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ABSTRACT

In this experimental study various strategies were developed and empirically tested for physics instruction designed to improve girls' and boys' attitudes toward and achievements in physics. Strategies included opportunities to integrate different pre-existing knowledge, variation of teaching methods to enhance cooperation and communication in the classroom, and supervision of teachers. The research design includes three experimental groups I-III and a control group. The teachers of experimental group I developed a set of teaching and learning materials (40 lessons on optics and kinematics), used it in their physics courses, and were supervised. Group II used the same set of materials with the same supervision. Group III used the set of materials with no further support. Data sources were various student and teacher questionnaires, tests in optics and kinematics, classroom observations, and semi-structured interviews with teachers. Contains 24 references. (Author/MKR)

Physics for girls and boys: teaching and learning strategies examined in 25 classes of the upper secondary level[1]

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Abstract: In this experimental study various strategies are developed and empirically tested for a physics instruction that should improve girls' and boys' attitudes toward and achievements in physics. Strategies include opportunities to integrate different pre-existing knowledge, variation of teaching methods to enhance cooperation and communication in the classroom, supervision of teachers.
The research design includes three experimental groups I-III and a control group: the teachers of experimental group I together develop a set of teaching and learning materials (40 lessons optics and kinematics), use it in their physics courses, and get a supervision. Group II uses the same set of materials, and gets the same supervision. Group III uses the set of materials, too, but gets no further support.- Data sources are various student and teacher questionnaires, tests in optics and kinematics, classroom observations, and semi-structured interviews with teachers.
In our talk the learning und teaching materials, first results of the entrance survey (Aug. 1995), and first results of the interviews with teachers are presented. Implications for the teaching and learning of physics, and for teacher education will be discussed.

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Overview

Objectives (Fig. 1)

Main research questions of our study are (Herzog & Labudde, 1993):

- What are criteria and strategies for physics instruction suitable for both genders, i.e. dealing with girls and boys?
- How can high school physics teachers become more sensitive for gender issues and what circumstances can contribute to an appropriate change of their attitudes and classroom practices?
- How do students and teachers experience such an instruction: what is its influence on teaching and learning, cooperation and communication, students' interests in physics, their knowledge in and about physics?

Theoretical framework

Since the beginning of the eighties the attitudes toward science and the achievement in science have been foci of gender studies. Results indicate, that boys have a more positive attitude toward physics and a higher achievement in physics than girls and that attitude and achievement are correlated (Greenfield, 1995; IEAP, 1992; Weinburgh, 1995). Looking for reasons researchers stated among other things the decline of interest in physics during the years of lower secondary education (Häussler, 1987; Hoffmann & Lehrke, 1986), the different interactions of male and female students with teachers (Brophy, 1985), teachers' attitudes toward girls and technology (Haggerty, 1995; Spear, 1985), the problem of culture, sex stereotypes, and school science (Byrne, 1993; Kelly, 1988), the difference in pre-existing knowledge between girls and boys and their different ways of learning (Pfundt & Duit, 1994; Räsänen, 1992; Roychoudhury, Tippins & Nichols, 1995), the girls' self-confidence in physics and technology (Guzzetti & Williams, 1996; Kenway & Willis, 1990).

Although many reasons for the different attitudes toward and achievements in physics of female and male students are known, only in a few projects - mainly at the lower secondary level - strategies have been developed and tested to improve students' attitudes and achievements (BLK-Modellversuch Rheinland-Pfalz, 1993; Harding & Parker, 1995; Häussler & Hoffmann, 1995; Hoffmann, 1993; Uhlenbusch, 1992). It is because of the small number of research projects, that Weinburgh (1995) concludes in her overview, "the first [implication] is the practical need to continue research that examines strategies in the classroom for improving all students' attitudes toward science, especially those of female students".

In our research project such strategies are developed and evaluated. They include: a strong relation between physics contents and students' everyday experiences (Labudde, 1993, 1996); learning opportunities to integrate different pre-existing knowledge; a variation in teaching methods enhancing cooperation and communication in the classroom (Herzog, 1994); supervision of teachers.

Our experimental study takes place in grades 10 and 11 (Fig. 1). There are three main reasons for this: 1. In most cantons of Switzerland specific physics instruction starts only at grade 10 or 11 (before that students learn "general science"). 2. All physics teachers have a masters degree in physics or mathematics; so they are mainly socialized by and familiar with these domains. How can these teachers become sensitive for gender and educational issues? 3. Until now most studies have involved grades 5-9, but not the upper secondary level. So our results can serve to confirm (or not) previous results of other research projects at other school levels.

Research Design (Fig. 2)

The core of this experimental study is an intervention in "normal" classes of public schools in Switzerland. The intervention includes the first 40 lessons of the first physics course, that all students have to take at the upper secondary level, i.e. it is the beginning of physics instruction at this level. Depending on the canton and on the individual school this means grade 10 or 11. The intervention takes place in the school year 1995/96 between August 1995 and January to May 1996 (depending on the number of physics lessons per week).

25 volunteer teachers have been recruited. All of them have at least a masters degree in physics, mathematics or science. In our experimental study these teachers and their classes are distributed into four groups (Fig. 2):

- *I* *Experimental group I (5 teachers):* This group chose the content of the physics instruction, geometrical optics and kinematics, and - between January and July 1995 - they developed one common set of teaching and learning materials. The materials are based on criteria for a physics instruction, that should be appropriate and motivating for girls and boys (Fig. 3). The teachers use these, i.e. "their" materials in their classes. Concerning the research focus "physics for girls and boys" the teachers get a supervision during the classroom intervention. This group of teachers has the highest engagement and involvement in the research project.
- *II* *Experimental group II (6 teachers):* These teachers use the same set of teaching and learning materials, that have been developed by their colleagues of group I. They also get the same supervision as group I together with those teachers.
- *III* *Experimental group III (6 teachers):* Also the teachers of this group use the same set of teaching and learning materials. But they do not get any specific supervision.
- *C* *Control group (8 teachers):* These teachers do not get any materials or any supervision. But they teach the same physics contents (geometrical optics, kinematics), at the same level (grade 10 or 11), at the same time (Aug. 95 - Jan./May 96), using their own personal materials.

Methods and data sources

At the beginning of the intervention (mid-August 1995) all the students answered a student questionnaire. This questionnaire, that is answered during 90', includes some subscales of standard I.Q. tests (spatial ability; language comprehension). Further items and scales in different domains have been developed by us, e.g.: everyday experiences in physics, science, and technology; attitudes toward physics and other school subjects; knowledge in optics and kinematics; expectations concerning the physics course; self-confidence and self-efficacy in physics and in general; attributional style; a standard androgyny scale.- At the same time all the teachers answered a teacher questionnaire. It includes e.g. the main objectives of their physics instruction; teaching methods used in the last two years; expectations concerning the research project and the set of teaching and learning materials; attitudes toward girls and boys in physics instruction; a standard androgyny scale; the view of physics as a science.

During the intervention data were collected by means of individual teacher interviews and classroom observations. The interviews were semi-structured, the observations based on a scheme. These data also served for the supervision of all teachers of the experimental groups I and II.
The interviews included 14 series of questions, each of the series dealing with one main subject concerning I) physics instruction and II) physics as a science: I) the role of experiments in physics instruction, prefered methods of instruction, physics as an experience for students, the role of everyday physics, students' pre-conceptions and language, the role of mathematics, cooperation and communication in physics instruction, differences between girls and boys; II) teamwork in physics research, science as a "correct" view of the world, science between empiricism and realism, the development of new scientific knowledge, characteristics of "the scientific method".- One of us, always the same person, was the interviewer. The interviews took between 45' and 60'; they were audio-taped and literally transcribed. Every teacher got the transcript of his or her interview and - in a personal conversation of about 60' - a feedback on selected statements.

At the end of the intervention all students and all teachers answer a student and a teacher questionnare, resp.. The items of the student questionnaire include e.g.: the learning and teaching methods during the intervention; the integration of pre-existing knowledge; cooperation and communication. At the end of each unit students performed a test in optics and kinematics, resp.. The items of the teacher questionnaire include analogous items as the student questionnaire.

First results of the project

Criteria for the development of the teaching and learning materials (Fig. 3)

These criteria, based on previous projects and on the literature, include among others:

- Contents and context of physics instruction have to be relevant for males and females: This is one of the reasons, that geometrical optics has been chosen as the first unit in physics instruction, and that in both units the everyday world of boys and (!) girls is a main base for physics instruction.
- Individual preconceptions and experiences of girls and boys are integrated in the texts (so far as they are known and common) or/and students are explicitly asked to tell their own ideas and experiences. During the lessons students get the opportunity to make up for unknown experiences.- The everyday language is a frame for the preconceptions. Therefore relations and differences between mother tongue and physics language are emphasized and discussed.
- Active and interactive learning environments are created whenever possible: e.g. hands-on-activities, little "research-projects", group-discussions, presentations of students, writing essays or designing posters. Teaching methods are favored, that enhance cooperation and communication between student-student and teacher-student.

- Text and figures are non-sexist and gender-balanced.

Some typical examples of the teaching and learning materials are presented during the talk at the NARST meeting.

First results of the entrance survey (Fig. 4 and 5)

Many of our results confirm previous results of other studies in other western countries or at other school levels (lower secondary or college level).

Differences in experiences and interests (Fig. 4):
Highly significant differences between the girls and boys of our sample exist in (sign. level: $p<0.001$; items with a rating-scale from 1 to 5):

- experiences in physics (active: hobbies related to physics; passive: media),
- activities and hobbies related to technics or household,
- interests in natural phenomena and technics.

Cognitive ability and self-concept (Fig. 4):

- In an entrance test the girls answered 29% of 12 multiple-choice physics problems correctly, the boys 34% (sign. level: $p<0.01$).
- But there were no significant differences between girls and boys in language comprehension and spatial ability (subscales of standard I.Q. tests).
- Ratings of girls and boys are different ($p<0.001$) when asked, how ability and effort influence their physics grades.

Most favorite school subjects (Fig. 5):

- Physics, mathematics, and chemistry are the least favorite school subjects of the girls. But also boys place physics and mathematics in the lower half of their most favorite subjects.

Our results confirm, that girls and boys - when beginning with their first physics course in the upper secondary level - have a different background and different interests in physics, but similar spatial and language abilities. These results and others of the entrance survey support several of our criteria for the development of learning and teaching materials (Fig. 3). They also support many of our teaching strategies.

Teaching strategies (Fig. 6)

These strategies have been developed in collaboration with the teachers of the experimental groups I and II. The teachers of the group III and of the control group had at no time access to these strategies. Only the teachers of group I and II were asked to choose and to apply some of the following strategies in their physics classes:

- *Interaction and feedback:* e.g. pay equal attention to girls and boys, state explicitly your similar expectations concerning their abilities in physics, give all students enough time to answer a question, collect several answers to one question, give positive feedback during the lesson and in personal conversations.
- *Self-concept of girls:* e.g. praise girls not only for their diligence and discipline but also for their ability and talents in physics, avoid any impression that physics is only something for highly gifted people or men, signal that girls are not less "attractive" (not less "female") when they are interested in and good at physics.

- *Contents of physics instruction:* e.g. pay attention to the different experiences of girls and boys and to the context of physics instruction, create relations between physics and people whenever possible.
- *Atmosphere and methods of learning:* e.g. arrange conversations and discussions as much as possible, form single-sex groups for group-discussions and practicals, support cooperation and suppress open competition, make your physics classroom more comfortable.

In order to support the teachers of group I and II in applying some of these strategies, they got a supervision: several meetings before and during the intervention, intervision of teachers (i.e. two of them visited each other during their physics lessons), an individual interview with each teacher and a personal feedback on that interview, classroom observations with a focus on the teacher-student-communication and personal feedback on these observations.

First results of the teacher-interviews (Fig. 7)

Some of the strategies for a physics instruction, that should be more suitable for girls (and boys), are well accepted, i.e. all teachers agree with these strategies and say, they would try to realise them - more or less - in their physics instruction. Accepted strategies are, that the context of physics instruction should be relevant for girls and boys and that students should perform their own experiments. Some teachers wonder, if they could and should discuss more natural phenomena instead of technical examples.

The integration of students' preconceptions gets a medium acceptance: some teachers are still not aware of the problem or other teachers do not know, how to operationalise this strategy; they miss specific techniques.

In general the most favorite teaching methods of the teachers are demonstrations, question-answer-method, and students' experiments. Students' "projects" and presentations, that were part of our unit "optics", were rather well accepted, but - till now - not used in other classes than in those of the research project: A problem for some teachers are wrong solutions of the students, another problem are poor presentations of some groups. But teachers praise also some excellent presentations of other groups. - Other more student orientated methods and techniques are hardly ever used. (There could be several reasons for this: teachers just do not know these methods, or they do not know how to use them, or learning and teaching physics this way does not correspond to their image of physics instruction.)

The main problem for the teachers, stated by most of them, is the time: Many teachers argue, they could not do anything, that needs more time than "normal" physics instruction. (If science educators want to change physics instruction, they have to keep in mind this obstacle.)

Further results and interpretations

At the time of the NARST-meeting (begin of april 1996) about half of the classes has finished the two units of our project and has answered the final survey. The other classes will finish some weeks later. Detailed results - including descriptions and multivariate analyses - of entrance and final survey, optics and kinematics tests, interviews and classroom observations will not be availabe before the end of autumn 1996.

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Physics for Girls and Boys ...

Objectives:

- Development of criteria for physics instruction suitable for girls and boys
- Sensibilisation of physics teachers for gender issues
- Evaluation of the applied strategies

Characteristics:

- Classroom interventions: Aug. 95 - May 96
- Grade 10 or 11: first physics course
- Teachers 25
  Classes 31
  Students 599

St. Louis, NARST 1996

Labudde et al: Fig. 1

Research Design

	Exp. I	Exp. II	Exp. III	Control
Development of materials				
Entrance survey (90')				
Unit 1 "Optics" (20 h)				
Supervision				
Test "Optics" (45')				
Unit 2 "Kinematics" (20 h)				
Supervision				
Test "Kinematics" (45')				
Final survey (90')				

St. Louis, NARST 1996

Labudde et al, Fig. 2

Criteria for materials

Context of physics relevant for both genders

Integration of individual preconceptions and experiences of girls and boys

Active and interactive learning environments enhancing cooperation and communication

Balance of genders and no sexism in texts and figures

St. Louis, NARST 1996 | Labudde et al, Fig. 3

Entrance Survey (selected results)

	girls	boys	sign.
N	384	193	
experiences in physics: passive	1.7	2.2	***
active	1.5	2.0	***
technics orientated activities	2.0	2.5	***
household orientated activities	3.5	2.8	***
interests in: natural phenomena	4.1	3.6	***
technics	2.6	3.1	***
knowledge in optics / kinematics	29	34	**
I.Q.: language comprehension	11	11	n.s.
spatial ability	11	11	n.s.
Influence on physics grade: luck	2.6	2.5	n.s.
ability	2.0	2.3	***
effort	3.3	3.0	***

***: $p<0.0001$; **: $p<0.01$
n.s.: not significant

St. Louis, NARST 1996
Labudde et al, Fig. 4

Entrance Survey
Most favorite School Subjects

Girls (N=384)	Boys (N=193)
1 English	1 Sports
2 Art	2 History
3 French	3 English
4 Biology	4 Biology
5 Music	5 Geography
6 History	6 Chemistry
7 Sports	7 Art
8 German	8 Music
9 Geography	9 Physics
10 Physics	10 Mathematics
11 Mathematics	11 German
12 Chemistry	12 French

St. Louis, NARST 1996 Labudde et al: Fig. 5

Teaching Strategies: Domains
(Exp. Groups I, II)

Interaction and feedback
Self-concept of girls
Contents of physics instruction
Atmosphere and methods of learning

Supervision of Teachers (I,II)

Development of materials (only group I)
Sensibilisation meetings
Intervision of teachers
Interview / Feedback
Classroom observations / Feedback

St. Louis, NARST 1996

Labudde et al, Fig. 6

Teacher-Interviews

Selected Results

Strategy	Acceptance	Problems
relevant context of physics	+	more nat. phenomena instead of technics
integration of preconceptions	+/-	not aware of problem, operationalisation?
hands-on-activities	+	time consuming, no materials
students' projects and presentations	+/-	wrong solutions, poor presentations
other student orientated methods	-	time consuming, no own experience

St. Louis, NARST 1996

Labudde et al: Fig. 7