

Integration of physics, biology and mathematics in upper secondary school

Claus Michelsen

University of Southern Denmark

claus.michelsen@dig.sdu.dk

Abstract

A structural reform introduced in upper secondary education in Denmark implies that students choose among streams. An important feature of each stream is that the participating subjects form a coherent program. Some of the streams have science and mathematics as core subjects. 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. Modelling provides a generic methodology that serves as a common denominator for learning disciplines, such as physics, biology, and mathematics. Furthermore a modelling perspective is ideal suited to make use of a wealth of recent advances in fields of physics, biology and mathematics. The paper describes a project, where a team of researchers in biophysics and educational researchers work together on clearing the core concepts of biophysics, and analysing which of them are teachable in a modelling context in the reformed upper secondary education.

Introduction

In Denmark a structural reform is introduced in upper secondary school from August 2005. The reform implies that students choose among streams instead of a more or less random selection of subjects. An important feature of each stream is that the participating subjects form a coherent program. To prepare students for studies in science, mathematics and technology in tertiary education it is the intention that some of the streams should have as its core subjects physics, chemistry, biology and mathematics. This calls for the development and implementation of a shared pedagogy for mathematics and the subjects of science in the reformed upper secondary school in Denmark.

1 Modelling – an interdisciplinary competence

In 1999, the Danish Parliament adopted the development programme for the upper secondary education programmes of the future [1]. As part of the development programme, a great number of specific innovation and development projects were initiated. The experience from these projects is part of the basis for the

reform of upper secondary education. Two reports from these projects define competences aiming at describing what it means to master mathematics [2] and science [3], and thereby describe progression in the teaching and learning of these subjects. Briefly a competence can be described as a well-informed readiness to act appropriately in situations involving a certain type of mathematics or science challenge.

The reports define eight central mathematical competences and four central competences in science. The modelling competence (and the representational competence) is presented as a central competence in both mathematics and science. The modelling competence emphasizes the connections between physics, biology and mathematics, which are usually regarded as separate subjects. It is an interdisciplinary competence, which serves as a basis on which we can rethink the curriculum of mathematics and science in upper secondary education.

2 Biophysics in upper secondary school

Molecular biology has been one of the most successful sciences of the 20th century. Along with the advanced in modern molecular biology, biophysics as a discipline is also undergoing a transformation. After the mapping of the humane genome, the next goal is to understand the interplay between on the one side the enormous amount of information encoded in the genome and on the other side the robustness of the living system, which this transformation is coding for. In practice this presupposes an understanding of the signal- and regulation systems in living cells, which in turn requires studies of molecular information- and control networks. In this way modern biology can be turned into a quantitative science, which opens up for the type of modeling applied mathematicians and physicist are used to apply to complex systems. Stewart [4] predicts that one of the most exiting growth areas of the twenty-first-century science will be biomathematics. New mathematical ideas will interact with the biological and physical sciences in totally new ways. Where physics and mathematics cease and biology takes over will be a matter of taste.

2.1 Integration of physics, biology and mathematics in upper secondary school

BioNET – Danish Center for Biophysics was established in the spring of 2004. The center's main aim is to boost Danish research within molecular biophysics in order to bring this country up to the level of the international trend within the field.

But it is also the aim of the center to propagate results of the biophysics research to the public and in particular to young people under education in order to enhance the general understanding of the importance of modern science and technology for society and culture. To fulfill this aim the project "Integration of physics, biology and mathematics in upper secondary school" will be initiated at the University of Southern Denmark in the autumn of 2004. The purpose of the project is the development, implementation, and evaluation of meaningful prototypes of instructional units for the reformed upper secondary school that integrates mathematics, physics and biology. In cooperation with teachers from upper secondary school a team consisting of researchers in biophysics, a science education researcher and a PhD.-student will work on the project. The first task of the project is a clearing of the core concepts of biophysics, and analysing which of them are teachable in a modelling context in the reformed upper secondary school.

3 Science education as a design science

The project employs a developmental research approach. Through a cyclic process of analysis, design, evaluation and revision activities are iterated until a satisfying balance between ideals and realization is achieved. In our view the discipline of science education is a design science. Instructional design research provides for the possibility of progress in the planning, implementation and management of learning environments. Science education may in this view be compared to some aspects of medical and engineering science. It is a reflective practice of planning and design, followed by testing and evaluation.

The project contributes to the application of the model of educational reconstruction [5], which involves three main components which mutually interact: First, analysis of the content structure (including the educational viewpoint); second, the execution of empirical investigations which at first have explorative character; and third the construction of instructional units. These three components are supposed to stimulate each other in an interactive and cyclic process. A detailed planning of the courses will be developed as a didactical structure designed in the form of a scenario of what is expected to happen in an instructional sequence. An important aspect of designing a didactical structure is, that of comparing

the devised didactical structure, as a prediction of what was expected to happen, to what an interpretation of what actually does happen when it is tried. In this way, the didactical structure goes empirical and thus become open for revisions.

A supporting domain-specific instruction theory for the design of instructional sequences and instructional materials is found in the model development sequence developed by Lesh et al [6]. In this approach the students are put in situations where they must express, test, and modify, revise, and refine their own ways of thinking during the process of designing powerful conceptual tools that embody constructs that students are intended to develop.

The project build on our experience from a course designed and implemented as a six weeks integrated grade 10 mathematics-physics course centred on exponential growth and radioactivity [7]. Based on the experiences from this course we regard an interdisciplinary approach as promising enough to be further developed to include the subject of biology.

Conclusions

Modelling provides a generic methodology that serves as a common denominator for learning disciplines, such as physics, biology, and mathematics. As such, modelling must play the most important educational and enlightening role in the Danish reformed upper secondary school. Furthermore the modelling perspective is ideal suited to make use of recent advances in science and mathematics.

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