HOW TO TEACH SCIENTIFIC MODELS AND MODELLING:
A STUDY OF PROSPECTIVE CHEMISTRY TEACHERS' KNOWLEDGE BASE

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Introduction

Preceding their annual meeting, the Chemical Education Research Group (CERG) of the Royal Society of Chemistry organised a Springtime Seminar (22nd March 2001), hosted by the Science and Technology Group of the Institute of Education, University of London. This seminar was conducted by a lecturer from abroad: Dr Onno de Jong, from the Centre of Science and Mathematics Education, Utrecht University, The Netherlands. He presented a study on the development of prospective teachers' knowledge base regarding the teaching of scientific models and modelling in chemistry education. This study was carried out in cooperation with Dr Jan van Driel, Leiden University, The Netherlands. A concise overview of the lecture is given below.

Knowledge base of science teachers

In recent years, there has been a growing interest in the knowledge base of science teachers (De Jong, *et al*., 1998; Gess-Newsome and Lederman, 1999). In the field of science teacher preparation, interest in the required knowledge base of prospective teachers is particularly promoted by the awareness that the study of an academic discipline may not provide them with the kind of understanding prospective science teachers need. Their academic knowledge must be transformed into instructional activities for the classroom (Sanford, 1988). Shulman (1986) has introduced the concept of pedagogical content knowledge (PCK) to acknowledge the importance of the transformation of subject matter knowledge per se (also called: content knowledge; CK) into "subject matter knowledge for teaching" (Shulman, 1986, p.9).

In the present study, the development of CK and PCK were explored among a group of pre-service science teachers. The science content deals with a central topic in science education, viz. the teaching and learning of scientific models and modelling. Scientific models are important tools for describing, explaining and predicting phenomena. Modelling is an interactive process, in which empirical data may led to the construction or revision of the model, while in a following step the model is tested by further study of the target. In current science teaching, the nature of scientific models is not always explicitly discussed (Greca and Moreira, 2000). Moreover, it seems to be unusual to invite the students actively to construct and revise such models (Grosslight, Unger and Jay, 1991).

In the context of this study, a new course module for pre-service science teachers was developed which is aimed at focusing more attention on the role and nature of models and modelling, and the teaching of these issues. The following research question is addressed: What development of pre-service science teachers' CK and PCK of models and modelling can be identified?

A new course module

Given the exploratory nature of this study, a naturalistic case-study design was chosen. During 1999/2000, a group of 12 pre-service chemistry teachers (all M.Sc.) was involved in the project. They entered the module halfway through a one-year post-graduate teacher education course. In order to monitor the development of their CK and PCK, a multi-method approach was chosen (cf. Baxter and Lederman, 1999). Data were collected at specific moments.

Before the module, all pre-service teachers responded to a written questionnaire, aimed at exploring their CK of models and modelling. For example, they were asked to describe a 'model' to someone who is not familiar with models, and to state the purposes for which chemists use models. The pre-service teachers responded a second questionnaire, aimed at exploring their PCK with respect to models and modelling. For example, they were asked to describe their own difficulties in understanding models and modelling when they were students at high school and university, and to write down students' difficulties, which they have observed during their classroom teaching. After answering both questionnaires individually, the answers were discussed in plenary session during a workshop.

During two other workshops, the pre-service teachers discussed selected sections of articles on models and modelling and the teaching of these issues. The first article (Van Driel & Verloop, 1999, pp. 1142-1143) identifies seven core characteristics of scientific models and modelling in science. The second article (Grosslight *et al*., 1991, pp. 817-819) describes three levels of understanding of scientific models and their use in science, which were found with middle and high school students and experts.

At the end of these workshops, they expressed teaching intentions and individually chose a curriculum topic for teaching, focusing on models. Examples include: characteristics of molecules in relation to macroscopic properties of substances (e.g. structures of alkanes and their respective boiling points), and the rate of reaction and the model of collision of particles. Each pre-service teacher taught the chosen topic at his/her practice school, using the current textbook.

After teaching the chosen topic at their teaching practice school, they reflected on their teaching experiences by writing individual reports.

During a final workshop, these reports were discussed and the first questionnaire from the beginning of the module was filled in again. All workshop sessions were recorded on audio-tape and subsequently transcribed.

Results of the study

The analysis of the answers to the first questionnaire can be summarised as follows. Before the module, all pre-service teachers considered a model as a simplified or schematic representation of reality. A majority of them stressed the explanatory function and the descriptive function of models, whereas a minority mentioned another function, *viz*. the predictive function. All pre-service teachers emphasized the importance of designing and revising models in science. After the module, it appeared that their answers to the written questionnaire were hardly changed.

The data from the second questionnaire, the workshop sessions and the individual reports were analysed to identify changes in the pre-service teachers' PCK. The results can be summarised as follows. Before teaching at the practice schools, nearly all pre-service teachers expressed the

teaching intention to pay emphasise the nature of scientific models and the designing and revising of models. However, from their lesson reports it appeared that they had presented the models as static facts without any modelling activity. For instance, a pre-service teacher had suggested that he would address the historical development of models of the atom to improve students' understanding of models and modeling. In practice, however, he focused on the use of visualizations to explain processes at a molecular scale. Another pre-service teacher had suggested the use of various models highlighting different aspects of the same target, but she apparently did not apply this strategy when she taught about hydrogen bonding and used it to explain differences in boiling point and solubility in Grade 10.

All pre-service teachers pointed out that they had gained knowledge of students' difficulties in understanding models. According to them, many of their students consider models to be confusing, misleading, or without any relationship to reality.

Finally, all pre-service teachers reported difficulties in finding appropriate models and ways of modelling for teaching purposes. For instance a pre-service teacher said that in the future he would "try to visualize as many concepts as possible using models and audiovisual aids. But how?"

They expressed concern to know more about these issues and their intentions to find out.

Conclusions and implications

Despite the fact that all pre-service teachers had an M.Sc. degree, their knowledge of models and modelling was not very pronounced. They rarely mentioned some key functions and characteristics of models, especially the predictive function was lacking. In this respect pre-service teachers look like experienced teachers. As Van Driel and Verloop (1999) have pointed out, experienced teachers' knowledge of models and modelling in science is also rather limited and diverse.

Although the module has not contributed substantially to the development of the pre-service teachers' CK, it has promoted their awareness of gaps in their knowledge of appropriate models and modelling. These gaps in their knowledge may have caused the observed discrepancy between their teaching intentions (models as constructs) and their teaching practice (models as facts). These gaps may also explain why the pre-service teachers taught about models in more or less the same way as they were taught when they were students. Nevertheless, they expressed teaching concerns and knew their learning intentions.

These results will be used as a starting point for the revision of the present module. In this module, much more attention should be paid to pre-service teachers' own initial CK and PCK of models and modelling, for example in the context of the preparation of lessons including the nature and role of models and their use. It will be also important to consider the presentation of models to the students and stress the need for the teacher to present a model carefully. For example by developing it through posing scientific problems, and discussing relevant and irrelevant attributes of the target under consideration.

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