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University physics students' explanations of phenomena involving interaction between matter and radiation

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Abstract. This project discusses university physics students' use of models when explaining phenomena involving interaction between matter and electromagnetic radiation. This is a content area which is heavily modelled and appropriate explanations for the chosen phenomena draw upon a number of different models. University physics students are familiar with the phenomena, but they are not generally used as exemplars of scientific models within undergraduate physics education. The data for this study, which is collected during the beginning of 1999, comes from written surveys and interviews. The sample is third year university physics students at different universities in UK and Sweden. Both surveys and interviews have been through a piloting phase.

Subject. A central aim of undergraduate physics education is to develop students' understanding of subject matter knowledge in physics. This involves introducing students to the phenomena of physics, and to the laws, theories and models which physicists use to explain these phenomena. For example, in learning about the absorption spectrum of the Sun, students need to be introduced to the absorption lines (the phenomenon), which can be seen when radiation from the Sun is viewed through a sensitive spectrometer, and to the way in which the quantised energy level model of atoms and molecules can be used to account for these dark lines in terms of quantised absorption of photons (the explanatory model).

It is our belief that understanding of physics subject matter knowledge involves an appreciation of the world of phenomena and the world of theories and explanatory models (Giere 1988, Tiberghien 1994). In particular, students need to appreciate the distinctions between these worlds, and how they link. They need to be aware of the limitations and applicability of a specific explanatory model linking theory to an observed phenomena. In other words, students' understanding of the epistemology and ontology of scientific knowledge is an important aspect of their understanding of physics subject matter knowledge.

There have been studies of university students' understanding of physics concepts in a number of concept areas, e.g. Linder (1993), Prosser (1994) and Viennot (1991). However, an area which has received limited attention is students' understanding of the interaction of electromagnetic radiation and matter. In addition, this is an area with a rich variety of explanatory models available. Given the emphasis above on the role of phenomena and models in students' understanding, we decided that a study of students' explanations of phenomena involving interaction of electromagnetic radiation and matter would be of interest.

The research questions this study is designed to address are:

1. How do students explain each of a series of phenomena involving the interaction of radiation and matter?

- *what scientific models do they draw upon?*
- *what analogies, if any, do students use in their explanations?*
- *what 'picture', if any, do students have of these phenomena at the atomic/sub-atomic level?*

2. Do students draw upon scientific models in an appropriate way in their explanations of these phenomena? (by 'appropriate' we mean 'at a level which could be expected of these university physics students')

- *do students recognise the limitations of these scientific models?*
- *do students recognise the approximations within these scientific models?*
- *do students recognise the distinction between scientific models, and the phenomena to be explained?*

3. When presented with a series of phenomena which could be explained appropriately using a single model, do students draw upon a single model in their explanations, i.e. do students use models consistently in their explanations of a number of related phenomena?

Design. This work is a co-operation between the Universities of Leeds and Kristianstad, and students from both countries are used in order to increase the sample size and to get data from several different institutes. The students in the sample need to have been introduced to appropriate scientific explanations for the phenomena covered in this study. This means, for both countries, students who are in the middle of their third year of university physics studies.

The written instrument is developed to address each of research questions 1 – 3. The formulation is such that responses will reflect the models used by the students and possibly reveal analogies. Furthermore, there are sets of questions in the instrument that cover different phenomena, but which are related in the sense that physicists would use the same model to explain these phenomena. Hence, we will be able to judge the "appropriateness" of models used and we can check for consistency, e.g. Gilbert, Boulter & Rutherford (1998), Mortimer (1995).

The pilot study, which was successful, showed the interviews to be validity checks on the survey responses and they also provided means to probe for deeper insight into students use of models. Furthermore, students was confronted with demonstrations of two of the phenomena during the interviews. 1) Thermal radiation from a heated metal rod; 2) The interaction of red light with a colour filter and research question 4 could be addressed.

Procedure. Survey questions were piloted with 29 Swedish students and 9 UK students, and interviews held with 2 of the Swedish students and 3 of the English. The survey and interview schedule is modified following piloting. Approximately 50 questionnaires will be completed in each country and the sample for each country will include students from more than one institution. Approximately 10 students from the survey sample in each country will be interviewed.

Analysis. The survey will be analysed to answer the research questions. Responses will be categorised to reflect which models students use and how they seem to view the models. The survey responses will be analysed in the same way for both countries. The sample has not been chosen to be representative, therefore no comparisons between the countries will be made. The interviews will be transcribed verbatim and the Swedish ones will be translated into English for a joint analysis.

Findings. Initial pilot studies have shown that university physics students have great difficulty in providing appropriate explanations of such phenomena. Whilst they draw upon scientific models in their explanations these are often applied in inappropriate ways. For example, in explaining the red glow of a heated metal rod, many students have tended to draw upon the Bohr model of *isolated atoms*. In their explanations, these students do not recognise that in metals atoms will interact to give an electronic structure very different from that of the 'exemplar' system of an isolated atom. We suggest that students' inability to appropriately distinguish between the world of phenomena and the world of models constrains their understanding of phenomena involving interaction of radiation and matter. This study sets out to investigate this suggestion.

General interest. The results of the study can have important implications for the curriculum development and teaching of university physics on intermediate level. The survey questions and the students' explanations of the phenomena in the pilot have raised much interest from the physics lecturers contacted in both countries. The research will hopefully give lecturers new means of probing their own students use of models in this physics content area.

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