Claus MICHELSEN, Odense

Modellbildungsprozesse und Integration von Mathematik, Physik und Biologie

A structural reform was introduced at Danish upper secondary education from August 2005. The reform implies that more lessons are set-aside for optional subjects organised as subject packages, where an important aspect is that the participating subjects form a coherent program ensured by a closer interaction between the subjects. Some of the subject packages have as its core subjects mathematics, physics, and biology. To implement the objectives of the reform cooperation across the traditional boundaries between the subjects both at the level of subject matter as well as at the level of pedagogy is required. The challenge is to replace the current monodisciplinary approach, where knowledge is presented as a series of static facts disassociated from time with an interdisciplinary approach, where mathematics, biology, and physics are woven continuous together.

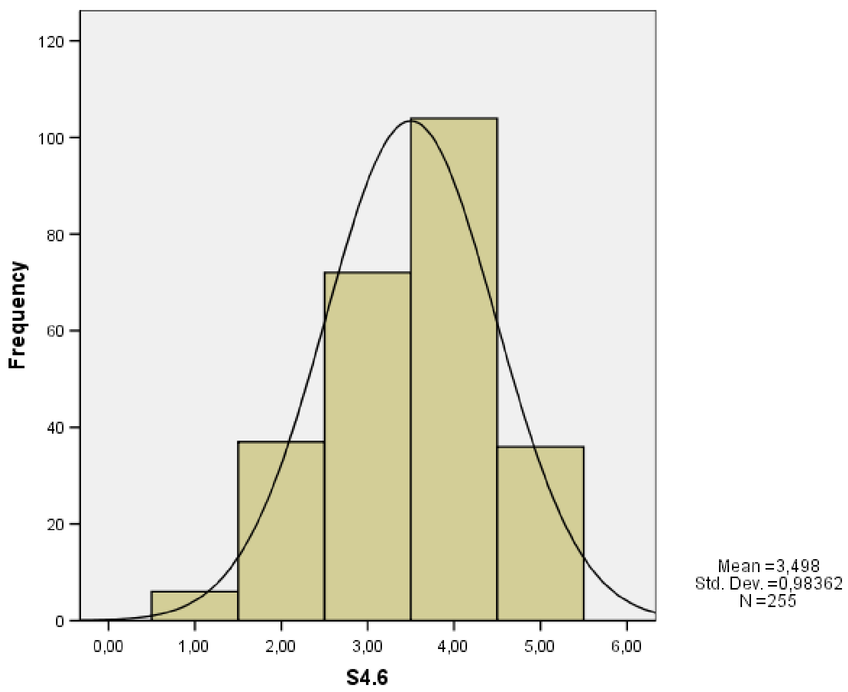
The importance of school mathematics should be justified by the fact that it provides the students with powerful tools for dealing with the quantitative aspects of the world. This role is brought about predominantly through the building, employment, and assessment of mathematical models. The models are the results of mathematizing situations, which people wish to study. Modelling activities emphasize the connections between mathematics, biology, and physics, which in upper secondary education are usually regarded as separate subjects. Modelling thus should be the central activity in an integrated mathematics and science curriculum.

At the University of Southern Denmark we have several research and developmental projects aiming at developing and implementing a shared pedagogy for mathematics and the subjects of natural sciences. In the projects *IFUN – Interests and interdisciplinary science and mathematics teaching* and *Interdisciplinary competences in mathematics and science* we approach the task from two perspectives:

- Promoting students' interests in mathematics and science by interdisciplinary activities
- Transcending the problem of domain specifity by interdisciplinary activities

Promoting interests in mathematics and science by interdisciplinary activities

An expressive amount of research from both mathematics education and science education points at active and student-centered activities centered on applications of mathematics and science in real world settings as a way to facilitate increased interests in the subjects [1]. The project *IFUN – Interests and interdisciplinary science and mathematics teaching* focuses on students' interests in interdisciplinary activities. It is the intension to take steps toward understanding how enhancing interest in the mathematics and science classroom may prove to be a most direct way to approach the problem of effective instruction. In the period from December 2005 to February 2006 a total of 255 grade 11 students from Danish upper secondary school in the Region of Southern Denmark were given a 143-item questionnaire that took up one class period. The items of the questionnaire address seven main domains, which shed light on different aspects of students' interests in interdisciplinary activities. One of the domains is centered on the question: How to make instruction in mathematics and science more interesting? This part of the questionnaire consists of 15 statements about possible changes in mathematics and science education each with a 5-point Likert scale and field for comments. The figure below shows the students' attitudes towards an increased interplay between mathematics and the subjects of natural sciences:



Responses from the students to the statement: "I think an increased interplay between mathematics and the subjects of natural sciences will improve my interest for the subjects." The Liekert scale reaches from "1: I disagree" to "5: I agree"

The figure reveals a general trend from the students' responses to the questionnaire: An overwhelming majority of the students think that their interests in mathematics and science will increase if interdisciplinary domains are included in the teaching of the subjects.

Transcending the problem of domain specifity by interdisciplinary activities

According to Niss [2] a significant example of the major findings of research in mathematics education is the key role of domain specifity. The student's conception of a mathematical concept is determined by the set of specific domains in which that concept has been introduced for the student. When a concept is introduced in a narrow mathematical domain, the student may see it as a formal object with arbitrary rules. This results in the recognised difficulty of application of the concept in new settings. As an alternative Michelsen [3] points at that interdisciplinary modelling activities between mathematics and the subjects of natural sciences offer a great variety of domain relations and context settings, that can serve as a basis for developing a more practical and coherent structure of a mathematical concept. By *expanding the domain* with contexts from physics and biology the problem of domain specifity is transcended and the curriculum is presented as a cohesive program. Michelsen [3] introduces a didactical model for coordination and mutual interaction across mathematics and the subjects of natural sciences. The model consists of two phases: *horizontal linking* and *vertical structuring*. In the horizontal phase thematic integration is used to connect concept and process skills of mathematic and science by modelling activities. Also in this phase explicit connections is established between the process skills of mathematics and science. The vertical phase is characterized by a conceptual anchoring of the concepts and process skills from the horizontal phase by creating languages and symbol systems that allow the students to move about logically and analytically within mathematics and science, without reference back into the contextual phase. The shift from the horizontal to the vertical phase thus might concur with a shift from integrated instruction to subject oriented instruction. It should be stressed that the didactical model is iterative. Once the concepts and skills are conceptual anchored in the respective subjects, they can evolve in a new interdisciplinary context, as a part of a horizontal linking.

The integrated modeling courses

To realise the instructional and learning potential of interdisciplinary modelling activities a team of mathematics and science teachers and educational researcher at University of Southern Denmark work on developing integrated courses within the framework of horizontal linking and vertical structuring. The courses are designed to integrate three components: the gathering of data from physical or biological contexts, development and exploration of mathematical models (verbal, symbolic, graphical and tabular) and a reflective discourse about the mathematical and science content of the models. To make the structure and content of mathematics and science as explicit as possible, the course material is organised around a small number of basic models. The use of context problems is very significant in the course approach. They not only function as a field of application, but must also be designed to help the students to capture and identify the basic processes underlying a functional situation. For example the students' investigation of the context problem **The Medicine Dosage** naturally extends their experiences with exponential growth to include models with piece by piece exponential growth:

The Medicine Dosage
Suppose that ¼ of a medicine dosage is eliminated from the body every four hours. If the initial amount of medicine taken is 100 mg then construct a model, which shows the amount of medicine in the body as a function of time.
Suppose now that every four hours an additional dose of 100 mg are added to the amount already in the body. Construct a model, which shows the amount of medicine in the body as a function of time.

Conclusion

Making connections and transferring ideas to a new context are difficult processes that many students cannot accomplish by their own. A focus on modelling in interdisciplinary contexts avoids the problem of domain specifity, because models make sense of complex situations, and the purpose of the models is to provide meaningful ways for students to construct explain, describe, explain, manipulate, or predict patterns and regularities associated with complex situations.

Acknowledgement:

The IFUN-project is supported by a grant from the EU-program INTEREG IIIa in the regions of Sønderjylland/Schleswig and Fyn/K.E.R.N.

Literature:

[1] Schiefele, U. & Csikszentmihalyi, M. Motivation and Ability as Factors in Mathematics Experience and Achievement. *Journal for Research in Mathematics Education,26(2),* 1995, pp. 163-181.
[2] Niss, M. Aspects of the nature and state of research in mathematics education. *Educational Studies in Mathematics 40*, 1999, pp. 1-24.
[3] Michelsen, C. Expanding the domain: Variables and functions in an interdisciplinary context between mathematics and physics. In Beckmann, Michelsen & Sriraman (eds.) *Proceedings of The First International Symposium of Mathematics and its Connection to the Arts and Sciences.* Verlag Franzbecker, Hildesheim & Berlin, 2005, pp. 201-214.