STUDENTS´ INTERESTS AND INTERDISCIPLINARY INSTRUCTION IN MATHEMATICS AND SCIENCE

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1. INTRODUCTION

This paper presents the research project *IFUN - Interest and Interdisciplinary Instruction in Science and Mathematics*. As researchers in mathematics and science education we are basically interested in how students' learning and understanding in these subjects might be improved. Many research studies indicate that students' interest in science and mathematics declines during lower secondary school level (Hoffmann et al. 1998), but international surveys as well as other indicators do not indicate any general decrease of interest in science among the population in most countries (Sjøberg 2003). A simple assumption is that many young people find various aspects of science and mathematics interesting, but it is beyond the capacity of the school to catch and hold this interest. Until recently research in interest has not to any great extent addressed the relation between interest and education at the upper secondary level. The reason for this could be the assumption that students have developed relatively stable individual interest profiles during lower secondary school. According to Prenzel (1998) there are several factors that lead to questioning this assumption. The students are confronted with an abundance of topics, and although many of these do not correspond to the students' individual interest they may lead to new areas of interest. At Danish upper secondary education the students' student can choose between different subject packages and a number of optional subjects. The choices of students might among other things be based on interest. Also the students' at upper secondary education have to make decisions about future education and profession. Personal interest is a key factor behind modern youth's educational choice and career aspirations are used as indicators of interest in scientific fields (Gardner 1998).
It is characteristic for research in students' interests that the domains, which have been studied, are ones that belong to academically defined curricula with focus on a single subject, for instance physics or mathematics. In the light of current tendency towards increased interplay and integration between different subjects, interest research in the field of mathematics and science should also include broader and interdisciplinary domains that are associated with the applied, environmental, technological and socio-scientific content. It is the intention of the IFUN-project to fulfill these gaps in interest research. With focus on interdisciplinary domains of the disciplines mathematics, physics, chemistry, biology and technology the research questions of the IFUN-project are:

Which variables influence the development and promotion of upper secondary students' interests in interdisciplinary domains of mathematics and science?

Which curricular and instructional methods help promote upper secondary students' interests in interdisciplinary domains of mathematics and science?

2. INTEREST AND LEARNING

Dewey (1913) advocated that interests are the most important motivational factors in learning and development and pointed on, that the positive contributions of the idea of interest are twofold. It protects us from a merely internal conception of mind and from a merely external conception of subject matter. Thinking of the mind as an inner world of itself is not compatible with the conception of interest as an activity that moves toward an end and search for means. To avoid externality of subject matter, the presented mater must mean something complete to the students in its readiness and fixed separateness. This means that interest it not obtained by thinking about it and aiming at it, but by considering and aiming at the conditions that lie back of it, and compel it. Pointing on the normative aspect of education Krapp (2003) argues that teachers must take into account which contents or objects are chosen for teaching and learning and what the long-term goals of development are to be. Therefore a theory of interest must state how contextual preferences develop and what the conditions are for a learner to have a more or less lasting interest in certain contents and to be ambivalent or even decline others. According to Cobb et al (2003) processes of learning should be interpreted broadly to encompass what is typically thought of as knowledge, the evolution of learning-relevant social practices and constructs as identity and interest.

The current state of interest research is the result of a fruitful exchange between researchers from psychology and educational science. Interest is conceptualized as a relational construct between a person and an object. An interest represents a more or less enduring specific relationship between a person and an object of interest in her or his life-space. The object of interest can refer to concrete things, a topic, an abstract idea, or any other content of the person's life-space. Three major views are reflected in interest research (1) interest as a characteristic of the person (individual interest) (2) interest as a characteristic of the learning environment (interestingness) (3) interest as a psychological state (actualized individual interest/situational interest) (Krapp 2002). The conceptual differentiation between situational and individual interests entails a focus on the process by which externally stimulated situational interest is stabilized and maintained and finally becomes integrated into a person's self as an individual interest. The overall implication of the literature in interest research is that situational interest can facilitate cognitive processing and improve students' learning. Mitchell (1993) proposes that situational interest is multifaceted and distinguishes between catching interest and holding interest. The shift from catching to holding a person's situational requires a learning environment that makes the content of learning meaningful for the students according to their actual goals. According to Krapp (2002, 2003) the transition from catch to hold will only occur if the student's activity is related to personal goals and the affective experience is positive and emotionally satisfactory. In the sense of situational interest an interest relationship depends on situational conditions, such as the specific context the object is presented or the activities the student is allowed to engage in. This dependency on favorable environmental conditions suggests an analysis of the content, the characteristics of the learning environment and the student's dispositional interest.

The design of interesting educational tasks encompasses studying alternatives existing to an actual practice in mathematics and science teaching, which demands an understanding of the characteristics of attitudes to the potential alternatives of the students who will engage in them. We therefore broaden the analysis to include the ways that students' think about themselves in relation to mathematics and science, and the extend to which they have developed a commitment to and have come to see a value in mathematics and science as it is realized both in and outside the classroom. We therefore include the notion of the students' personal identities in our analysis, and conduct the study of the individual student's interests in interdisciplinary domains of mathematics and science within a framework consisting of the three dimensions:

- Content context: The student's interest in a particular crosscurricular domain of science and mathematics
- Learning setting: The characteristics of a specific learning setting that causes a situational interest in the topic and promote and support a shift from catching interest to holding interest
- Identity: The student's affiliation with and valuation of mathematics and science

3. INTEREST AND CROSSCURRICULAR TEACHING

The choice of focus on broad and interdisciplinary domains of mathematics and science is motivated by an expressive amount of research from both mathematics education and science education pointing 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 (e.g. Schiefele & Csikszentmihalyi 1995) An interest based approach to teaching raises the issue of the mathematics and science curriculum's content as problematic. Most students experience their curriculum as a series of courses in different disciplines rather than as an integrated interdisciplinary experience. Looking at the traditional mathematics and science curricula, one could say that in general the concepts taught are the basic concepts of mathematics and science. Only a tiny fraction has been concerned with cross-curricular, technological, and socio-scientific content of the mathematics and science curricula, and one might ask the question if contemporary education prepare the students to think mathematically and scientifically beyond school. To prepare future citizen for future life competencies are needed for the individual to cope with the complex world and some specific competencies can be acquired better in domains interdisciplinary contexts of mathematics and science than in others. Also a proper image of the current scientific activities must include the interdisciplinary aspect – mathematicians, physicist, biologists, economists etc. are involved in the study and modeling of complex interdisciplinary systems.
Raising the issue of what is of relevance for and interesting for the students in mathematics and science education requires us to rethink what the students should know and understand. To illustrate this consider the German sociologist Ulrich Beck (1992) description of today's society as a risk society, where the definition of risk is not solely reserved to scientists or technologist. An understanding of risk is an essential cultural mission of any pedagogical institution. Coping with risk involves issues of sociology and psychology. But clearly the competence of modeling reality by mathematics and science is powerful tool to cope with risk. In a more up-to-date content there is a shift in perspective from realizing mathematics and science by first teaching what is to be learned and the applying these concepts in realistic situations to model reality by first putting students in sense-makings situations where the conceptual that they develop on there own are later de-contextualized and formalized. Including topics like risks, dynamic systems, self-organization in an interdisciplinary context makes the usefulness and strength of mathematics and science visible for the students, and at the same time they are cultivated to cope with complexity.

4. RESEARCH DESIGN AND METHODOLOGY

4.1 Educational research as a design discipline

Based on the reviewing process in educational research over the past few decades Schoenfeld (1999) concludes that the field of educational research has evolved to the point where it is possible to work on problems whose solutions help make things better in the practice of teaching and contribute to theoretical understanding. Research in understanding the nature of science thinking,

teaching, and learning is deeply intertwined with the use of such understanding to improve science instruction, for the simple reason, that without a deep understanding of thinking, teaching and learning, no sustained progress on the ”applied front” is possible. This emerging research approach that includes significant efforts to change educational practices introduces the notion of educational research of that of a research design akin to engineering and other interdisciplinary fields which involve the interaction of humans, conceptual systems and technology influenced by social constraints and affordances. Educational researchers should not only concentrate on the question of whether a theory yields coherent an accurate prediction, but also on the kind of research that includes developmental work in designing learning environments, formulating curricula, and assessing achievements of cognition and learning.
A basic motive for considering science education as a design science stems from the experience that traditional approaches in mathematics and mathematics education, with their focus on descriptive knowledge, which hardly provide the teachers with useful solutions for a variety of problems in teaching of mathematics and science. Greeno et al. (1996) describes an approach to research – interactive research and design – that provides a syncretic combination of research, development, and practice of interactive research and design. Design experiments are as cases of the process of supporting groups of students’ learning in a particular domain. The theoretical perspective therefore is to account for successive patterns in student thinking by relating these patterns to the means by which their development was supported and organized (Cobb et al. 2003).
The IFUN-project emphasizes the ways in which students’ interests and learning styles can be capitalized upon a resource to ensure that all students have access to significant interdisciplinary ideas in mathematics and science. In this approach the focus is on practices of learning and understanding, including changes in resources and activities of practices that would strengthen the learning environment. The project includes students and teachers from 6 upper secondary schools, 3 from the southern part of Denmark and 3 from Schleswig-Holstein in the northern part of Germany. The implementation of the study in the border region between Denmark and Germany offers an opportunity to include a comparative study in the project. The project is divided into a descriptive/explanative phase and an intervention phase.

4.2 The descriptive/explanative phase

The first phase of the study is designed to provide a stimulus for interesting instruction in mathematics and science. The aim of this is to give empirical evidence on what interdisciplinary topics the students are interested in learning about. Focus is on situational conditions, such as the specific context the topic is presented in or the activities the student is allowed to engage in, that causes a situational interest in the topic and promote a shift from catching interest to holding interest A major point here is that the development of situational interest is an individual process that cannot be understood separately from the environment in which it emerges and develops and from the individual student’s identity. We apply a holistic view to examine the characteristics of content contexts and learning settings in which the students will engage, and follow Greeno (1998) in considering learning as the students’ attunement to constraints and affordances of the social practices they participate in. We use self-reports – questionnaires and interviews - from the students for assessing students’ interests.
In the period from December 2005 to February 2006 a total of about 500 grade 11 students from Danish upper secondary school in the Region of Southern Denmark will be given a 143-item questionnaire that takes up one class period. A similar study is carried out in 3 upper secondary schools in Schleswig-Holstein.

The 143-items of IFUN questionnaire address seven main domains, which shed light on different aspects of the three dimension of the IFUN-study:

1) Science and mathematics in basic school and general upper secondary school: The basic school (Folkeskole) of the Danish education system is a 9-year comprehensive school. Prior to this, there is a voluntary pre-school class, and after there is a voluntary 10th school year. About 40% percent of a year group continue after completion of basic school to the academically oriented 3-years general upper secondary school (Gymnasium). The shift from basic school to general upper school is tremendous for many students. While the teachers of basic school are educated at teacher colleges the teachers of general upper secondary school are educated at universities. This part if the questionnaire provides information about the students' interest in relation to the subjects of mathematics, physics, chemistry and science in lower and upper secondary school, and it consist of 18 questions, where the student rates their interest in and the relevance of the subjects of basic and general upper secondary and 1 questions, that provides information about what the students finds interesting an uninteresting in mathematics, Danish language, sports, physics, biology, English, chemistry and history.
2) The individual student's learning style: This part of the focuses on the students' conceptions of what is of central importance when they learning a new topic. There are 6 statements about the learning setting each with a 5-point Likert scale and field for comments. Examples of the statements is “It is important to me that a topic taught can be used in daily life”, “It is important for me that the teacher is aware of my effort to learn the topic”, “It is important to me that I can relate my own attitudes towards the topic”
3) The subjects of physics, mathematics, chemistry and biology: The students' experiences with the subjects of mathematics and science stem the disciplinary teaching. This part of the questionnaire focuses on the students interests in each of the subjects at upper secondary school. It consists of 4 identically question to each of the subject. One of the questions relates the subject's contribution to the student's view of current problems of the globe. To provide insight in changes in the students' interest in a subject, the students respond to the question: “Did you interest in the subject change during the last two months? If yes then why and how?”
4) Making instruction in mathematics and science more interesting: The intention of this part is to shed light on the students' views on towards changing mathematics and science education towards a more interdisciplinary approach with the aim of improving t more interesting and relevant. 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 following sample of questions illuminates this part of the questionnaire: ”Instruction in mathematics and science would be more interesting if examples of application of the subjects in the labour market were included”, ”Instruction in mathematics and science would be more interesting if it was possible to discuss ethical and moral questions related to the subjects (e.g. nuclear weapons, gene technology) ”, ”Instruction in mathematics and science would be more interesting if examples of the peoples' or groups of peoples' importance for scientific development was included”
5) Justifications for physics, mathematics, chemistry and biology in upper secondary education: The aim of this part is to get information about how the students justify the subject of physics, mathematics, chemistry and biology at upper secondary education. The students are in this part presented to 15 statements each with a 5-point Likert scale and field for comments. This part includes questions like: ”Mathematics and science play in important

role in our culture", "Mathematics and science give admission to tertiary education", "Mathematics and science is the important for the Danish competitive capacity"
6) Mathematics and science outside school: This part of the questionnaire provides information about students' experiences with mathematics and science in out-of-school settings. It consists of 6 statements each with a 5-point Likert scale and field for comments.
7) Mathematics, science and the individual student's future: In this part the students are asked would they like as their future profession and to consider to what extend mathematics and science are and are not related to their life values. Furthermore the students are asked to write an essay or make a figure of the way they expect that mathematics and science will impact their life when they are 30 years old.

Up to now only about 75 students have answered the questionnaire, which means that there is no finally analysis of the data collected. But a scrutiny of the collected data reveals some general trends:

<u>Mathematics and science in lower and upper secondary school:</u>

- Mathematics is among the three most interesting and important subjects at lower and upper secondary school
- Interest in mathematics does not changed from lower to upper secondary school
- Interest in physics and chemistry does change from lower to upper secondary school. Physics is either interesting or not interesting!
- There is no significant change in general interest in mathematics and science from lower to upper secondary school

<u>Relevance of the subjects and impact on the students' view of the future:</u>

- The subjects – especially mathematics – are relevant for the students
- The subjects – especially biology – have impact on the students view of the future of the globe

<u>Changes in interest</u>

We here cite some typical answers from the students to question: "Did your interest for physics change during the last two months (if yes how and why)":
- *I am more interested now because I understand physics better*
- *We got a new teacher in physics, and now I am more interested*

<u>Making instruction in mathematics and science more interesting</u>:

- An overwhelming majority of the students thinks that their interest in mathematics and science will increase if disciplinary domains associated with the applied, environmental, technological, career opportunities and socio-scientific content is included in the teaching of the subjects
- Use of modern technology in teaching mathematics and science does not have a significant impact on the students' interests

Mathematics and science outside school

- An overwhelming majority of the students do not have leisure activities related to mathematics and science

Justifications for mathematics and science at upper secondary education

- There is not a significant number of students who thinks that the justification for mathematics and science in the educational system is the importance for the Danish competitive capacity
- There is not a significant number of students who thinks that the subjects develop creativity

Mathematics, science and the individual student's future

- The importance of mathematics and science for the students' future is related to career
- Several students hope that mathematics and science will contribute to a better future, e.g. by developing a cure for AIDS

The design of interesting educational tasks demands an understanding of the characteristics of the students who will engage in them. To shed light on the to great extend general results from the questionnaire interviews with 15 grade 11 students from Danish upper secondary school will be conducted.

4.3 The intervention phase

In the second phase an intervention project will be initiated based on the insight gained in the first phase. The intention is to develop, implement and evaluate a didactic concept for interdisciplinary instructional units in mathematics and science. The intervention is planned as an implementation of 6-8 different instructional sequences with a framework based on Sjøberg's (1998) 3 dimensions for science mathematics education (i) The products of science (ii) The processes of science (iii) The role of science in society.
The development of instructional sequences will be based on the model of educational reconstruction that closely links analytical and empirical educational research with development of teaching and learning sequences. The model 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 (Katmann et. al. 1997). A detailed planning of an instructional sequence is 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.
This phase of the IFUN-project will be characterized by a close cooperation between educational researchers and teachers from upper secondary school with the aim of producing meaningful change in the classroom practice. This means that decisions concerning the development of instructional sequences are drawn from the local context, and leads to the suggestion of a strategy that deliberately create opportunities for the stakeholders to influence the design process and focus on

adaptation to already existing practices. Furthermore the close collaboration in the process places the teachers in direct ownership of the designs.

5. FINAL COMMENTS

The ultimate criterion of success for the IFUN-project is its applicability and the extent to which it can be used to solve fundamental problems of teaching and education in mathematics and science. 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. We are convinced that a reform of the content of mathematics and science at upper secondary education towards a interdisciplinary approach that includes applied, environmental, technological, career opportunities and socio-scientific aspects have the potential to appeal to the minds of upper secondary school students. Students at upper secondary school should experience mathematics and science as interesting, meaningful and relevant for their lives and their ability to shape and influence their future.

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