International Workshop on

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Descriptions of BIQUA DFG-Projects and Cooperating Projects

Classification of BIQUA projects and cooperating projects participating in the workshop

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Cognitive activation in the classroom: The application of professional knowledge of mathematics teachers

Jürgen Baumert[1], Werner Blum[2], Michael Neubrand [3] & Stefan Krauss[1]

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The frame

"Mathematics literacy" forms the main component of PISA 2003. Besides the investigation of mathematical competencies in the main study, a particular attention to instructional processes and practices seems to be necessary and ready to administer. Therefore, we intend to conduct a teacher survey on mathematics instruction, to allow a reconstruction of the predominant patterns of mathematics instruction. Making use of all information gathered in PISA-2003, the instructional survey will focus on

(1) a multivariate investigation of the goal structure of mathematics instruction, among them epistemological beliefs about mathematics and learning mathematics, domain-specific problem solving competence, and domain-specific motivational orientations.

(2) a reconstruction of instructional activities on the basis of teaching and learning materials, predominantly on the basis of the mathematical problems given in class for various purposes. This allows a multi-perspective approach since teachers' and students' perspectives towards mathematics instruction are focussed at problems, in characteristic ways respectively.

(3) the analysis of the pedagogical content structure of mathematics instruction on the one hand, and on teachers' pedagogical content knowledge on the other. The emphasis here will be on selecting and handling mathematical problems as learning opportunities and on coping with critical incidents during instruction.

The study will have a clear focus on mathematics, and will thus go beyond previous, more generic research on teaching. Thus, a major objective of the study is to "strike up a conversation" with mathematics teachers as experts for pedagogical content knowledge, and thus to obtain information about the normative and empirical structure of mathematics instruction.

The instruments

There is a conventional student and teacher questionnaire addressing the basic dimensions. However, to fully exploit the teachers' expertise, we use a new, computer-based instrument for the teacher survey, including short video clips, thus allowing the teachers' perception of authentic lesson situations to be tapped. A traditional teacher questionnaire covers the professional background and job-related attitudes of the teachers. Finally, a database of problems set for homework and classwork will be devised.

The analysis of the problems: Analysis of the opportunity structure for insightful learning in mathematics classes

As the teacher's classroom behavior becomes manifest in the mathematical problems being set, problems constitute the most salient indicators for opportunities for insightful learning. Mathematical problems structure the teaching process in two ways:

(i) by the selection of specific problems and the sequence they are given for specific purposes, and

(ii) the preferred way of dealing with the problems during classroom instruction.

Teachers will be asked to assess the instructional suitability, frequency of use in their classes, didactical significance for learning mathematics, and class-specific difficulty of some structurally different problems presented to them. The aim is to describe the distribution of structural types of

problems, as defined by their characteristic features. That distribution will indicate the implicit design of instruction. The analysis of the problems will use categorization schemes for mathematical problems, as e.g. developed for the German option of the PISA main study.

The presented sets of mathematical problems can be used to probe the didactical possibilities that teachers associate with the problems in question. The main objective is to capture and describe the range of cognitive demands that mathematics teachers associate with a given problem, and the teacher's instructional potential to react to students' proposals. An additional feature in the study is to investigate the ways in which mathematics teachers respond to incorrect answers.

Regarding the video sequences in the study, teachers can be asked about (a) their overall evaluation of the instructional approach shown in the video, and (b) their perception in terms of different dimensions, as e.g. wether they would assign the problem to independent work, group work, or classwork, or whether they would break the task down into subtasks. Two main strands in the answers are, if the reaction is teacher or student centered, or if the emphasis is on understanding or on procedural thinking when problems are assigned to be worked on.

Subject related coaching as a means to modify teachers'

classroom behaviours

Teachers' expertise and teaching scripts: Conditions for their modification

Helmut Fischler, Free University of Berlin, Germany

Many empirical studies show that teachers' professional competence is one of the main factors for the quality of teaching. Therefore, *the research project investigates how it might be possible to change physics teachers' conceptions about teaching and learning and to which extent achieved modifications in central fields of a teacher's cognition have an effect on his/her decision making in classrooms and on students' learning.*

Reports on traditional training courses for teachers in all phases of teacher education, aiming at long-lasting modifications of teachers' competencies, show only little effects even when these courses are prepared carefully and are oriented at everyday problems in classrooms.

New approaches to an in-service teacher education program aiming at long-lasting modifications of conceptions and behaviours have to integrate ideas offered by research and practice fields in which enduring changes of behaviours depending on mental processes play a significant role. There are different traditions which can contribute to effective processes within teachers' professionalization:

(1) Theories of cognitive and emotive therapy are the basis of processes which focus on the transformation of an individual's problem specific frame of references and of his/her corresponding behaviour (Meichenbaum 1977).

(2) Psychological theories emphasising individuals' subjective theories as the foundation for their reflective decision making point out that any process of behavioural modification has to base on corresponding mental processes.

(3) Modifications of teachers' conceptions can be regarded under a constructivist view. Teacher education, therefore, has to have the same characteristics as teaching processes which are designed in line with constructivist principles.

Subject related pedagogical coaching is influenced by the ideas mentioned above and therefore meets the following demands:

a) Any procedure to help teachers modify their behaviours has to address the level of reflective awareness.

b) Teachers' conceptions are a complex cluster of knowledge, metaphors, attitudes, beliefs, emotions, judgements, etc., therefore any coaching procedure has to take into account the idiosyncratic and emotive prerequisites of this process.

c) The often observed discrepancy between teachers' intentions to act and their concrete acting in classrooms requires the inclusion of teachers' teaching practice into the coaching processes and into research activities connected with these processes.

Methods

The research project is carried out along the following design:

Initial analysis:

- Identification of teachers' rules of action and underlying conceptions
- Reconstruction of teachers' conceptions teaching/learning, nature of science, pedagogical content knowledge
- Structuring the conceptions by means of maps

- Communicative validation of the maps
- Videotaping of two lessons.
- Analysis of the lessons: Identifying rules of action and reconstructing underlying conceptions of teaching and learning
- Measuring students' achievements and identification of students' specific attitudes towards science education

Treatments to change teachers' expertise: Modification of their views towards and their rules about appropriate decision making in processes of teaching and learning by means of coaching procedures.

Methods:

- Reframing
- Transformation of rules of action
- Reflecting-Team

Final analysis

- Analysis of the differential effects of the treatments
- Identification of teachers' expertise and their teaching scripts
- Questioning of the students

Results

The investigation is designed for six years at the most, including the development of research instruments and the investigation of changes in students' attitudes towards physics (teaching) and of changes in their achievements. In the first phase, an exploration study was designed to lay the foundation for a large scale study.

In this exploration study, in several case studies it was possible to realise all phases described in the research design. In general, it can be summarised that the processes of interviewing, structuring and validating are appropriate means to reconstruct teachers' rules of action and their conceptions. A treatment structure was developed which integrates several elements of different theoretical views towards processes of behavioural modification (Transtheoretical Approach according to Prochaska & DiClemente 1984).

Conclusion and implications

The problem how to enrich not only teachers' knowledge and their conceptions of teaching and learning but also their acting in classrooms could be solved by means of subject related pedagogical coaching processes which are oriented at theories of cognitive-emotive modification. These theories and their practical consequences have been adapted to the demands of an improvement of science education via the enhancement of teachers' teaching competencies. In essence coaching aims to address a teacher's thinking and acting because it is important that teachers incorporate the widened knowledge and the modified conceptions into their behavioural structure. Different forms of subject related pedagogical coaching processes are likely to be appropriate methods to help teachers on the way from thinking to acting.

The treatments proposed are appropriate means for working with very small groups of teachers. Future research should determine a program for more extensive procedures which include many teachers and therefore make possible a broader reform.

Interdisciplinary education in technical-vocational education:

A challenge for teacher education

Peter Labudde & Barbara Szlovak

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Since 60% of the Swiss adolescents attend a vocational school, vocational education takes an important position in our educational system. There is need for empirical research on how far vocational teachers are able to fulfil the demand for IE in the new curricula. The focus of our study are teachers instructing students for professions that are related to the experimental sciences or engineering. Our main research questions are the following:

1. How can the quality of teacher education with reference to interdisciplinary instruction be increased?
2. What kind of training programs for in-service teachers and teacher-students are powerful and sustainable?

In the first phase (status quo, 2001/02) the current practice of IE was examined by interviews with 26 teachers. The results showed that in spite of some good examples it is necessary to promote IE in several areas, e.g. teacher education, school organization, and curriculum.

In the second phase (intervention, 2002/03) 18 vocational teachers participate in an in-service training. They develop interdisciplinary units and put them into practice. Our findings will be used to increase the quality of teacher education in terms of IE. First results show that a combination of training events, coaching sessions, and supporting materials initiates an intensive process of reflection which affects the preparation and realization of IE, but also the intensity of the co-operation of teachers.

This research project is financially supported by the Commission for Technology and Innovation (CTI) of the Federal Office for Professional Education and Technology (OPET); project number 5563.1 BFS. The persons involved in the study are Peter Labudde and Barbara Szlovak from the University of Bern, Martin Wild-Näf, Beat Schären and Jürg Weber from the Swiss Pedagogical Institute for Vocational Education.

Examples-based learning

Alexander Renkl, University of Freiburg, Germany

In this short sketch of my major research area (example-based learning), I will outline our project within the BIQUA focus program. In the second part, I will briefly mention, additional projects we conduct on this topic.

BIQUA: Learning how to teach by worked-out examples

(funded by DFG)

Alexander Renkl and Silke Schworm

Research has shown that learning from worked-out examples (problem – solutions steps – solution) is of major importance for initial skill acquisition in well-structured domains. In addition, research on self-explanation theory and on cognitive load theory has provided considerable knowledge about how to structure worked-out examples and how to effectively guide learners in studying such examples. Against this background, the goal of the present project is to develop an internet-based learning environment in which teacher (students) can learn how to effectively employ worked-out examples in their teaching. A first module of this learning program has been developed that provides information about relevant example features. In this program, examples of unfavorable and favorable designed worked-out examples are the primary source of information. It is important to note that the examples (of worked-out example) that are used in the learning program are not themselves worked-out example because the solution steps are missing (i.e., only the product / solution was shown, not the construction process of the favorable worked-out examples). We call this type of examples "solved example problems." We investigated to what extent teacher students' learning from such solved example problems can be fostered by prompting self-explanations and by providing instructional explanations. Results show that especially the prompting of self-explanations had favorable effects. Thus, it can be concluded that self-explanations foster learning not only from worked-out examples, but also from solved example problems.

Before the learning environment is further developed, it is reasonable to examine systematically the application of the teaching method "learning by worked-out examples" in current classroom instruction ("needs assessment"). The following research questions are addressed: (1) To what extent are worked-out examples used in current mathematics or science instruction? (2) In which context are worked-out examples used in current mathematics or science instruction (introduction to a new topic; illustration of an imported principle etc.)? (3) In which way do worked-out examples used in classrooms correspond to the criteria of effective example design? (4) In which way are student's self-explanations promoted during the study of worked-out examples? How are instructional explanations used? To answer these questions half-standardized interviews with teachers have been performed and textbooks have been analyzed. Additionally video-taped instruction units in mathematics and physics have been analyzed to find out how worked-out examples are actually used in classrooms. The videos have been searched for instruction episodes that contain worked-out examples. These episodes are transliterated and categorized with a specially developed coding system. First results show that worked-out examples are actually used in schoolbooks. They usually instantiate a former introduced principle. The employed examples are not designed effectively according to the design criteria found in the literature, and multiple examples are quite rare. The examples used in classrooms do not fit the criteria either. Most of the time they are not implemented to foster student's understanding but mainly to allow low-achieving students to reach to correct problem solutions (e.g., before an exam). To foster students' understanding, their self-explanation activity has to be promoted, but neither teachers nor schoolbooks show convincing approaches to do so. The results definitely underline the necessity of training teacher students how to effectively implement worked-out examples in their instruction. Special attention should be devoted to the issue of fostering self-explanations.

Other main projects on example-based learning

Learning from incorrectly worked-out examples (funded by DFG)

Alexander Renkl & Cornelia Günther

In this project, a restriction of usual forms of example-based learning is addressed: No opportunity is provided for learning from errors. We analyze to what extent learning can be fostered by using correctly and incorrectly worked-out examples and concurrent instructional support for processing these examples.

Structuring the transition between example study and problem solving in cognitive skill acquisition (partly funded by DFG)

Alexander Renkl & Robert K. Atkinson

On the basis of a larger series of experiments, we have developed an instructional model of how to structure the transition from example study in earlier stages of skill acquisition to problem solving in later stages. The main instructional components are: (1) Examples with successively faded worked-out steps, (2) self-explanation prompts focusing on domain principle, (3) specially designed instructional explanations. Presently, we plan to work on how to individualize the fading procedure.

Learning from worked-out examples: Solutions in multiple representations (planned)

Alexander Renkl (in cooperation with: T. de Jong P. Gerjets, F. Hesse, F. Paas, J. van Merrienboer) (submitted to DFG)

In this project, the research on multiple representations and on example-based learning is brought together. Multiple representations are used to foster the understanding of solution methods. It is especially investigated to what extent self-explanation prompts and instructional explanations can be employed in order to support the mapping between different representations.

Learning from worked-out examples with multiple solutions

Cornelia Günther & Alexander Renkl

In this project, a restriction of usual forms of example-based learning is addressed: The in most cases incorrect impression is fostered that mathematics problems can be solved by just one correct method. We analyze to what extent the acquisition of flexible knowledge can be fostered by using worked-out examples with multiple solution methods and concurrent instructional support for processing these examples.

Learning from video examples / models

Silke Schworm & Alexander Renkl

In this project, it is investigated to what extent the acquisition of argumentation skills can be fostered by video examples (models). Specifically, it is investigated to what extent self-explanations prompts on different levels of abstraction foster learning.

These research projects are mainly conducted in laboratory settings. Extensions to the field are intended.

Teachers' Pedagogical Content Beliefs in Elementary Mathematics: Why they Matter and how to Transform them in Practice

Fritz C. Staub

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Teachers' pedagogical content knowledge is widely thought to be at the core of teaching expertise. Specific pedagogical content beliefs may be in agreement or conflict with different theories of learning. Does it matter what kind of beliefs teachers espouse? How can such beliefs be refined or even revised? The poster will draw from two different strands of my work related to teachers' pedagogical content beliefs in elementary mathematics education. The first strand is pure empirical research on the impact of teachers' pedagogical content beliefs on student learning and teaching. The second strand is design research that lead to a professional development model, which aims to address and refine teachers' pedagogical content beliefs in practice.

In an empirical research project in collaboration with Elsbeth Stern we asked whether teachers' pedagogical content beliefs in elementary mathematics have an impact on teaching and student learning. In particular, we looked at the hypothesis that students realize higher achievement gains in the domain of word problems when taught by teachers whose beliefs are based more on a cognitive constructivist framework than a direct-transmission view of teaching as supported by associationist theories of learning. In a longitudinal study of 496 students in 27 self-contained German elementary school classrooms, performance in mathematical word problems and arithmetic tasks was measured at the end of Grades 2 and 3. A questionnaire was used to assess the degree to which teachers' pedagogical content beliefs in elementary mathematics reflect a cognitive constructivist orientation, rather than an associationist or direct-transmission view of learning and teaching. Our findings show that a cognitive constructivist orientation was associated with larger achievement gains in mathematical word problems. Moreover, teachers with a direct transmission view were not more successful than teachers with a cognitive constructivist orientation in fostering students' computational proficiency (Staub, F.C. & Stern, E. (2002). The Nature of Teachers' Pedagogical Content Beliefs Matters for Students' Achievement Gains: Quasi-Experimental Evidence From Elementary Mathematics. *Journal of Educational Psychology*, 2002, 94(2), 344–355).

Given our knowledge about the pivotal role of teachers' pedagogical content knowledge for instructional practice and student learning and taking into account the difficulties of changing personally held beliefs, how can teachers be assisted in theoretically grounded yet practical ways to enrich, reflect and transform their pedagogical content beliefs? In collaboration with University of Pittsburgh's Institute for Learning (Lauren B. Resnick) I developed Content Focused Coaching[SM], a professional development model, which consists of settings and conceptual tools that aim to assist teachers on-the-job in fostering student learning and in developing teaching expertise. Activity settings created with Content-Focused Coaching allow teachers to collaboratively build new and transform existing pedagogical content beliefs. The most advanced implementation of this evolving approach has been arrived at over the past five years in New York City's school district 2 (West, L. & Staub, F.C. (2003). *Content-Focused Coaching[SM]. Transforming Mathematics Lessons*. Portsmouth, NH: Heinemann / Pittsburgh, PA: University of Pittsburgh).

Teachers' Concepts and Teaching Strategies in Physics Instruction and their Effects on Instructional Design and Learning Outcomes

Prof. Dr. Hans E. Fischer, Prof. Dr. Wilfried Bos*, Nicole Höllrich, Thomas Reyer
University of Dortmund, June 2000 til May 2002

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Description

Regarding Oser & Patry (1990) the latent knowledge base is a decisive factor for both, a teacher's design of instruction and his or her action in the classroom. A manageable quantity of so-called "concept types" about the students' learning processes are developed and represented as typical structures of the lessons (choreographies). Choreography characterizes the teacher balancing between pedagogically necessary decisions and the multitude of methodical realization. In this project we want to describe the structures of typical physics lessons and try to find hints for successful choreographies. Regarding the TIMS Videotape study traditional mathematics instruction at German schools is organised by means of only few concept types but till now there is no empirical evidence for physics lessons.

We try to find out which concept types are relevant for teachers' activities in the physics classroom, if teachers' ideas about instruction have any influence on the observable so-called apparent structures of lessons, if there are typical teaching strategies and if there is a correlation between the choreography and the students' performance and interest. We expect, that teachers training on concept types might improve the students' performance. In a subsequent study we want to investigate the influence of the teacher's repertoire of concept types on the efficiency and the success of physics education.

Aims of the Project

- Description and analysis of teachers' concepts about teaching and learning and performing physics lessons
- Modification of Oser's theory of concept types of learning to fit it into requirements of physics education
- Comparison of lessons structured by theory and lessons structured by teachers
- Test of the students' performance
- Design of a subsequent project:
  Implementation of teachers' training on concept types to improve their professional flexibility an efficiency

Design and Empirical Methods

The study will take place in two schools in Dortmund in October 2000. Six eighth grade classes will be analysed along three topics that match the physics curriculum of North Rhine Westphalia. Within a period of 18 month the lessons will be performed using Oser's theory in four classrooms and traditionally in two.

Documentation of lessons:

- Video-recording of six lessons per topic
  using the criteria of TIMS Videotape Classroom Study
- Documentation of the lessons by the teachers

Probing teachers' concepts:

- Video-recorded teacher interviews
  concerning teachers concepts and explanation referring to each lesson observed

- Teacher questionnaire
  concerning teachers' evaluation of each lesson observed
- Questionnaire concerning attitudes towards physics education and science
  (excerpts from STAS II and additional TIMSS items)

Inventory for pupils learning:

- Questionnaire concerning attitudes towards physics education and science
  (excerpts from STAS II and additional TIMSS items)
- TIMSS test concerning interests and motivation
- "Kognitiver Fähigkeitstest KFT 4-12+ R" measuring intelligence
- Tests measuring learning success, belonging to the subjects:
  electricity by Shipstone/ Rhöneck, optics test (N.N.), Force Concept Inventory, TIMSS

IPN-Physics-Video-Study-Group

A Videotape Classroom Study about Teaching and Learning in Physics Instruction

What really happens in classrooms can only be superficially investigated by measuring achievement or interviewing students and teachers. For this reason video studies document physics lessons in order to identify typical instructional scripts. The data analysis is expected to yield valuable information about important teaching and learning processes and about good teaching practices in science instruction.

Theoretical background

- **Videotape classroom studies within large scale assessments**

International comparative studies (TIMSS, PISA) have shown that science teaching in Germany is much less effective than desirable. Of special concern is the fact that major deficits concern the reflective application of scientific knowledge. In addition, science instruction obviously fosters interest only to a very limited degree.

The videotape classroom study of TIMSS allowed a systematic cross-cultural comparison of mathematics instruction in Japan, the United States and Germany. Its findings revealed significant differences between the three countries in the organization of classrooms and in beliefs about „good“ teaching practices. Thereby the German instructional „script“ is characterized by a „questioning-developing“ procedure that is closely connected to one single teaching goal. It does not invite students to apply multiple problem solutions. This could be the reason for German students not being able to flexibly apply their knowledge in transfer situations.

- **Teaching and learning processes in physics instruction**

Since TIMSS-Video is restricted to mathematics instruction and findings of TIMSS-R Video are yet to be expected it remains unclear to what extent these findings can be applied to science instruction. Within science instruction experiments play a central role. They offer rich opportunities for variations in instructional patterns.

Up to date systematic findings on instructional patterns in science classrooms are missing. Furthermore the data collection in many studies like TIMSS-Video is restricted. Instructional patterns are mainly identified by the analysis of video recordings. Only limited data on teacher characteristics and/or student developments is available. Therefore conclusions on student developments can be drawn only to a very limited degree.

Aims of the study

A. Identification of instructional patterns

The first aim of the study is to identify typical „scripts“ for classroom organization. Thereby differences between physics and mathematics instruction are investigated. For that purpose the results of our study are compared to TIMSS-Video findings.

B. Function of instructional patterns for student learning

The second aim is to go beyond identifying patterns of classroom organization and to investigate instructional patterns with regard to their effects on student learning. Thereby four research areas are focused on:

(a) Goal orientation

(b) Scaffolding student learning

(c) Student concepts and handling mistake situations

(d) Role of experiments

C. Student development

Physics instruction is considered successful if students develop at various levels. Indicators for student development are:

- development of interest in science resp. physics
- aquisition and reflective application of scientific knowledge

- internalization of scientific research methods and processes

Design of the study

Sample

In the first study (2000-2002) the sample comprises 13 classes in introductory physics instruction (grades 7/8). In the second study (2002-2004) 53 randomly selected classrooms in grade 9 are video taped. A parallel study is going to be conducted in the German speaking part of Switzerland (cooperation: Prof. Dr. Peter Labudde, Bern)

Video recordings

Sample 1 (2000-2002): Within one school year two introductory topics comprising three lessons were video taped (13 classes x 2 topics x 3 lessons). Sample 2 (2002-2004): Within each class one topic (out of two possible ones) comprising 2 lessons are video taped (53 classes x 1 topic x 2 lessons).

Questionnaires, tests and interviews

Within one school year additional data is collected by means of student questionnaires and tests. Furthermore the teachers are interviewed with respect to their beliefs about physics instruction.

Findings (Sample 1, 2000-2002)

- Student development within one school year

Significant differences between the classes (13 classrooms, 344 students) are shown for the development of competence and interest.

- Instructional patterns

Compared to TIMSS-Video we identified two basic instructional patterns. (1) Chalk-loaded demonstration lessons with an emphasis on elaborating physics phenomena by classwork. (2) The second pattern is characterized by a combination of classwork and seatwork. Within seatwork students are conducting experiments. Overall, classwork and experiments play a dominant role in the organization of physics instruction. However to a very large degree classwork is very narrow-focused and experiments are not systematically integrated in the course of instruction.

- Instructional patterns and student development

Up to date we found no general effect of the organization of classroom activities and student development. However, we found that instruction with a high degree of narrow-focused classwork has a negative effect on the development of student interest in physics. High goal-orientation (by offering a clear and sound structure) has a positive effect on the students` competence development.

- Teacher beliefs

The interview findings indicate that the teachers focus on content rather than on learning theories and didactics. Currently we investigate systematic relationships between teacher beliefs and their actual instruction in class.

Perspectives

In the long run we plan to use the findings of our studies for teacher training. Thereby we are going to use our special design of combining perspectives (video, student questionnaires, teacher interviews) for implementing reflective practitioner groups at school level.

Videos as a tool to foster the professional development of physics teachers in upper secondary schools

Helga Stadler, University of Vienna, Austria

Theoretical framework

If we want to raise the quality of teaching and learning, it is important to know more about what happens in classrooms. Videos give us the chance to get an inside view, but even more they are a valuable tool to make teachers and learners reflect upon teaching and learning processes. In that way, videos can be used to initiate reflective processes. The documentation itself provides a basis for expanding teachers' knowledge about ways of teaching and learning. Moreover classroom videos may be an excellent starting point for professional discussion, creating a basis for networks, in which teachers with different profiles, different biographies etc. exchange their ideas and experiences.

If we look at learning as a social process, for which all participants are jointly responsible, videos are an important tool to make students reflect upon their own learning processes and to establish learning communities in class. We use videos as a starting point to initiate feedback processes and as a document, which students and their teachers can use to reflect jointly about what happens in class, what indicates quality and which improvement might be necessary.

Ways to foster the professional development of science teachers by using class videos within the project IMST_

The project IMST_: IMST_ (Innovations in Mathematics, Science and Technology Teaching) is a nationwide initiative of the Austrian government to improve mathematics and science teaching. The two major tasks of IMST_ (2000-2004) are first the initiation, promotion, dissemination, networking and analysis of innovations in schools (and to some extent also in higher teacher education), and second the planning of a sustainable support system for the further development of mathematics and science teaching in conjunction with federal educational agencies (see e.g. Krainer 2001). Four major programs – S1: Basic education, S2: School development, S3: Teaching and learning processes and S4: Practice-oriented research – have been established. Four teams support initiatives at schools as well as develop corresponding theoretical concepts.

Learning and Teaching Processes – IMST_: This part of the program concentrates on improving teaching and learning practices in math and science (mainly physics) classes. In the following we concentrate on the system we developed concerning the science part of the project. We support individual teachers and teams in their innovations, in reflection and networking by

- building structures for reflection and networking
- offering seminars (teachers report and discuss their work)
- informing about external research: results and tools are given to teachers (and students)
- providing innovative material
- editing and publishing reflective papers
- offering financial support

The use of videos within the project IMST_: For teachers working in the third program (Learning – and Teaching Processes) of IMST_ videos have become an important tool:

- to document teaching and learning processes in order to give a basis for networking and to further teacher education (in-service and pre-service)
- to build learning communities of teachers and students
- to reflect (with their students or colleagues or teacher students) upon teaching and learning processes in their class

Teachers who want to analyse their teaching with videos encounter a lot of problems. To improve the quality of the videos we support the teachers with technical guidelines. In general, the problem in analyzing videos is the complexity of data. We tried to find ways to reduce that complexity for teachers, mainly by suggesting a set of explorative questions and providing guidelines for discussions. Videos are way to look at things from a distance (xxx), but teachers report, that it is

difficult to find that distance. We developed guidelines for reflective papers and edited these papers to make other teachers learn from these experiences; we also made interviews using stimulated recall and counseled teachers in using data in form of triangulations. The most important task was to find ways, how to use videofeedback, within groups of colleagues and – that seems to be the most effective way to improve practise – with students in class.

Characteristics of work: Improving practice means that everybody involved in the process has to be active. So the teacher tries a new instruction module and evaluates it by documenting, analyzing with colleagues and students (e.g. using videofeedback) and disseminating their knowledge by writing reflective papers, presentations in and outside school. But the students also have to take responsibilities: summing up questionnaires, making videos, writing and commenting transcripts, protocols, summaries of discussions etc. Both, teachers and students, are responsible that the loop of innovation is going on. We as mentors

provide and improve structures to support reflection and networking

give a written feedback paper

interview the teacher and his / her students (stimulated recall)

Preliminary results

Preliminary analyses of data show the effectiveness of this intervention concerning:

- professionalizing (networking, reflection, action); - establishing a community of learners within the classroom

- structured exchange of teacher knowledge inside and outside school

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Stereotypes about different school subjects: Their effect on learning and interest and their activation/ inhibition in different school environments

Bettina Hannover & Ursula Kessels, Free University of Berlin, Germany

In our research project we focus mainly on the questions

a) whether the lack of interest for certain school subjects such as maths and science is due to specific stereotypes students hold about these subjects and

b) whether the activation of possibly negative aspects of these stereotypes can be inhibited via different classroom settings, teaching techniques, or curricula.

Why are the stereotypes about school subjects important for learning in school?

We assume that when at school, children and adolescents do not only acquire knowledge about different school subjects, but they also develop an understanding about who they are – that is they shape their self-concept or identity. Liking certain school subjects while disliking others may serve as a tool for developing an identity as a person with specific interests and characteristics (e.g. "I am a typical science freak" or "I hate French"). We assume that certain characteristics of the maths and science stereotype or of the stereotype about students who are in favor of these subjects can prevent certain groups of students (for example, girls) from entering into the maths and science field. By avoiding these subjects, they can develop an ever clearer notion about who and what they are.

What is the stereotype about math and science like?

Two aspects of the stereotype have to be considered: a) the stereotype about the characteristics of the school subject itself and b) the stereotype about people/ students engaging in this subject.

We have conducted several studies to examine both aspects of the stereotype of math and science compared to other school subjects. In short, we found the following characteristics to be important descriptors of the stereotype of math/ science: a) difficult, b) diagnostic for students' general capability, c) masculine/ "boys' subjects", d) affording no opportunity for self-realisation, e) being not "sensual"/ not sensuous.

For example, in one of our studies we asked students to describe the prototype of a girl/ boy whose favourite school subject is physics and the prototype of a typical girl/ boy whose favourite subject is music, finding the following pattern of masculinity and femininity for these prototypes (Fig. 1):

What is more, we found the extent to which a student considered himself or herself to be similar to the prototypical student favouring physics to be a strong predictor of the liking of physics.

Sources of activation or inhibition of the stereotype about maths and science:

We conceive of the following aspects of the school environment to *trigger* a negative stereotype about maths and science:

- teacher feedback that relates failure to a lack of ability
- prototypical science lesson scripts
- reference to gender stereotypes

Aims for future studies

In future studies we want to focus on the question of how to avoid aspects of the school environment that trigger the negative stereotype. For example, by training teachers in giving effort-related feedback instead of ability-related feedback should have a positive outcome on students motivation, because then students will attribute failure not to lack of ability (perceived as invariant), but to lack of effort (perceived as variable/ can be directly influenced by the student) (see Mueller & Dweck, 1998). Or, by developing a curriculum that offers opportunities to link the subject matter to one's self, by giving room for self-realisation and experiencing sensuous aspects of physics. As a means to inhibit gender related stereotypes in school lessons, we found single-sex learning groups to be very efficient because in gender-homogenous settings gender is less salient than in mixed-sex settings. Therefore, in single-sex settings gender related-self-knowledge is less accessible, resulting in less sex-typed behaviour.

School Culture, Segregation of the Sexes and Socialization of Girls Girls' Schools in Augsburg

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The investigation supported by the Deutsche Forschungsgemeinschaft (DFG) helps to answer the question about the interplay between different socialization contexts and the current debate on the quality of schools. It is expected that the results of the research, above and beyond the situation in girls' schools, will provide new insights into the educational needs of girls and the educational situation of girls and boys in co-educational schools. They will provide new insights into the configurative interplay of various factors of school quality, and will therefore produce suggestions for the future development of schools.

The project is organized into two lines of research and is intended to:

- investigate the context of the sex segregated school with the concepts and strategies used specifically to encourage girls, especially in science lessons
- investigate the subject-specific development of girls' interests in connection with the orientation of the peer group and the stages of development that female adolescents have to go through.

The first focal point of the research is directed towards two central areas: the investigation of the context and the observation of lessons. From a methodological point of view, the investigation of the context is primarily aimed at the observation of selected interactions of school life, such as school celebrations. A portrait of the school and an assessment of the quality of the gender role socialization is to be established from the observations of interactions in the context of the school, supplemented by the analysis of the conditions of the school and the intentions of the individual school.

The second point focuses on the observation of lessons. The objective here will be to observe the following aspects of the lessons:

- the aspect of content, establishing what connotations the subject has relating to the sexes, i.e. whether it is a boys' or girls' subject
- a selected aspect of teacher behaviour focused on the sex of the teacher, the behaviour as a specific 'performance', consisting of spontaneous and routine activities
- the aspect of pupils' behaviour – as interactions of the female pupils – between the demands of school life and peer culture.

The second focal point of the research is directed towards the investigation of the attitudes and experiences of the peer group. Bohnsack's procedure of group discussions is regarded as an adequate method. Two subject areas are of particular interest here: on the one hand the development of the interests of adolescent female pupils, with particular focus on reflections on 'the compatibility of family and profession', and on the other hand an aspect of peer culture, the forming of peer relationships both with people of the same sex and of the opposite sex. The study is being carried out at selected girls' grammar schools in Augsburg; a girls' high school ('Realschule') and a co-educational grammar school are being used as a control.

The Development and Enhancement of Students' Motivation – Family and School characteristics as determinants of different kinds of motivation and achievement in mathematics

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Taking into account alarming results of international comparative studies such as TIMSS and PISA the aim of this project is to *identify proximal processes underlying the development of literacy and motivation in the domain of mathematics*. In particular, we propose that German students' difficulties in solving complex problems result (at least in part) from deficits in self-determined kinds of motivation (e.g., intrinsic motivation, interest, mastery orientation) that, in turn, can be interpreted as a function of mismatches between students´ needs on the one hand and characteristics of family and school context on the other hand. Therefore, our prospective study focuses on the *influence of characteristics of family and classroom environments* on children's motivation by focusing on teaching strategies of parents as well as on instructional strategies of teachers.

Since much of the work on students' motivation builds on cross-sectional studies and self-reports of students with basic reading skills (Murphy & Alexander, 2000), longitudinal studies considering early socialisation processes and including behavioral observations are badly needed to explore the short- and long-term effects of different environments and school transition on specific motivational patterns and achievement (Eccles, Wigfield & Schiefele, 1998). Therefore, our prospective study encompasses a longitudinal period extending from *3rd to 9th grade* and the transition from elementary to junior high school. To overcome reductionisms in research on motivation the project refer to various motiational approaches, namely *self-determination theory (Deci & Ryan, 2002), interest theory (Krapp, 1999)* as well as *goal theories (Pintrich 2000)* and the *stage-environment-fit-approach (Eccles et al., 1993)*. By integrating these perspectives and incorporating domain-specific attitudes, regulatory styles, goal orientations and self-evaluations as central conceptual issues we want to extent our understanding of the development of motivation, the mechanisms underlying the socialization of motivation and the effect of motivation on the acquisition of skills in the domain of mathematics. Furthermore, by using a comprehensive set of instruments including tests, questionnaires as well as videotaped interactions and by analysing the data from students, parents and teachers we hope to gain information concerning several questions such as: Do math-related attitudes and goals of children and (early) adolescents change due to (changing) experiencies stemming from interactions with teachers and parents? What kinds of educational environment are developmentally appropriate for children at different ages? What are the most common environmental changes that parents and children expect to take place after the transition in junior high school? To what extent do these expectancies correspond with changes that in fact occure during transition? What subgroups are especially at risk to experience developmental mismatches and do these mismatches contribute to well-known decreases in early adolescents' motivation and self-concept by undermining students' sense of competence, autonomy and relatedness?

To investigate these questions, the project started in spring 2001 by contacting a respresentative sample of families from Bielefeld (a city in North-Rhine-Westfalia with app. 300.000 inhabitants). Approximately 300 third graders and their parents ("base sample") agreed to participate. All *students* yielded questionnaires adressing their motivation in terms of regulatory styles (extrinsisc and identified regulation), attitudes (interest and aversion), goal orientations (ego-orientation, task orientation and avoidance), academic self-concepts and self efficacy. Students' grades and competencies in mathematic were also assessed, the latter by using a standardized mathematics tests (developed in PEARLS/IGLU). In addition, student's perception of parenting practices (autonomy support, control, rules and rituals, stimulation and responsivity) and teaching strategies (e.g., autonomy supportive instruction, stimulating interactions, emotional support in dealing with failure, achievement-oriented pressure, provision of structure, learning vs. performance orientation) was assessed. Math teachers' instructional practices (as perceived by students) were assessed via a newly developed instrument that refer to the same dimensions underlying the questionnaires concerning parental teaching strategies.

Parents (similar to their children) filled out questionnaires concerning their parenting and teaching practices and, in addition, were interviewed about their educational goals, their epistemological beliefs and their implicit theories on learning and teaching.

A subsample of 40 families ("video sample") passed (and will pass) a more intense investigation including videotaped family interactions and diaries. These diaries entails questions concerning students' experiences with respect to learning situations at home in terms of task difficulty, student's effort to solve the task, their emotional experiences during problem solving and their perception of parental techning practices (autonomy support, control, stimulation and relatedness) in a particular learning situation.

To validate our questionnaire data and to get deeper insight into the effect of instructional contexts on within-person changes in motivation as well as the "co-construction" of meaning in learning situations, mother-child-interactions during homework were videotaped. Different kinds of instruction were used to get information about the degree to which families adapt to different tasks and situational conditions. During the first task, children and their mothers were asked to read a text about marmots that was taken from the MOSIMA (Materials for open situations in math, Eggenberg & Hollenstein, 1998). The text contains a lot of information the dyads have to use in order to generate math problems and to solve them. The second task was designed to investigate interactions when participants are stressed. Stress was induced by a difficult math problem presented as to be solvable for fourth graders. To evoke interactions that do not relate to school or achievement-related issues we used the "plan-something-together-paradigm". Mothers and children were asked to discuss how to divide up a lotterie prize among family members.

According to attachment theory it was suggested that differences in the quality of interactions and children's way to explore (learning) situations may depend on parental responsivity and internal working models of the interacting persons. Therefore, the Adult Attachment Interview (George, Kaplan & Main, 1985) was used to assess the attachment experiences of mothers during their own childhood. In addition, the attachment style of mothers and children was classified via self-report questionnaires.

Because the second wave of measurement including the whole sample is not yet completed, only cross-sectional analyses are available up to now. First of all, they support the view of motivation as a multidimensional construct and suggest that it is useful even with respect to elementary school to differentiate at least between different regulatory styles as well as achievement-related goals and attitudes toward mathematics. In addition, significant correlations between parental teaching strategies and the instructional practices of teachers (as perceived by students) on the one hand and the degree of different kinds of motivation support some main assumptions derived from self-determination theory and interest theory (Wild & Remy, 2000a, 2000b; Wild, 2003), namely the hypotheses that characteristics of learning environments influence self-determined kinds of motivation to the extent to which they serve to fulfill psychological needs. Nevertheless, one of the most crucial environmental aspect refer to the way parents frame potential learning situation. The degree to which parents focus on the learning process was the single best predictor for students' intrinsic motivation and interest in math. At the same time, children become disaffected and report higher degrees of extrinsic forms of motivation (e.g., performance or ego-orientation) the more their parents emphasize achievement and grades.

Also in line with previous results (e.g., Wild & Hofer, 1999) results suggest that parents and children have systematically different points of view (with coefficients ranging from r=.01 to r=.28). Therefore, it is important not only to consider both perspectives in further analyses but to analyse reasons and consequences for more or less divergent points of view.

Two central questions underlying current analyses:

a) School transition and motivational development

b) Evaluation of an intervention program adressing families with enduring conflicts round about homework situations

a) At present we investigate the transmission from elementary school to junior high school by asking app. 300 families of the “base sample” and, more intense, the “video sample”. In particular, we focus on changes in parental teaching strategies indicating an increasing achievement-oriented pressure in view of the transmission that draws near and the factors that might influence the decision of parents what (type of) secondary school their child will visit. By comparing beliefs of parents and children before the transition with their experiences after the transition into secondary school it becomes possible to separate effects of “objective” environmental changes, expectancies or the experience of discrepancies between both on motivational development and achievement.

b) Apart from these basic research questions we pursue more application-oriented issues by developing a first version of a parent training. In autum 2002, 22 mother-child-dyads with enduring conflicts in homework situations were invited in small groups to discuss the importance of self-regulated learning, their beliefs about the nature and acquisition of knowledge, and the determinants of intrinsic motivation as well as the origins of dysfunctional types of motivation and coping behavior such as avoidance or helplessness patterns.

To evaluate the first version of the training a pre-post-test design was used. 22 dyads of the experimental group were compared with members of the waiting-control-group (N=10) in terms of attitudes (assessed via self-reports) and behavioral changes (assessed during videotaped mother-child-interactions before and after the training). On base of these results a revised (and presumable optimized) training adressing families with low achieving children and enduring conflicts round about the child’s performance in mathematics will be developed and evaluated in 2003.

Teaching an Understanding of the Nature of Scientific Knowledge to Elementary School Children

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A metaconceptual understanding of the nature of scientific knowledge is a domain-general prerequisite for knowledge acquisition in scientific content domains. Students' as well as teachers' understanding of scientific knowledge has often been described as severely deficient, lacking a clear differentiation of theory and evidence, as well as the notion of theory construction and revision in science. In our project, we aim at (1) describing elementary school students' (3rd and 4th graders') as well as teachers' intuitive epistemologies of science (2) testing the effects of Nature-of-Science curricular units, and (3) exploring the effects of enhanced Nature of Science understanding on conceptual change in content domains in two curricular intervention studies.

In Studies 1 and 2, we assessed 4th graders' understanding of the Nature of Science prior to instruction, and tested the effects of a 5-hour instructional unit, based on a curriculum developed by Carey et al. (1989) for junior high school students. As expected, children, prior to instruction, mostly conceived of science in terms of concrete activities, effects, as well as collection of facts. The instructional unit proved to be effective in moving students' understanding beyond this initial level, towards an (at least implicit) recognition of the importance of ideas or theories, and a basic understanding of the logic of experimentation.

In Study 3, we assessed elementary school teachers' (two groups with different amounts of professional expertise) epistemologies of science. Results indicate that explicitly constructivist epistemologies of science were rare in both groups. There was a tendency towards more relativistic epistemological views in unexperienced than in experienced teachers. In Study 4 (ongoing research) we explore the effects of teacher training in Nature of Science understanding through curriculum development.

Studies 5 and 6 will address the relation between metaconceptual understanding and conceptual change in 4th grade classrooms.

Co-operative Learning of Chemistry in Different Contexts:

Group Research and Parent Involvement

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Introduction

The reason for the deficiency of German students in conceptual understanding of sciences (TIMSS, PISA) is often seen in the dominant teaching practice, which is determined by relatively narrow questions aiming at specific terms to be used. Concerning applicable knowledge self-regulated problem solving might be favourable to direct instruction which prevents the building up of a flexible knowledge structure (Gerstenmaier & Mandl 1995). A main point of discussion is the optimal degree of self-control versus external control because learners achieve worse in complex and totally open-ended learning environments. (Fischer, Gräsel, Kittel & Mandl 1997). While using their own concepts to solve chemistry problems the students should experience the quality of their knowledge. Discussing their own ideas with other students and then testing them in an appropriate experiment should enable the students to recognise their own misconceptions. Several studies show that also the family context bears good chances for interactive learning. Interactive homework-designs characterised by active parent-child interactions positively influence school learning.

This investigation focuses on improving co-operative learning of chemistry in the scholastic and family context in order to change students' daily-life conceptions. In the scholastic context the co-operative working of students in small groups is compared to direct teaching. The co-operative learning environment consists of an interactive box containing the material needed to solve the task by group research. There is no prescribed plan for the solution, no "what-to-do-list". In the family context the influence of a specifically designed parent-child interaction is compared to a traditional homework practice (Sumfleth 2003). During the interactive homework the students assume the role of a teacher and explain to the parents what they have learned in the chemistry lesson. Afterwards parent and child discuss the homework task which contains a daily-life problem.

Methods

We use a 2*2 design with 8 classes grade 7. In this way we can trace back if the main influence on knowledge acquisition or interest in sciences results from the scholastic or family learning conditions. The teaching unit gives an introduction to the topic acids and bases after half a year of chemistry instruction. First of all a pre-test is carried out to assess variables such as personal interest and motivational orientations as well as a specific pre-knowledge. As a pre-, post- and follow-up test-design is realised we can analyse changes in the students' conceptions and interests caused by the interventions.

In addition all lessons and several parent-child dyads are videotaped. The videos offer relevant insights into mechanisms for the construction of meanings and on conditions influencing the effects of co-operative learning. Depending on the research questions several theory-driven coding systems are developed and will be evolved further on. Most of them start from TIMSS Video (Stigler et al. 1999) and advance to coding categories concerning special instructional features.

Results

The pre-test results are equal in all groups. With regard to the instructional intervention in classroom there are very clear time effects comparing the scores of pre-post as well as of pre-follow-up tests. We suppose that these effects are due to the problem orientation. The students achieve a deeper understanding. Looking at the interaction effects (group*time) the students working in small groups perform significantly better in the multiple select test than the others and according to the test with open questions slightly better. These results underline that teaching small groups can be at least as effective as teaching the whole class even during the same time used for instruction.

The video data show that the students discuss intensively what to do and why they should do it, but they have problems to keep in mind the key ideas they agreed on. Students throw over scientific correct hypotheses, strategies and ideas in favour of their existing daily-life conceptions.

Comparing the results of the written homework of the traditional and interactive homework group there are just slight differences. It becomes obvious that the students who join the interactive homework group do not perform better in all six homework assignments. They achieve better than the traditional homework group in the first three homework assignments and in the end the traditional homework group has better scores. Concluding from first videoanalysis it seems that this cognitive development results from the parents' misunderstanding. As the topic becomes more and more complex the students' introduction is not sufficient for a good understanding of the parents. The parents' arguments seem to lead the students' on a wrong argumentative direction which is reflected in bad homework results. However, this is just a first hypothesis which needs to be checked by a qualitative videoanalysis based on special categories.

Conclusion and Implications

Our results show that students benefit slightly more from self-regulated learning and working on experimental problems in small groups or in parent-child dyads than from the normal classroom or homework situation. The effect size is small, too. So, in class this kind of working and learning must be improved by more structuring of the working processes in order to underline the aim orientation of the group research and the reflection of the hypotheses and the results received. The interactive homework needs to be optimised by supplying the parents with sufficient information for a optimal understanding of the contents.

Acknowledgements

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LEARNING WITH INTERACTIVE MEDIA IN SCIENCE AND MATHEMATICS

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This research project focuses on learning with interactive media in science and mathematics. Research results show that successful implementation of interactive media in learning processes depends on three main levels.

The first level is determined by the properties and the structure of the institutional environment. Important variables for the implementation of interactive media in schools are: the curricular framework, the technical infrastructure and the knowledge and didactical know-how of the teachers.

The second level enfolds the cognition and abilities of students. For example, the knowledge about heuristic strategies plays an important role for successful learning with interactive media. Other relevant aspects are the experience with computers or ability in self-guided learning.

The third level is given through the quality of the computer-based learning environment itself. According to the cognitive load theory (Sweller et al.) it is important that the computer-based learning environment is designed in a way that the extraneous cognitive load will be reduced and the germane cognitive load will be increased. One aim of research is to work out optimised design principles and identify adequate kinds of interactivity in computer-based learning environments to foster learning success.

The research in this project tries to approach all three levels. There were studies done on each level with the aim of identifying the important variables which foster or hurt learning with interactive media.

(1) Study about teachers and interactive media

This empirical investigation centres on variables which are relevant for the implementation of new media in schools. In the study 184 teachers from eight German schools completed a questionnaire about the use of new media in their lessons. The test instrument contains scales about engagement, cooperation, stress, further training, beliefs regarding the use of computers, and role understanding. With the help of probabilistic test models (Latent Class Analysis) five classes could be identified. These classes could be interpreted as five types of teachers. Each class has a specific profile regarding the scales of the questionnaire and how this group of teachers uses new media in schools. A post-hoc analysis indicates that the behaviour of the head master of a school influences the number and the distribution of the five groups of teachers within a school.

(2) Study about students and interactive media

In a study with 114 students from three German schools it should be worked out which are the main important variables which explain the difference in the post-test results after working with an interactive learning environment. A first analysis shows that these are: prior knowledge, self-concept, motivation and ability in self-guided learning. A further result could be found in the analysis of video recordings while students are working with the learning environment. In this analysis some interaction strategies could be identified which support successful learning. The evaluation of the video data showed that different persons work in different ways with the interactive learning modules. For instance it could be shown that students with an inquiry learning style (e. g. going on systematically or looking at special cases) within the interactive learning modules gain a significantly better post-test result than students who work less systematically.

(3) Studies about the design of interactive learning environments

A first study in this area focuses on learning with interactive simulations using different levels of interactivity. The main objective here was to identify which role the degree of freedom in simulations plays for learning success. For the examination two versions of a computer-based learning environment about the theorem of leverage were compared (simulations with a high vs. a low degree of freedom). In the study 114 students participated from three German schools. The treatment consisted of working with the specific learning environment. The post-test results showed a significantly better performance of the simulation group with a high degree of freedom. This result shows that reducing the degree of freedom in simulations can increase the extraneous cognitive load and decrease the germane cognitive load. The reason for that seems to be that the learning material becomes less interconnected and is a detriment in constructing an adequate schema of the complex learning task.

A second study is going to be started this year in cooperation with the University of Joensuu (Finland). The aims of this research program are: (1) to investigate and categorize the different ways students act when working with dynamical representations of mathematical objects, (2) to create and test structured online learning material for studying basic concepts like functions, based on idea to combine the linking of conceptual and procedural knowledge with the use of multiple representations (verbal, symbolic, graphic) of interactive objects. The technical base for the learning environment will be dynamical geometry applets.

Horst P. Schecker

Areas of Research and Development

R&D Interests

- implementation of multimedia in teaching physics (university and school)
- effectiveness of multimedia for learning physics
- development of standardized inventories for testing the effects of physics teaching

Current Projects (selection)

Multimedia Physics — Teaching and Learning Modules for University Physics Courses (2001-2003, funded by the Federal Ministry of Education and Sciences)

Five German Universities are cooperating to set up a teaching and learning platform for physics which consists of the following modules:

- course management
- multimedia self-study units (physics as a minor subject)
- media database
- assignment database
- tutorials for lectures about the use of multimedia in specific domains

The project focuses on development and evaluation. It has a spin-off potential for these research questions:

- Which factors influence the reluctance / motivation of lecturers (teachers) to try out and evaluate the use of multimedia in their teaching? (with conclusions for ICT implementation strategies)
- What would be the appropriate design of self-study materials to ensure an effective usage by students? (aptitude-media-treatment-interaction issues)

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Roberta — Robotics Courses for Girls (2003-2005, funded by the Federal Ministry of Education and Sciences and in cooperation with the Fraunhofer Institute for Autonomous Intelligent Systems, AIF)

The AIF develops courses for enhancing the motivation of girls to choose science courses at school (technological basis: Lego Mindstorms). The IDP evaluates the course concepts: empirical investigations about the motivation of the participants to enroll for a robotics course and its effects on attitudes towards technology as well as possible changes in their vocational orientations or studies subjects.

Research issues:

- How do the robotics courses have to be designed (content, methods) in order to obtain an optimal fit between students' predispositions and intended effects?

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Previous Projects (example)

System Dynamics in Learning Physics (1996-1999, funded by the German Science Foundation, a project together with E. Klieme)

System Dynamics software (Stella) can be used by students to actively model physics processes (e.g. complex motion, oscillatory circuits, radioactive decay. Students work out the conceptual structure

similarly to a concept map. The software transforms the map into a set of functions and difference equations. Mathematical restrictions (analysis) are thus reduced. The study used a pre-post design comparing classes where over a period of four months, groups of students were repeatedly working with Stella with classes where a conventional approach to mechanics was being employed (more teacher centered phases).

Our research showed a higher increase of semi-quantitative reasoning in the experimental classes. However, the overall effect on understanding mechanics (as) tested by the FCI was not significant. Systems thinking as a transferable, cross-curricular competence did not develop “as such” but arose from a combination of modeling abilities and domain-specific knowledge. Further results of the study lie in the operationalization of “system thinking” and the construction of a set of instruments for its diagnostics.

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Project Plans

Development of standardized inventories for testing the effects of physics teaching

Doctoral dissertations starting in 2003/04. Domains:

- conceptual understanding (e.g. mechanics, electric circuits, nuclear physics)
- scientific reasoning

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Self-regulated learning from expository texts

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Learning strategies have been considered to be an important component of self-regulated learning (Boekaerts, 1997; Pintrich, 2000; Zimmerman, 1994). One reason for this is that students regulate and actively facilitate their own learning process through the use of appropriate learning strategies. Consequently empirical research has focused on distinguishing und training different strategies such as rehearsal, elaboration and metacognitive strategies and examining their relation to academic achievement.

Purposes of the project

1 - Survey

First, we focused on identifying strategies, successful learners would use when learning from expository texts.

Theories of self-regulated learning state that applying elaborative and metacognitive learning strategies, as apposed to simple rehearsal strategies, should result in better knowledge acquisition in learning from texts. Empirical evidence shows that there is substantial variation in the correlations of self-report measures of learning strategies and learning achievement. A review of the literature indicates that higher correlations can be found when the students are not too young, when strategy use and learning achievement are measured in a state (i.e. learning in a specific learning situation) rather than a trait context (i.e. learning in general), and when the strategy assessment is focused not only on quantity but also on quality (relevant concepts) of strategy application. It was tested whether combining these three aspects would result in substantial correlations beween self-reported learning strategy use and learning achievement.

The research questions were: (1) Does learning strategy use change with students' age? (2) How is learning strategy use related to achievement and does this relationship also change with students' age?

Results: 1. Linear trends were found showing that student use of elaboration and metacognitive strategies increases with age, while the use of rehearsal strategies decreases. The trend was more pronounced for elaborations on specific text contents rather than for more general elaborations. 2. Correlations between learning-strategy use and learning achievement showed the same trend: For elaboration and metacognitive strategies, the correlations increased with increasing age, whereas for rehearsal strategies, the correlations decreased down to negative scores. Again, this trend was more pronounced for elaborations of specific concepts rather than for more general elaborations. Furthermore, the correlations between strategies also increased with age.

In summary, successful learners report to use strategies that are focused on organizing and elaborating relevant concepts and text ideas. In addition, they report to monitor and regulate their own learning process.

2 - Training

Second, we examined the effect of two versions of a learning strategy training program (cognitive strategy training vs. cognitive & metacognitive strategy training) on learning from expository texts.

Theories of self-regulated learning state that combining cognitive and metacognitive learning strategies should facilitate learning from texts. Results of the self-report study indicate that metacognitive strategies facilitated the quality of cognitive strategy use and thereby promoted learning achievement.

Therefore strategy training was conceptualized to support quality of strategy use by means of metacognitive strategies. Metacognitive strategies, such as planning, self-observation, self-judgement, self-reaction were derived from Bandura's (1986) social cognitive theory. Cognitive strategies, such as networking (Dansereau, 1978; Metzig & Schuster, 1993) and underlining (Duhmke & Schäfer, 1986) were adapted from current training programs. Combined and single strategy training were performed both as computer-based training and as teacher-based training. Results show that combined training compared to single training was beneficial in terms of learning from text at both conditions.

In a second step we adress the question of developing a training program focussing on specific science learning strategies.

IMST_ - Innovations in Mathematics, Science and Technology Teaching

An Austrian research and development project aimed at enhancing the quality of mathematics and science teaching in upper secondary schools.

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Issue and Objective: Cooperation of teachers and scientists in order to improve both teaching and educational research

IMST_ is a 4-year-program (2000 – 2004), initiated by the IFF (Institute of Interdisciplinary Research and Education, University of Klagenfurt) and the Austrian Ministry of Education, Science and Culture (bm:bwk) as a response to the unsatisfactory results of TIMSS. Its overall goal is the creation of a support system for schools. Annually about 60 general and vocational secondary schools cooperate with educational scientists in an endeavour for independent learning, problem-solving, reasoning, critical self assessment and understanding of key concepts**.** Mathematical and scientific literacy including the ability to apply one's knowledge in everyday contexts is considered as a crucial part of every student's education. Examples of good practice in teaching and learning are designed, realized and carefully documented. The results are disseminated and used for further research.

Focus and key question: Designing and analysing an intervention in the educational system

What are the effects of the IMST_-cooperation between schools and universities on classroom teaching, on educational research and on the school system as a whole? This question is tackled theoretically and by engaging in several dozens of practical studies, which are evaluated both by teachers and by scientists. The evaluation is intended not only to improve the processes and to assess the outcomes of the project itself, but also to generate knowledge on how to systematically and effectively support innovation in schools on a large scale. The project is an exemplary study in intervention research, investigating the strengths, weaknesses, opportunities and threats of participatory action in a public domain.

Strategy: Innovative teaching and teamwork as a basis for school development

IMST_ addresses groups of mathematics, biology, chemistry and physics teachers, as well as interdisciplinary teams, who work together and experiment in new teaching methods with 15-18 year old students. Teams of teachers rather than individuals are involved and must be supported by their school administrations. If a positive attitude towards innovation prevails, creative ideas can have an impact on the organizational development of the whole system. The exchange of practical ideas with teams from other schools is intended to encourage the participants and to create positive conditions for innovation in their own school.

Practical Aspects: Schools can choose their own way of cooperation

Each school is a world of its own. Its profile, human resources, local infrastructure and parental interests can be as distinctive as its specific goals and its expectations concerning supervision. IMST_ therefore offers a variety of ways in which teams of teachers can participate and cooperate:

- **Four priority programmes**: Mathematical and scientific literacy (S1), School development (S2), Teaching and learning processes (S3) and Practice-oriented research (S4).
- **Four** subjects - biology and environmental education, chemistry, mathematics and physics, and in some cases computer technology, geography (including earth sciences).

- Four **intensity levels of cooperation** - information school, contact school, collaboration school or focus school.

A team of more than twenty scientists and school experts cooperate with experienced teachers in order to engage in a dialogue between theory and practice for the benefit of both groups. The results include designs for teaching units, worksheets for science lessons, mathematical teaching materials, questions and test items, research tools such as questionnaires about students' attitudes or teachers' beliefs, and numerous case studies and their analysis. Evaluation is an important component of IMST_ both as a steering instrument and a means for generating knowledge. A panel of expert practitioners and international scientists support the quality development and assessment of IMST_.

Four priority programmes (S1 – S4) with different tasks

1. **Mathematical and scientific literacy (S1)**: The four S1-teams (biology, chemistry, mathematics and physics) support initiatives at schools where the goals of general mathematics and science education are reflected: What mathematical and scientific knowledge and qualifications should every literate person have?
2. **School development (S2)**: The S2-team supports schools that focus on mathematics and science teaching and at the same time engage in school development processes. A network of such schools is being established in order to enhance the efficacy of mathematics and science teaching.
3. **Teaching and learning processes (S3)**: The S3-team both supports innovation at schools focusing on teaching and learning processes and aims at working out a concept for generating, analysing and evaluating such processes, supplemented by material like a CD with video-clips of authentic classroom and laboratory situations intended for use in teacher education.
4. **Practice-oriented research (S4)**: The S4-team supports teams of school teachers or university educators (or mixed teams), who carry out either investigations of their own teaching (action research) or classical research projects focussing on aspects of teaching a specific subject.

Gender mainstreaming and gender sensitivity (GM) is a common feature of all four priority programmes listed above. A team of specialists initiates and supports projects focussing on gender issues in mathematics and science teaching.

Publications:

- Innovations in Mathematics, Science and Technology Teaching (IMST_). Initial Outcome of a Nationwide Initiative for Upper Secondary Schools in Austria. (Contribution at the ICTMT5-Conference in Klagenfurt, Aug. 2001)
- Innovations in Mathematics, Science and Technology Teaching (IMST_). Examples from a nationwide initiative for Upper Secondary Schools in Austria. (Contribution at the EU-Conference in Denmark, Nov. 2002)
- Lernen im Aufbruch: Mathematik und Naturwissenschaften. Pilotprojekt IMST_. (Recent book about IMST_, StudienVerlag: Innsbruck-Wien, Sept. 2002. http://www.studienverlag.at/titel.php3?nr=883).

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