skills involved in inquiry processes. Following, from both our knowledge about modelling and our experience with modelling-based teaching, we selected from this list, those skills that we viewed as necessary for the performance of each of the steps of the modelling process (as presented in the 'Model of Modelling' diagram). We are aware that this is a tentative outcome, and that the skills we had related to each of the modelling steps do not cover the whole range of possibilities. On the other hand, our final list was validated by some experienced science educational researchers who agreed about its plausibility. Therefore, we assumed

**Table 1.** Summary of the modelling-based lessons.

<i>Activity</i>	<i>Problem posed</i>	<i>Learning objective</i>	<i>Relationship with the 'Model of Modelling' framework</i>
1. The formation of a substance	What happens at sub-micro level when magnesium is burnt? Explanation of the 'magic bottle' <sup>1</sup> Relations in graph of potential energy vs. inter-nuclear distance	How chemical bonds occur: decrease in energy & increase in stability	'Have experience with the target' (by developing or remembering some of the prerequisites needed to the production of the models for the ionic bond).
2. A model for the formation of ions	Why do Na <sup>+</sup> & Cl <sup>-</sup> exist? (from ionization energy and electron affinity)	Use of energy ideas to explain ion formation	'Define the aims' 'Produce mental model' from the integration of some previous knowledge
3. A model for the interaction of ions	What is a sub-micro model for dissolving of cooking salt in water? What is the model of the same system when all the water boiled off? How can the model be justified?	Production of model without overt requirement to use ions from (2)	'Produce mental model' 'Express it in suitable modes of representation'
4. Testing a model of sodium chloride	Use model from (3) to explain high melting point of sodium chloride	Use of model to explain other empirical data	'Conducting thought experiment'
5. Attraction of ions in a lattice	Model change to incorporate energy changes (quantity of energy liberated by the formation of both a Na <sup>+</sup> Cl <sup>-</sup> pair and a NaCl lattice)	Abandonment of 'molecule of sodium chloride' model in favour of electrostatic ion lattice	'Conduct thought experiment'
6. Consensus model for sodium chloride	Use of ion lattice model to explain all properties of ionic compounds & calculation of lattice energy	Testing of new model, establishing relation between energy & lattice formation	'Conduct thought experiment', 'Consider scope and limitations of model'

<sup>1</sup> A system composed of a solution of sodium hydroxide, dextrose and methylene blue, which changes its colour as soon as it is shaken and when it is in rest.

such skills as being some of the core ones required for modelling. Table 2 presents the modelling steps and the skills associated with each of them.

The next stage in analysing the video data was focused on teachers' actions and speech during her interaction with students in distinct moments of the activities that we could link to students showing each of the core skills previously identified. All relevant speeches and dialogues were identified.

Finally, from a molecular analysis of such data, the basic teacher's roles in supporting students' development of modelling skills were proposed and the research question was discussed.

## Results

By analysing the moments of the activities when students showed one of the main modelling skills, several examples of dialogues between the teacher and her students were selected. From the context in which they had occurred, it was possible to realise that the way the teacher behaved contributed to make students use or develop a particular skill. In order to keep this paper in a reasonable size, we do not present evidence of all such dialogues. Rather, we opted to present one evidence related to each of the main stages of the modelling process (according to the 'Model of Modelling' diagram). In all dialogues, 'T' identifies the teacher, 'Sn', where 'n' is a number, identifies a given student, and 'Ss' means that more than one student answered at the same time.

### Stage 1: Production of the mental model

This stage is composed by the interrelationship between four elements: 'decide on purpose', 'have experience', 'select source for model', and 'produce mental model'. In the teaching situation, the purpose of a given model is always presented in the teaching activities and the main role of the teacher is to assure that students understood it. Then, due to their nature, all other elements exert influence on each other.

In Activity 2, when students were discussing the values of ionisation energy and electronic affinity in order to propose a model for the ions originated from sodium and chlorine, the following dialogue occurred between the teacher and the students from group 1:

- T: What did you realise concerning with the values for a given atom? For instance, how are the values for sodium?  
 S1: Both values are small.  
 T: What does it mean?  
 S3: It is easy to lose an electron.  
 S4: The atom has a tendency to lose an electron.  
 T: So, it is necessary to give it a small energy in order to form a positive ion. And what does it mean the electronic affinity also has a small value?  
 S3: It does not have a tendency to form a negative ion.  
 T: Is this coherent?  
 Ss: Yes.  
 T: And what do you notice when analysing the values

**Table 2.** Modelling steps and core skills required for its performance.

Stages	Modelling Process		Skills to be developed by students when involved in the process
	Stages	Elements	
1	Decide on purpose Have experience Select source for model Produce mental model		<ul style="list-style-type: none"> <li>To observe important properties of the system that is being studied.</li> <li>To select previous knowledge (in the cognitive structure).</li> <li>To identify properties of the system or previous knowledge on the subject related to the system under study which are important for the production of the model.</li> <li>To know different ways to get and establish relationships between information.</li> <li>To link ideas, data, and models in the production of new knowledge by taking into account the previous defined purposes for the model.</li> </ul>
2	Express in mode(s) of representation		<ul style="list-style-type: none"> <li>To use and interpret different modes of representation.</li> <li>To communicate ideas clearly and correctly.</li> </ul>
3	Conduct thought experiments Design and perform empirical tests		<ul style="list-style-type: none"> <li>To plan and conduct adequate experiments, identifying important variables, and selecting adequate procedures.</li> <li>To use measure and calculus tools.</li> <li>To gather, analyse, and interpret data.</li> <li>To analyse the obtained results and their implications.</li> </ul>
4	Consider scope and limitations of the model		<ul style="list-style-type: none"> <li>To analyse if and how the model reached its purpose.</li> <li>To establish relationships between the produced model and a new context.</li> </ul>

- for fluorine?
- S1: The ionization energy is high and the electronic affinity, too.
- T: What does it mean the ionization energy be high?
- S2: It is easy to remove an electron from the atom.
- T: And what does it mean the electronic affinity be high?
- S4: It releases a lot of energy when it becomes a positive ion.
- T: So, every time you have to think about the formation of ions, you should establish a relationship between the values of these properties.

The understanding of the meaning of ionization energy and electronic affinity — concepts that these students had already studied — was essential in supporting them to analyse the data adequately and propose a coherent model. The dialogue shows us how the teacher was able to engage students in thinking about the data and to favour them remind their previous knowledge in a way to support the establishment of relationships between such knowledge and the available data.

### Stage 2: Expression of the model

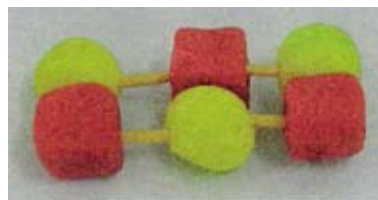
The dynamic and creative process of interaction between the elements from stage 1 resulted in the elaboration of a mental model that must be expressed in an adequate mode of representation. However, as indicated by a double arrow in the 'Model of Modelling' diagram (figure 1), during the expression of the model (i.e., the selection of the adequate mode of representation and/or the building and the communication of the model), it can also be changed.

In order to favour both the development of students' skills concerning with the expression of their model and the occurrence of discussions that could result in changing the initial

model, the teacher gave students several materials like colour pens, play-dough, different size polystyrene balls, sticks etc. Then, they had to analyse the adequacy of each of them for coherently expressing their models.

During the activities, rich learning moments were related to the occurrence of this process. The main evidence were discussions between the students in their original groups and between them and the teachers, as exemplified next:

- T: Why have you represented it in this way?



- S7: First we made a lot of molecules.
- T: What are you naming a molecule?
- S8: Each of these pairs. When one  $\text{Na}^+$  attracts one  $\text{Cl}^-$ , they form a molecule, they stay very close to each other.
- S7: Then we thought that a salt grain could not be composed by a unique molecule. So, we joined several molecules. And we did that in this way (showing the organization of the structure) because we thought that the salt was solid and that in the solid materials there was not a lot of movement. So, it had to be more organised.
- T: And why have you used sticks?
- S8: Because we thought the interaction between one molecule and another was weaker than the interaction between one ion and another. We still don't know which kind of interaction is this, but we think it is

weaker. That is why we represented the molecules a little bit separated from each other.

The main aim of teachers' questions was to favour students' clear communication of their models. She did this by questioning all the elements involved in this communication: the modes of representation, and the ideas represented in the model — that, from the teachers' question, had not only to be expressed, but also to be justified.

### Stage 3: Testing of the model

Due to the abstractness of the theme — ionic bonding — all tests conducted by students in this teaching strategy occurred through thought experiments. They took place in two distinct moments: each group's discussions and the whole class discussions (when not only the teacher asked questions, but also students from other groups questioned their colleagues). The following dialogue was between the teacher and students from group 1 during Activity 4:

- S2: I think our model explains the melting temperature.  
T: Why?  
S2: Because we got them all together. As there is a bond between these two and between these two as well, it will be necessary a huge force to separate all these molecules, to form ions.  
T: And how does the system become when they are separated?  
S2: How do you mean?  
T: You said the molecules will separate. Will the system look like this (1) or that one (2)? (The teacher used the 'molecule' models produced by students to produce the two options representing separation of molecules and separation of ions.)



- S2: I think it is going to be like this (2).  
T: So, is the energy going to be used to separate bonds and interactions?  
S2: It will separate everything.  
T: But previously this group thought there were bonds and interactions...  
S2: Yes, but we changed our mind after the presentation of the models from the other groups. We concluded that all the forces were bonds.  
T: So, you have already changed your model...  
S2: Yes. All are bonds. And when we give energy, all of them will be broken and the molecules will be separated.  
T: But, if all of them are bonds, are there molecules?

- S2: Well teacher... theoretically... it should be... but we don't know...  
T: If there would be interactions between the molecules, how would be the needed energy to separate them?  
S3: A low one, because the interaction would be weaker.  
S1: Thus, there is not going to be molecules. There will be only bonds between ions that need a lot of energy to be broken because they are strong.

Although S2 asserted that they believed there were only bonds between the ions, the dialogue clearly shows that, at the beginning, they were not sure about that. It seems they interpreted the data (the NaCl high melting point) as an evidence of the existence of only strong bonds, but they were not able to abandon their 'molecule' model. The teacher's questions were the ones that helped them in both conducting thought experiments and analysing the outcomes of such experiments.

### Stage 4: Consideration of scope and limitations of the model

This last stage of the process is essential for students' learning. After the conclusion that their model reached the aims previously defined, they attempted to persuade their colleagues and/or the teacher of its value. During this process of advocacy, the scope and limitations of their models could have become apparent, leading to a reconsideration of earliest elements of the modelling process.

During the teaching strategy, such a stage happened mainly in two distinct situations: at the end of Activities 4 and 5 (when students had tested their models and believed they fulfilled their purposes), and at the end of Activity 6 (when they had performed the last test and a class consensus model was produced in the final discussion). In both cases, the teacher played an important role, as exemplified by her discussion with group 5 at the end of activity 4:

- S18: The cycle is the outcome of the joining of the molecules. It is as if it were a special structure. But we had no idea about how the NaCl structure is like. We built it as a cycle just to show that all of them interact with each other.



- T: Do you think this model explains the melting point?  
S19: Yes. It has to make facts evident.  
T: But are you sure this model explains?  
S18: It is explaining the fundamental aspect: that the molecules interact with each other.

- T: And how do you know it really explains?  
 S18: We think it explains. But to be sure, we need to have other models to compare with. How could I know if my model is true, if I have no other one to compare with it?  
 T: What about having other data?  
 S19: I don't know...  
 S18: If you gave us the bond energy and the energy of the interaction it would be possible to improve the model.  
 T: Why?  
 S18: Because these data would support our thinking about how the structure is.  
 T: So, wait until the next activity.

Here, she fostered students to analyse their model deeply and to establish relationships between their model and a new context. This had been done by asking questions that help students to realise possible incoherence between their model and properties of the system under study (by questioning students' certainty that their model explained the NaCl high melting point) and by fostering them to think about a different test for the model (by vaguely suggesting the possibility of analysing other data).

## Conclusion

Our current analysis showed that teacher's PCK concerning with the conduction of modelling-based activities includes a series of actions that can support students' development of modelling skills. From the data we discussed in this paper, we can summarise such actions as presented in Table 3.

Therefore, teachers who wish to conduct modelling-based teaching should try to make them part of their practices. However, they are far from straightforward actions, which implies that their implementation in teachers' practice will not follow their simple identification. Teachers' education programmes that aimed at contributing to teachers' skill development which could support such actions should present the following general characteristics:

- Initially, be focused not only on the development of teachers' knowledge about models, but also on the development of a comprehensive understanding about modelling and its use in science teaching. This is because without such understanding, teachers will not even realise the relevance of modelling-based teaching in promoting a more authentic science education.
- Have a strong emphasis on the development of teachers' PCK on modelling. This would include teachers' understanding about: (i) production of modelling-based teach-

**Table 3.** Teachers' actions in supporting students' development of modelling skills.

<i>Stages of the modelling process</i>	<i>Skills to be developed by students when involved in the process</i>	<i>Teachers' actions in supporting students' development of modelling skills</i>
1	<ul style="list-style-type: none"> <li>• To observe important properties of the system that is being studied.</li> <li>• To select previous knowledge (in the cognitive structure).</li> <li>• To identify properties of the system or previous knowledge on the subject related to the system under study which are important for the production of the model.</li> <li>• To know different ways to get and establish relationships between information.</li> <li>• To link ideas, data, and models in the production of new knowledge by taking into account the previous defined purposes for the model.</li> </ul>	<ul style="list-style-type: none"> <li>• To favour students' engagement in thinking about a given phenomenon or system.</li> <li>• To favour students remind their previous knowledge or models and establish relationships between them and the system under study.</li> </ul>
2	<ul style="list-style-type: none"> <li>• To use and interpret different modes of representation.</li> <li>• To communicate ideas clearly and correctly.</li> </ul>	<ul style="list-style-type: none"> <li>• To favour students' clear communication of their models (by asking questions about both the ideas expressed in their models and the modes of representation used by them).</li> </ul>
3	<ul style="list-style-type: none"> <li>• To plan and conduct adequate experiments, identifying important variables, and selecting adequate procedures.</li> <li>• To use measure and calculus tools.</li> <li>• To gather, analyse, and interpret data.</li> <li>• To analyse the obtained results and their implications.</li> </ul>	<ul style="list-style-type: none"> <li>• To favour the development of students' abilities of conducting thought experiments.</li> <li>• To help students in analysing the results of their thought experiments.</li> </ul>
4	<ul style="list-style-type: none"> <li>• To analyse if and how the model reached its purpose.</li> <li>• To establish relationships between the produced model and a new context.</li> </ul>	<ul style="list-style-type: none"> <li>• To help students realise possible incoherence between their models and both current evidence or previous knowledge.</li> <li>• To foster students to elaborate questions that could result in the model being tested in different contexts.</li> </ul>

ing strategies, i.e., which aspects could favour students' meaningful learning and which relationships should exist between them in order to reach this purpose; (ii) conduction of modelling-based activities, i.e., what roles teachers should play in discussions with students, how teachers could provide the needed conditions for students to perform the modelling activities, which steps of the modelling process would be more difficult to a given class of students and how to make them easier for students, which skills students would have to use in performing a modelling activity and how teachers could help them.

In order to present such characteristics, we advocate that teachers' education programmes should be based on contemporary views of teachers' knowledge development like, for instance, the 'model of pedagogical reasoning' proposed by Wilson, Shulman and Richert (1987). According to them, teachers' knowledge grows through their professional experience in a process that begins with *comprehension* of a given proposal, followed by *transformation* (through *critical interpretation* of curricular material with respect to the teachers' understanding of the subject matter, *representation* – by using metaphors, analogies, illustrations, examples etc. – of the content in ways that favouring students' understanding, *adaptation* of such representations to students in general, and *tailoring*, the adapting of representations to specific students); *instruction* in regular classrooms; *evaluation* of students' understandings and misunderstandings; *reflection* on the previous elements; thus resulting in *new comprehension*.

In a just recently finished research project that analysed the development of chemistry teachers' knowledge when participating of a collaborative action-research group in which the elements of this cycle model were fostered (Figueirêdo, 2008), we showed the model has a great potential for explaining teachers' knowledge development. In particular, we identified that the ways some elements of the model of pedagogical reasoning were fostered – mainly, teachers having opportunities and being given support and time to perform each of the elements, as well as working collaboratively on the planning, production, implementation, and evaluation of the modelling-based activities – were fundamental for the educational programme success. This is certainly not the unique way to improve teachers' role in supporting the development of students' modelling skills (and knowledge), but it is an option that may be considered by those who are interested in providing conditions for the dissemination of modelling-based teaching.

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## VIII CONGRESO INTERNACIONAL SOBRE INVESTIGACIÓN EN DIDÁCTICA DE LAS CIENCIAS EXPERIMENTALES

Barcelona, del 7 al 10 de septiembre de 2009

Del 7 al 10 de septiembre de 2009 tendrá lugar en Barcelona el VIII Congreso Internacional sobre Investigación en Didáctica de las Ciencias, organizado por la revista **Enseñanza de las Ciencias**. L'Institut de Ciències de l'Educació de la Universitat Autònoma de Barcelona y el Vicerectorat d'Investigació de la Universitat de València, como editores de la revista, os invitan a participar. En esta edición el tema central es:

### **Enseñanza de las ciencias en un mundo en transformación**

La sede es el CosmoCaixa de Barcelona. El periodo de envío de propuestas de comunicación se inicia el **15 de noviembre** y estará abierto hasta el **19 de enero**. En lo que se refiere a la inscripción estará abierta hasta el **31 de mayo**. Todos los trámites pueden realizarse a través de la página web del Congreso

<http://ensciencias.uab.es/congreso2009/>