Models and Modelling for Teacher Courses?

Joan BORG MARKS
University of Malta, Malta

Abstract. Mental modelling has been given importance in educational research by a number of prominent researchers who have claimed that models and modelling are central to understanding key concepts in science. Asking, however, by how far the several research studies conducted on mental modelling and the consequent recommendations presented thereof are being applied by teachers in the classrooms to help in the teaching and learning process, remains a relevant question that needs to be addressed. Students at all levels studying science/physics are expected to learn the basic concepts of physics and teachers are expected to teach these to students in the most effective of ways. This is a primary objective especially with students in primary schools who need to have a good basis of scientific ideas and concepts, on which to build further ideas for the understanding of physics. Teaching that looks at the mental models held by students, trying to help in the evolution of students’ ideas and visualizations of a concept, offers one way of making teaching more effective and learning more meaningful. This paper describes a short study about how the author probed students’ mental models of concepts related to simple electric circuits. The reactions from colleagues when the study was presented at a staff development course helped the author to reflect on the importance of having modules on mental models and modelling in teachers’ pre-service and in-service courses. It will be argued that including mental modelling in teacher preparation programs offers a better chance for teachers to be better informed about how scientific reasoning and understanding develop. Thus, teachers can be better prepared to probe students’ ideas and to better address problems with students’ learning, whilst improving the quality of their teaching.

1. Introduction
A key function of schooling is to educate students. Students need to socialise, communicate, acquire knowledge and share it with others and come to feel a never ending motivation for learning. Students need to grow intellectually and not just learn or be taught how to pass examinations. In putting an emphasis on students’ growth, one needs to emphasise also the way in which this can be brought about more effectively. This paper looks at a period through a scholastic year when the author was teaching and conducting research on students’ understanding through the use of models and analogies, while at the same time attending a staff development course for lecturers at university. Reflections on the research results of the study and on colleagues’ comments during a presentation of these results show that not all teachers know of the existence and use of mental models and how the latter are central for the understanding of key concepts in science. The importance of including modules on mental models and modelling in teacher preparation and staff development courses is thus highlighted.

2. Background
2.1 The importance of Mental Models and modelling
Mental models and modelling are central to understanding key concepts in science [1,2,3,4,5,6]. Some prominent researchers consider that to understand science is to understand the models used by scientists (see for example [7]). Mental models refer to personal knowledge that each of us builds as we perceive the world [3,8]. Each and every one of us owns some mental model related to some concept which we are thinking about and developing. However, not all of us know that we construct these models in our mind. Moreover, not all ideas can be classified as mental models because mental models have a function and a purpose. This author looks at mental models as intermediate steps
created in the mind as ideas evolve towards the scientific view (see [9]). This emphasises the fact that not all models start by being scientific.

2.2 Looking for mental models
A review of the existing literature can definitely be a source of information describing what mental models students seem to hold related to concepts linked to a particular topic. Both diagnostic testing and interviews using the Predict-Observe-Explain as a technique to help students explain their views of how they relate with concepts, have been used to delve further into students’ alternative ideas about a scientific topic. Borg Marks (2012) used these tools to probe mental models students seemed to hold in the area of electric circuits and found them very effective. Furthermore, teachers’ accumulated wisdom and experience in the classroom can further help to discover ideas some students seem to hold as learning is in progress.

2.3 The link between mental models and analogies
One cannot speak of mental models without referring to analogies. This author very much agrees with Duit and Glynn (1996) when they say that ‘analogies are at the heart of modelling’ [3 p166]. When one compares elements of the analogue to those of the target, a mental model of the target is built, helping the development of ideas [10].

2.4 The role of teachers
Teachers play a central role in students’ learning. The way teachers relate with students’ ideas as learning progresses is of utmost importance. Teachers need to be sensitive to what is happening at students’ level, being able to gauge students’ understanding, offering the right opportunities for the students, with the aim of having students cognitively involved in their learning. Of course, some teachers may naturally have the gift of being emphatic towards their students. Even so, teachers need to know the meaning of modelling and how models and analogies can be used to help students’ understanding.

3. The study
3.1 The scope of the study
During the same scholastic year, this author was involved in teaching the topic of electric circuits to pre-university students, as well as attending a staff development course with other colleagues from different faculties at university. Some of the latter, mentioning a few, were the Faculties of Art, Law, Social Well-Being, Science and Education. As part of the staff development course, all participants were asked to prepare a short presentation based on a small action research project each participant would conduct with his/her students. This author decided to conduct a short classroom research with some of her students studying electric circuits, with the aim of finding out by how far students’ understanding had progressed and whether analogies would help this progression in any way. This paper looks at some results from this research study with students. It also looks at some comments on these results, coming from colleagues during the staff development course. Some reflections on these comments are also discussed.

3.2 The sample and method
The research was conducted with 16 eighteen year old students. The students had just finished a course on electric circuits and were starting another course on electromagnetism. Students had not been asked to prepare for the electricity test, even if it is usual that students expect to be tested at the end of a course unit. Students were asked to sit this test on a voluntary basis and were told that this test would help their understanding of the topic. All 16 students accepted to sit the test. The electricity test consisted of 5 diagnostic test questions related to current, resistance and potential difference. All 5 questions asked for an answer and the reason behind the answer. All diagrams used were of simple circuits with resistors/electrical components connected either in series or in parallel. Answers to questions were purposely not discussed with students after the test.
A week later, the author showed students a short PowerPoint presentation with analogies related to circuits, including the water analogy. These analogies had not been discussed with students during the course of study, but students were now urged to discuss the analogies during class time, relating them to the electric circuit, and commenting on the diagrams shown. The teacher guided the discussion. After another week, students sat another paper and pencil test, which again had not been previously announced. Part of the test question asked students to describe what happens in the circuit shown in figure 1, below, explaining their answer in terms of the water analogy (‘the analogy test’).

This part of the question prompted students to think in terms of the following idea:

Let us say that with S1 only closed, 100 cm$^3$/s of water was flowing through the circuit.

What do YOU imagine happens when S2 is switched on?

Figure 1. Part question on the analogy test.

4. Results and Discussion
The results of this study are split up into two parts. Part 1 will describe the results of the research undertaken with the students. Part 2 will deal with the comments and observations made by my colleagues during the staff development course presentation.

4.1 Results from the research conducted with students
Students had been asked to sit a test without being asked to prepare for it. My students were obviously not used to a situation like this. Some students did not cope well with it, but others were curious and motivated to know whether their answers were correct or not. The following are some students’ remarks after the electricity test:

• On what topic have we been tested here? Was it CAPACITORS, or what?
• You should have told us beforehand that we had to sit for a test!
• I left some questions out! I had no idea what to answer!
• I am very curious now about whether I answered correctly and what the answers should be. When do we discuss these?

With reference to the diagnostic test questions, I had expected students to do somewhat poorly on questions related to potential difference. However, students not only did poorly on questions related to this difficult concept but also gave incorrect answers to questions about current which are usually considerably easy to answer. The following are details of student performance on what is deemed as the most important questions on the test:

Only 4 out of 16 students (25%) answered correctly and completely saying that the current decreases when a resistance is added in series with a first resistance connected in the circuit.
Only 8 out of 16 students (50%) answered correctly and completely saying that the current in the main circuit increases when an extra path is added to the circuit for current to flow through, now adding a second resistance connected in parallel with the first. Only 6 out of 16 students (37.5%) answered correctly saying that the potential difference across resistances connected in parallel is the same as that across the battery.

Looking at the answer from a student about potential difference across parallel resistors, shown in figure 2, it can be seen how sometimes students act as if simple logic does not exist. This answer is an example of how even the bright students sometimes think that understanding physics means applying equations and substituting numbers into these equations.

With reference to the ‘analogy test’, only 2 students answered correctly saying that:

“200 cm$^3$/s pass through the main circuit when S2 is closed”

These 2 students had answered correctly and completely also, 2 weeks previously, in the multiple choice diagnostic test. In all, 8 students had answered correctly to this question on the diagnostic test. The 6 students who did not answer correctly to the analogy question seem to be indicating that learning had not been meaningful for them. Visualising what is happening in circuits and comparing this to what happens with water flow in pipes was not easy for the students who answered incorrectly. Changing the context and not just remembering words repeatedly said in class, seem to have created problems.
Looking closer at an answer from one of the students who answered correctly to the question about potential difference across parallel resistors, in both diagnostic and analogy test (see figures 3 and 4 below), it can be seen that this student had a picture in mind of what she ‘saw’ was happening and presented it as a drawing. The answer explaining why, when resistors are connected in parallel more current flows through the main circuit was explained in terms of having 2 straws in one glass from which to drink. This had not been one of the examples presented to students or mentioned by students in the classroom discussion. It seemed that discussing the analogies in class had provided the opportunity for students to ponder on ideas and come up with more ideas which made sense to them individually, helping them understand concepts.

4.2 During the staff development course
My colleagues at the university staff development course were quite impressed with the idea of models and modelling and how these can be used for probing and understanding scientific concepts. Some admitted that the words ‘mental modelling’ immediately gave the impression that this was something which had to do with ‘the mind’. However, they also admitted that they had not known before of the actual meaning. Through my presentation, one lecturer coming from the Faculty of Science expressed how worrying the results of my study were. He said:

“But how can it be that somewhere along the line of the students’ scholastic years, not even one teacher actually corrected the unscientific ideas students were experiencing?”
This was a very interesting remark. The way this lecturer expressed his surprise at students still finding difficulty, even at pre-university level, with understanding concepts which may seem easy, made me think of how many times it crossed my mind that some lecturers go into a classroom and just teach in a transmission mode [11]. This puts the emphasis on the teacher rather than the learner and if it happens throughout most of the classroom time it can prove ineffective in as far as students’ meaningful learning is concerned. The surprised lecturer made me realise that sometimes, working with adult students attending university, who are more motivated towards study and understanding, some lecturers may forget that other students are failing because they are not being given the attention they need to progress in their work by using a pedagogy which enhances student development with understanding.

5. Further reflections and conclusion
This author’s research studies based on mental models and modelling have mainly been conducted with students at pre-university and university level. It does not mean, however, that the reflections on the points made in this paper apply only for students and teachers/lecturers involved at the higher levels of schooling. Even students at primary level hold alternative ideas about science topics which are part of the curriculum at this level (see [12]). Throughout their schooling years, students meet different teachers who should be capable of gauging how students’ growth evolves or can be better helped to do so. This is certainly not an easy task. What is certain is that teachers are key when it comes to making classroom time effective. The different teachers a student meets throughout his/her years of schooling will be the many links in a chain of events.

In conclusion, it is therefore felt that the following proposals be made:

• It is important that teachers learn how to best search/probe students’ alternative ideas early so that teachers can try to direct students’ learning towards the scientific view.
• It is important for teachers to be careful on how to use models and analogies systematically to help student understanding, allowing students to be creative, allowing students to be creative as they progress towards understanding the scientific view (as we saw in this research, with the example of the straws).
• It is important for teachers to use methods of teaching which include guided discussion in the classroom, students’ drawings, pictures, simulations and hands-on experiences. All these can be very powerful in enhancing visualisations of concepts and helping continuous students’ growth even in the primary years.
• It is also important for all those involved in teacher education to understand the importance of introducing a module on models and modelling in pre-service and in-service teacher training, where this does not yet exist.

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