Implementation of empirical-mathematical modelling in upper secondary physics: Teachers’ interpretations and considerations

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Background, Aims and Framework
Models and modelling receive increasing attention from the science education community as important components of a contemporary science education (Gilbert, 2004; Gilbert & Boulter, 2000; GIREP, 2006; Greca & Moreira, 2002; Hestenes, 1987). In this paper, we draw on experiences from a project, PHYS 21, which has implemented an empirical-mathematical modelling approach in upper secondary physics education in Norway (Angell, Henriksen, & Kind, 2007). By empirical-mathematical modelling we mean physics teaching emphasizing activities where students conduct experiments and construct and evaluate mathematical models of phenomena. We see modelling as important both because it reflects the nature of physics and because modelling activities are considered useful for learning physics concepts and processes.

Dolin (2002) suggests that physics appears difficult because it requires students to cope with a range of different representations of physical phenomena (experiments, graphs, verbal descriptions, formulae, pictures/diagrams) and to manage the translations between these. According to Prain and Waldrip (2006), a focus on multiple representations may contribute to effective science learning by catering for students’ individual learning needs and preferences and promoting students’ active engagement with ideas and evidence. Thus, the use of different representations was emphasised in PHYS 21.

In this paper, we look at how the curriculum approach was received and implemented by project teachers in the classrooms, more specifically:
1. How was the intended empirical-mathematical modelling curriculum (PHYS 21) interpreted and adapted by project teachers?
2. How did the PHYS 21 philosophy fit into the existing ‘culture’ of physics teaching?

Methods and Samples
PHYS 21 took place over a period of three years: An introductory year with teacher workshops and design of learning activities; a ‘pilot year’ and a full implementation year (2005-2006). 10 schools and about 20 physics teachers participated in the initial phases of the project, whereas 6 schools, 13 teachers and 289 students took part during the full implementation year, employing the PHYS 21 course material and activities involving empirical-mathematical modelling along with a focus on multiple representations and scientific reasoning.

Three workshops and several regional meetings for project teachers were arranged. A teacher booklet introduced the view of physics applied in the project, aspects of scientific method and reasoning, examples of scientific models and the modelling process, and suggestions for student modelling activities.

Researchers visited all project schools during modelling activities. After the full implementation year, a short, online questionnaire was administered to the 13 teachers who had been actively involved in teaching PHYS 21. 12 teachers responded. The questionnaire comprised both open questions and closed questions with a 4-point Likert scale.
Semi-structured interviews with 6 teachers were conducted during the pilot year. Interviews were transcribed and analysed qualitatively with special attention to teachers’ interpretation of the project’s purpose, their descriptions of actual implementation in the classroom, and their views on physics and on teaching and learning. Interpretations were discussed among the researchers, and the transcripts were reread to check preliminary interpretations until a consistent account was constructed and agreed upon.

Results
Indications of the degree of teachers’ dedication to the project may be extracted from the questionnaire. Responses showed that the majority of teachers had conducted the ‘obligatory’ modelling activities in their classrooms. When asked to indicate the percentage of classroom time where the ‘modelling idea’ was prominent in their teaching, eight teachers gave answers in the range 15% - 30% and four teachers answered less than 15%. Most of the teachers answered ‘to some extent’ when asked to what extent they felt that PHYS 21 had changed their teaching practice. The teachers were also asked to what extent they thought PHYS 21 had improved students’ understanding of physics, of the nature of science and of the role of experiment in physics. The majority responded ‘to some extent’. On the question of whether PHYS 21 had increased students’ motivation and interest, answers varied more.

Most teachers had applied the modelling approach when teaching mechanics, but they found it difficult to continue in ‘modelling mode’ in their teaching of other topics. However, all the teachers expressed that they would continue to employ the material and the philosophy from PHYS 21 in their future teaching.

All the six teacher interviews indicate that new curriculum ideas were adapted to teachers’ ways of doing and reflecting on teaching and learning rather than radically changing these. They all found a place for modelling in their personal rationale for teaching physics. Similarly, Stein et al. (1999) claimed that teachers interpret new ideas and practices through the lens of their existing habits of practice and filter information about new ways of teaching through their prior experiences.

Physics teaching is generally known to be ‘conservative’(Angell et al., 2004). Carlone (2003) describes how ‘prototypical physics’ is maintained and reproduced even in an allegedly ‘reformed’ physics course. All the teachers in the PHYS 21 project referred to ‘traditional teaching’, and some expressed that a motivation for being involved in PHYS 21 was to break out of this pattern. However, what the teachers saw as a main problem of physics teaching was the way it is delivered, not the content of the subject. Classroom observations and teacher interviews show clearly that “modelling as a method to teach physics content” was found most attractive by the teachers. Although several of the activities were designed to teach ‘modelling’ rather than concepts, the teachers assessed their quality in the perspective of conceptual learning. Teachers generally agreed that learning skills and learning ‘about physics’ were important, but they had few strategies for handling these feature in their teaching.

Physics teaching is embedded in a more general ‘school culture’ where the attitudes of students, parents and society at large are involved. Some PHYS 21 teachers reported difficulties to get students to adopt the way of thinking and working with physics employed in the project. It has been documented before (e.g. Angell et al., 2004) that students have certain expectations concerning ‘proper physics teaching’. These expectations are often influenced both by school culture (Carlone, 2003) and by parents, peers etc. (Geelan, 1997).

In promoting modelling in physics teaching, it appears important to focus not only on teaching materials, but also on the views on the nature of science and on physics learning that underlie teachers’ practice. Many project teachers had not ‘internalised’ the view of physics as models that was underlying the project. Similarly, Henze et al. (2007) typify three
characteristic ways in which teachers conceptualise and use modelling in science teaching, and they identify a need to extend teachers’ knowledge about the use of models and modelling in teaching scientific inquiry and the nature of science.

Conclusion and Implications
In this paper we have pointed out some challenges connected with implementing modelling in an upper secondary physics course. We do think that there is reason to develop this strategy further. It takes long-term work, both with teachers and with students, to adopt and internalize new views on the nature of physics and what it means to teach and learn it, but the rewards may be rich in the form of competent, motivated and reflective students taking their skills and understanding with them out of the physics classroom and into the workforce and civic life.

Bibliography
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