INT. J. SCI. EDUC., 2000, VOL. 22, NO. 2, 143-157

RESEARCH REPORT

Girls and physics: teaching and learning strategies tested by classroom interventions in grade 11

Peter Labudde, Universitaet Bern, Hoeheres Lehramt, Postfach, CH-3000 Bern 9, Switzerland, e-mail: labudde@sis.unibe.ch
Walter Herzog, Markus P. Neuenschwander, Enrico Violi and Charlotte Gerber, Universitaet Bern, Abteilung Paedagogische Psychologie, Muesmattstr. 27, CH-3012 Bern, Switzerland

In this quasi-experimental study various strategies are developed and empirically tested for an approach to physics instruction that should improve girls' and boys' attitudes toward and achievements in physics. Strategies include opportunities to integrate different pre-existing knowledge and the variation of teaching methods to enhance co-operation and communication in the classroom. The core of this study is an intervention in 31 classes of public schools in Switzerland. The intervention, one unit in optics and one in motion (velocity/acceleration), includes the first 40 lessons of the first physics course that all students have to attend at the upper secondary level. Data sources are various student and teacher questionnaires, tests and semi-structured interviews with teachers. Results of the entrance and final survey are presented. The focus will be on some of the applied strategies. Implications for the teaching and learning of physics and for teacher education are discussed.

Introduction

From the beginning of the eighties, attitudes toward science and the achievements in science have been the foci of gender studies. Results indicate that boys have a more positive attitude towards physics and a higher achievement in physics than girls; attitude and achievement are correlated (Baumert and Lehmann 1997, Beaton *et al*. 1996, Greenfield 1995, Mullis *et al*. 1998, Parker *et al*. 1996, Weinburgh 1995). Looking for reasons, researchers state: the decline of interest in physics during the years of lower secondary education, i.e. grades 5-9 (Häussler 1987, Häussler *et al*. 1998, Keller 1997); the different interactions of teachers with male and female students (Brophy 1985, Enders-Dragässer and Fuchs 1989, Kahle 1988, Kelly 1988); teachers' attitudes toward girls and technology (Haggerty 1995, Spear 1985); the problem of culture, sex stereotypes, and school science (Byrne 1993, Kelly 1988); parents' expectations toward their daughters and sons (Eccles and Jacobs 1986); the difference in pre-existing knowledge between girls and boys and their different ways of learning (Johnson 1987, Pfundt and Duit 1994, Räsänen 1992, Roychoudhury *et al*. 1995, Sjøberg and Imsen 1988) and the girls' self-confidence in physics and technology (Guzzetti and Williams 1996, Kenway and Willis 1990).

International Journal of Science Education ISSN 0950-0693 print/ISSN 1464-5289 online
http://www.tandf.co.uk/journals/tf/09500693.html

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 and Parker 1995, Harmon *et al*. 1997, Hoffmann *et al*. 1997, Uhlenbusch 1992). It is because of the small number of research projects of this kind, that Weinburgh (1995: 396) 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 have been developed and evaluated (Herzog 1994, 1996, Herzog *et al*. 1997a). They include a strong relation between physics contents and students' everyday experiences (Gerber 1998, Labudde 1993, 1996); learning opportunities to integrate different pre-existing knowledge; a variation in teaching methods enhancing co-operation and communication in the classroom (Labudde 1997a/b, 1999) and training of teachers. The project as a whole is based on the assumption that gender differences in attitudes toward physics and abilities in physics are due to motivational problems and not to gender differences in gift or talent. All our criteria and strategies are based on this assumption. Two main research questions of our study are:

1. How can physics teachers become more sensitive to gender issues and what circumstances can contribute to an appropriate change in their attitudes and classroom practices?
2. What criteria and strategies for physics instruction are suitable for both genders, i.e. dealing with girls and boys; how do the strategies influence students' attitudes toward and achievements in physics?

Research design

Our quasi-experimental study took place in the upper secondary level. There were three main reasons for this: In most cantons of Switzerland, specific physics instruction starts only at grade 11, in a few cantons at grade 12 (in lower grades, students have to take courses in general science). Secondly all physics teachers have a masters degree, most of them in physics, some of them in mathematics or in other sciences; therefore, they are mainly influenced by and familiar with these domains, but less with educational issues. Finally until now, most studies have involved grades 5-9, but not the upper secondary level. So, our results can confirm previous results of other research projects at other school levels.

The core of this experimental study were classroom interventions in public schools in the German speaking part of Switzerland. All schools are so-called '*gymnasiums*' or schools very similar to those. The interventions included the first 40 lessons of the first physics course that all students have to attend in the upper secondary level, i.e. it was the beginning of physics instruction at this level. The intervention took place in the school year 1995/96 between August 1995 and January to September 1996, depending on the number of physics lessons per week. Twenty-five volunteer teachers with 31 classes and about 600 students had been recruited. All teachers had at least a masters degree in physics, mathematics or chemistry; eight had a PhD in physics.

As seen in table 1 the teachers and their classes were divided into four groups:

I. *Experimental group I (5 teachers):* This group, together with the research team, chose the topics and the contents of the physics instruction, optics and motion (velocity/acceleration), and developed between January and July 1995, together with two of us, one common set of more than 200 pages of teaching and learning materials. Some of the materials were developed by the teachers of group I themselves, others had been copied from different publications. All materials were based on criteria for a physics instruction that should be appropriate and motivating for girls and boys. The teachers used these i.e. 'their' materials in their classes. They received special training before and during the classroom intervention to improve their teaching strategies with regard to girls and physics. This first group of teachers had the highest engagement and involvement in the research project.

II. *Experimental group II (6 teachers):* These teachers used the same set of teaching and learning materials that had been developed by their colleagues of group I. They also got the same training as group I together with those teachers.

III. *Experimental group III (6 teachers):* The teachers of this group also used the same set of teaching and learning materials, but they did not get any specific training.

C. *Control group (8 teachers):* These teachers did not get any materials or any training. However they taught the same physics contents (geometrical optics, kinematics), at the same level, at the same time (August 95-January/September 96), using their own personal materials.

Methods and data sources

As indicated in table 1, data have been collected in the entrance and final survey, in two physics tests in optics and in velocity/acceleration and during the training of the teachers:

Table 1. Overview of the project phases, the research design (three experimental and one control group) and of the data collection (the entrance survey, the teacher-training, the physics tests and the final survey).

Project phases and data collections	*Time*	*Exp. group I*	*Exp. group II*	*Exp. group III*	*Control group*
Development of learning materials		X			
Entrance survey	90 mins	X	X	X	X
Unit 1: geometrical optics	20 hours	X	X	X	
Training		X	X		
Physics test 1: geometrical optics	45 mins	X	X	X	X
Unit 2: kinematics	20 hours	X	X	X	
Training		X	X		
Physics test 2: kinematics	45 mins	X	X	X	X
Final survey	90 mins	X	X	X	X

Entrance survey

At the beginning of the intervention, all the students answered a questionnaire. It included sub-scales of standard I.Q. tests (spatial ability, language comprehension). Further items in different domains had been developed and were formed to scales using factor analysis: active and passive experiences in physics; technology orientated activities; household orientated activities; interests in natural phenomena and in technology; attitudes towards physics and other school subjects; expectations concerning the physics course; connotations with physics; self-confidence and self-efficacy and attributional style. For example, the scale 'technology orientated activities' is based on nine items asking students how often they 'use a drilling machine', 'fix something with dowel and screw', 'assemble a plug', 'repair a bike', 'do handiwork', 'change an electric cable', 'repair household appliances', 'prepare the barbecue', 'lighten fireworks', 'clean a brush'. The five answer categories are from 1 (very seldom) to 5 (very often). A reliability analysis has been performed yielding a Cronbach-Alpha of 0.86. All items and scales of the entrance survey have been analysed and checked in a similar way and proved to be of satisfactory quality (Herzog *et al*. 1997b/c). At the same time, all the teachers answered a teacher questionnaire. It included items asking for the main objectives of their physics instruction, the teaching methods used in the last two years, the expectations concerning the research project and the set of teaching and learning materials, the attitudes towards girls and boys in physics instruction and their view of physics as a science.

Training

In order to support the teachers of experimental group I and II in applying the strategies that should be effective for girls they received training: several meetings before and during the intervention; peer observation of teachers i.e. two of them visited each other during their physics lessons; an individual semi-structured interview with each teacher and a personal feedback on that interview; classroom observations with a focus on the teacher-student-interactions and a personal feedback on these observations. Interviews and classroom observations were also used for data collection.

Physics tests

At the end of each unit all students performed a 45 minute test each in optics and kinematics. The tests included 15-20 multiple-choice-questions and 3-5 short-answer-problems. They had been developed by one of the researchers together with four physics teachers who were not engaged in the intervention study. All questions and problems had been pre-tested in these teachers' classes.

Final survey

At the end of the intervention, all students and all teachers answered a student and a teacher questionnaire, respectively. The items of the student questionnaire included: the learning and teaching methods during the intervention; the integration of pre-existing knowledge; co-operation and communication in physics lessons; several questions concerning the teacher (e.g. his/her ability to explain something, student's satisfaction with the teacher, discrimination of individual students) and student's expectations with regard to future physics instruction, i.e. after the intervention. For example, the last scale, 'expectations', is based on 5 items: 'Physics instruction will be fun for me'; 'I'll be good in physics'; 'physics instruction will be interesting for me'; 'physics instruction will be easy for me' and 'I will understand, what is going on in physics instruction'. The four answer categories are from 1 (do not agree) to 4 (agree). The reliability of the scale is characterized by a Cronbach-Alpha of 0.87. Like this scale also all other scales in the final survey are based on several items and checked by reliability analyses (Herzog *et al*. 1997b/c). Additionally, some scales of the entrance survey were used in the final survey too.

The analyses of the final survey only included the data from 26 of the 31 classes (see table 4). Three classes have been excluded because they were single-sex classes. Two other classes were excluded because the instruction had not fulfilled all conditions of the research project, e.g. other contents than the prescribed one had been taught. The teacher questionnaire of the final survey included questions and scales of different topics: the physics content; the teaching methods and strategies used during the intervention; the value of the teaching and learning materials; the value of the training and the attitudes towards girls, boys and gender issues.

All data have been processed by means of the standard software SAS 6.12. Items, scales, reliability analyses, results of descriptive analyses, procedures and results of multivariate analyses are described in detail in two appendices of the final research report (Herzog *et al*. 1997b/c).

Criteria and strategies for a gender-balanced physics instruction

Our criteria for the development of the learning and teaching materials are based on previous projects and on the literature as mentioned in the Introduction. All criteria were summarized in a checklist, which was used by the teachers of experimental group 1, when they developed the learning and teaching materials. The criteria include:

- *Contents and context* of physics instruction have to be relevant for males and females. This was one of the reasons for optics being chosen as the first unit in physics instruction, and that in both units the everyday world of boys and girls became a main basis for the instruction.
- *Individual preconceptions and experiences* of girls and boys should be integrated in the texts, so far as they are known and common, or/and students are explicitly asked to tell their own experiences and ideas. During the lessons students get the opportunity to make up for unknown experiences. Relations and differences between everyday language and physics language are emphasized and discussed.
- *Active and interactive learning environments* have to be created whenever possible: e.g. hands-on-activities; little 'research-projects'; group-discussions; presentations of students and writing essays or designing posters.

Teaching methods are favoured that enhance co-operation and communication between student-student and teacher-student.
- *Texts and figures* should be non-sexist and gender-balanced.

The teaching strategies that should be employed during physics instruction were discussed in detail and developed in collaboration with the teachers of experimental groups I and II. The strategies were summarized in another checklist. The teachers of group III and the control group had at no time access to this list, i.e. only the teachers of group I and II were asked to apply the following strategies in their physics classes:

- *Interaction and feedback:* 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:* praise girls not only for their diligence and discipline but also for their ability and talent in physics, avoid any impression that physics is only something for highly gifted people or men, emphasize that girls are neither less 'attractive', nor less 'female', when they are interested in and good at physics.
- *Contents of physics instruction:* 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:* arrange conversations and discussions as often as possible; form single-sex groups for group-discussions and practicals; support co-operation and suppress open competition and make your physics classroom more comfortable.

Results and discussion 1: entrance survey

Some of the main results of the entrance survey are shown in table 2, the mean values of nine different scales are separately given for girls (n = 384) and boys (n = 193):

Experiences, activities and domain specific interests: The results are based on scales and items with a rating scale from 1 to 5, i.e. from no experiences (activities, interests) to many. As seen in table 2 significant differences between the girls and boys of our sample exist in their experiences in technologies, in their media experiences in physics, in their activities and hobbies related to technology and household and in their interests in natural phenomena and technology. In comparison with the boys, the girls have less experience with and interest in physics and technology but more experience with household orientated activities and more interest in natural phenomena.

Cognitive ability: There are no significant differences between girls and boys in language comprehension and spatial ability, the mean values given in arbitrary units of sub-scales of standard I.Q. tests (Amthauer 1973) are the same for both genders (Herzog *et al*. 1997c: 27).

Self-confidence and general interest in physics: Further data of the entrance survey indicate that the girls of our sample show significantly less self-confidence

Table 2. Results of the entrance survey.

Scale	Mean values: Girls $n = 384$	Mean values: Boys $n = 193$	Level of significance
Media experiences in physics	1.7	2.2	***
Experiences in technology	1.5	2.0	***
Technology orientated activities	2.0	2.5	***
Household orientated activities	3.5	2.8	***
Interests in natural phenomena	4.1	3.6	***
Interests in technology	2.6	3.1	***
I.Q.: language comprehension	10.8	11.0	n.s.
I.Q.: cubes and spatial ability	11.4	11.6	n.s.
I.Q.: figures and spatial ability	11.1	11.5	n.s.

x: smaller sample; ***: $p<0.001$, **: $p<0.01$, n.s.: not significant

and interest in physics than the boys. Both genders associate physics with male connotations (Herzog *et al*. 1997a: 51-60).

Our results confirm that girls and boys - when beginning with their first physics course in the upper secondary level - show significant differences in their experiences, self-confidence and interest in physics, but have similar spatial and language abilities. The data support our assumption that gender differences in attitudes towards and achievements in physics are due to motivational problems but not to gender differences in gift or talent. The results also back up several of our teaching strategies and criteria for the development of the learning materials, e.g. consideration and integration of the different individual preconceptions, relevance of the physics contents for males and females, working on students' self-concept related to physics.

Furthermore our data confirm many of the results of the studies quoted in the Introduction, i.e. also those studies, carried out in other western countries and/or at other school levels (lower secondary; college), show similar sex-differences in attitude, interest and achievement.

Results and discussion 2: final survey and physics tests

Sensitization of physics teachers

'How can physics teachers become more sensitive towards gender issues and what circumstances can contribute to an appropriate change in their attitudes and classroom practices?', is our first research question stated in the Introduction.

Sensitivity for gender issues: In the teacher questionnaire of the final survey all teachers of the experimental groups I-III agree - many of them agree strongly - that they have become more sensitive and that they have got new ideas from the teaching and learning materials. They state that the project as a whole has been valuable for them. The teachers of the experimental groups I and II emphasize the value of the training. The answers indicate that each measure of the training has its specific value: In the meetings before and during the intervention, teachers learnt many facts about specific gender problems in physics instruction; the classroom observations and the peer observations made them sensitive for gender specific interactions and the interview yielded a general personal profit concerning gender issues and helped them to think about their own teaching style.

Transfer to classroom practice: Did the teaching materials and the training have an effect on the classroom practice of the teachers? The data of the two physics tests and in particular of the students' answers in the final questionnaire yield the following results:

- All teachers of the three experimental groups have taught the physics contents of the two units, 'geometrical optics' and 'kinematics', including girl friendly topics that were new or uncommon to them.
- Almost all teachers applied specific teaching methods that had been suggested in the teaching materials, like hands-on activities, project-learning, and presentations of students. The teachers of the three experimental groups applied these methods significantly more than the teachers of the control group.
- On the other hand, specific strategies were not applied as much as expected and hoped for, e.g. integration of individual preconceptions, more co-operation and communication. There are almost no significant differences between the data of the three experimental groups and the control group.

Influence on students' attitudes and achievements: The data of our four groups show almost no significant differences between the groups, as it had been expected. The classes of the experimental groups I and II do not perform better in the physics tests and do not show more positive attitudes towards physics than the classes of the experimental group III and even of the control group. There can be several reasons for this: The distribution of the 25 teachers into the four groups was not by chance, but by preferences of the individual teachers. Perhaps the teachers, who have voluntarily agreed to be part of the control group, are not representative, because they teach already in a girl friendly manner. Perhaps not all teachers of experimental groups I and II applied the criteria and strategies sufficiently. The only small differences between the four experimental groups was the reason that we made a further analysis based on an *a posteriori* categorization as described below.

Our interpretation of all the data above is that physics teachers can become more sensitive to gender issues by a project like this one: The teachers argue that discussions with researchers and colleagues, peer observations, classroom observations and individual feed-back can contribute to their sensitivity; each of these measures has specific value. We assume that this sensitivity is a necessary but not sufficient condition for any changes in classroom practices.

New units and teaching materials that are developed by physics teachers in collaboration with science educators, can support a change in physics instruction: There is a good chance that new ideas concerning physics contents and teaching methods will be applied in daily instruction. However, we assume that it needs more time and more training - as it has been the case in our project - to introduce specific strategies. The differences between the various groups of the research project are small or even non existent. From our results we do not know in detail, to what extent the training of the teachers of the experimental groups I and II has promoted the application of specific strategies. In the interviews, many teachers state that they do not know enough suitable techniques and specific examples to be able to implement strategies like that to integrate and evaluate students' preconceptions, to analyse differences and similarities between the mother tongue and physics language and to enhance communication and co-operation between students.

Strategies for physics instruction

'What are criteria and strategies for physics instruction suitable for both genders; how do these strategies influence students' attitudes toward and achievements in physics?' Regarding this research question, table 3 summarizes several results of

Table 3. Correlations between teaching strategies, competence of the teacher, characteristics of the parents, out-of-school activities and students' expectations and achievements in physics.

	Expectations of the students at the end of the intervention	*Achievements of the students at the end of the intervention*
Teaching strategies:		
Individual learning process		
Integration of preconceptions	0.45***	0.17***
Physics as an experience	0.37***	0.10*
Student-orientation	0.34***	0.01
Physics contents		
Everyday physics	0.15***	– 0.02
Physics and society	0.12**	– 0.06
Teaching methods		
Co-operation between students	0.14**	0.09
Discussion among students	0.22***	0.00
Hands-on activities	0.10*	0.06
Demonstrations	0.10*	0.01
Lectures	– 0.10*	– 0.10*
Teacher		
Ability to explain something	0.49***	0.10*
Contentment with teacher	0.45***	0.12**
Discrimination of individual students	– 0.27***	– 0.10*
Authoritarian leadership	– 0.28***	– 0.09
Parents		
Physics knowledge of father	0.23***	0.01
Physics knowledge of mother	0.32***	0.01
Importance of physics as seen by parents	0.38***	0.12**
Expectation of own child's ability in physics	0.56***	0.34***
Experiences, activities, interests[1]		
Media experiences in physics	0.25***	0.13**
Experiences in technology	0.14***	0.06
Technology orientated activities	0.12**	0.03
Household orientated activities	– 0.09*	– 0.14**
Interests in natural phenomena	– 0.05	– 0.10*
Interests in technology	0.25***	0.07

[1] Experiences, activities and interests have been measured in the entrance survey
***: $p<0.001$, **: $p<0.01$ *: $p<0.05$

our analyses of the final survey and of the two physics tests. These results originate from the individual data of all students in our sample, the four different groups of the research design are no longer distinguished. All data are based on scales except for the teaching methods and the parents, where we use single items. The 'expectations of the students at the end of the intervention' are identical to the scale given above in the chapter 'methods and data sources', the 'achievements of the students at the end of the intervention' are measured by the sum of the outcomes of the two physics tests in optics and kinematics (Herzog *et al*. 1997a/c).

We interpret and summarize four main results of the correlation analyses presented in table 3:

1. *High correlation with students' expectations*: There are several significant correlations between teaching strategies, teachers' and parents' characteristics and the expectations concerning the future physics instruction. The results confirm that many of our teaching strategies and many of our criteria for the development of the teaching and learning materials are appropriate. In particular the integration of preconceptions, the student-orientation and physics as an experience seem to be highly useful. Also the contents of physics instruction, i.e. everyday physics and relations to our society and communication and co-operation between students are important as well. The teacher plays a key role, his or her ability to explain something and the kind of leadership are main factors influencing students' expectations. Our teaching strategies, entitled 'interaction and feedback', 'self-concept of girls' and 'atmosphere and methods of learning' are confirmed.
2. *Low correlation with students' achievements:* There are only a few weak correlations with students' performance in the physics tests. The only criteria and strategies that are supported by significantly positive correlation coefficients are the integration of preconceptions and physics as an experience. All the other criteria and strategies do not show any significant correlation, but also no negative correlation. Therefore, a more positive interpretation of the data is that students learn as much physics in a course in which the teacher applies girl friendly criteria and strategies, as in a traditional course.
3. *The important role of the parents:* Factors other than teaching strategies and the competence of the teacher are decisive as well, e.g. parents, experiences in technology and physics from everyday life. Although it was not an aim of this research project to investigate all the different factors, we analysed at least the part of the parents. In addition to the teacher, they play a key role in influencing students' expectations and to a lesser degree their achievements. In particular their attitudes toward physics and their expectations of their own child's ability in physics are crucial.
4. *Factors explaining the expectations:* Based on our data of the final and the entrance survey we developed a model that could explain students' expectations. It is described in detail elsewhere (Herzog *et al*. 1997a: 154–159). The model, that is based both on theoretical assumptions and on LISREL VII analyses, indicates that four factors can be extracted, which mainly explain students' expectations: the integration of preconceptions, the satisfaction with the physics teacher, the parents' attitudes toward physics and

the motivation of the student in physics at the beginning of the physics course (which has been measured in the entrance survey). Most other factors can be reduced to these four, e.g. co-operation in groups is not a strategy *per se* for a girl friendly physics instruction but only if the group work helps communicating and eliciting preconceptions.

The analyses above are on the micro-level of the individual students. In order to test our criteria and strategies on the level of the classes we performed a further analysis whereby all classes, independent of which group of the research design they belong, were re-categorized *a posteriori*. This categorization is based on students' judgements about the physics instruction. We used 13 criteria, ten scales and three items that can be seen as an operationalization of our strategies. The 13 criteria include e.g. integration of preconceptions, everyday physics, co-operation between students, student-orientation, discussions and hands-on-activities. If a criterion's mean value of a class is *above* the mean value of all classes, the criterion is interpreted as fulfilled. Depending on the number of fulfilled criteria the classes are re-categorized into four groups that we call 'criteria groups 1-4'. The classes of group 4 fulfil 9.2 criteria on average i.e. the instruction is very girl friendly; the classes of group 1 fulfil only 3.3 criteria on average i.e. the instruction is not girl friendly. In table 4, several mean values of the four criteria groups are presented: achievements in the physics tests; expectations with regard to the future physics instruction; teaching strategies and characterization of the teacher.

With regard to our criteria and strategies for a physics instruction, that should be more suitable for girls, we take four results from table 4:

(1) *Validation of criteria:* The 13 criteria and the four *a posteriori* categories based on these criteria prove to be useful. In general, there is an increase (or decrease) of the mean values from group 1 to 4. Two examples: Everyday physics is taught significantly more in group 4 than in groups 3, 2 or 1, there is a continual decrease from group 4 to 1: 2.88 - 2.77 - 2.55 - 2.30. The discrimination of individual students is less in group 4 than in all other groups, the mean value of group 4 is 1.59, the values of the other groups are 1.95, 1.86 and 2.01.

(2) *Expectations:* The students of criteria group 4 show significantly better results than all other groups. For both genders, there is an almost continuous improvement from group 1 to 4. A physics instruction, in which several of the mentioned criteria and strategies are applied, is correlated to higher expectations with regard to the physics instruction in the future.

(3) *Achievements:* Taking the data of girls and boys together, the students of groups 3 and 4 show significantly better results than their colleagues of groups 1 and 2. But analysing the data of girls and boys separately, one can see a continuous improvement from group 1 to 4 for the boys, but not for the girls. They perform in groups 2, 3, and 4 almost the same.

(4) *Gender differences:* There are still gender specific differences. In all groups, the boys show higher expectations and better achievements than the girls. This holds also for the most girl friendly group, number 4. The applied strategies seem to improve the expectations and achievements of girls and boys as well. Therefore the gender differences that are noted at the beginning of physics instruction in the upper secondary level still exist after the intervention.

Table 4. Teaching strategies (individual learning process, physics contents, teaching methods), expectations and achievements of the four criteria groups 1-4.

	Criteria Group 1 n = 123 6 classes	*Criteria Group 2 n = 113 6 classes*	*Criteria Group 3 n = 99 5 classes*	*Criteria Group 4 n = 175 9 classes*	*Significance*
Expectations and achievements					
Girls' expectations	2.09	2.08	2.24	2.50	***
Boys' expectations	2.38	2.22	2.48	2.82	***
Girls' achievements	77.6	86.6	86.4	84.7	***
Boys' achievements	80.2	86.7	97.9	100.7	***
Teaching strategies:					
Individual learning process					
Integration of preconceptions	3.12	3.00	3.21	3.47	***
Physics as an experience	2.29	2.18	2.43	2.56	***
Student-orientation	2.29	2.12	2.48	2.61	***
Physics contents					
Everyday physics	2.30	2.55	2.77	2.88	***
Physics and society	3.13	2.89	2.76	2.90	***
Teaching methods					
Co-operation between students	2.10	2.28	2.35	2.32	**
Discussion among students and hands-on activities	2.54	2.58	2.62	2.62	n.s.
Lectures, demonstrations and question-answer-method	3.67	3.63	3.63	3.62	n.s.
Teacher					
Ability to explain something	2.08	2.22	2.47	3.06	***
Satisfaction with teacher	2.22	2.42	2.58	3.18	***
Discrimination of individual students	2.01	1.86	1.95	1.59	***
Authoritarian leadership	2.39	2.52	2.39	2.09	***

***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, n.s.: not significant

Conclusions

In this research project, we discussed and evaluated several strategies that should be effective for girls. Our results indicate that especially the *girls' attitudes* i.e. the expectations concerning physics instruction in the future can be improved by a collection of strategies. Most effective prove to be the integration of individual preconceptions, student-orientation (in particular the co-operation between teacher and students), physics as an experience, discussions among students and everyday physics. These results are confirmed in another research project that one of us has performed within the Swiss part of the 'Third International Science and Mathematics Study' (Labudde and Pfluger in press).

Girls' achievements in physics, as tested in conventional tests like ours, can be increased by some of the strategies, especially by the integration of girls' preconceptions. But the improvement of the achievements is definitely less than that of the students' expectations with regard to the future physics instruction. It remains an open question whether the achievements of girls and boys could have been changed by a longer intervention. The applied strategies improve not only the girls' but also the boys' achievements in and attitudes toward physics. The evaluated kind of physics instruction is effective for both genders. Therefore, the gender differences that can be seen at the beginning of physics instruction in the upper secondary level, remain rather the same after our intervention project. Presumably it needs further strategies in addition to ours to improve not only students' achievements and attitudes but to reduce the gender differences, too.

Our results clearly confirm that the physics teachers play a key role in improving girls' (and boys') attitudes and achievements. It is he or she who has to implement the strategies; it is his or her social competence that affects the co-operation with the students and it is his or her ability to explain something. From the data of the students' questionnaires and physics tests, we cannot analyse how far the training has changed teachers' attitudes and instruction. But there are several hints in the data of the teacher questionnaires and interviews that at least their knowledge about and their sensitivity towards gender issues have increased. Each part of the training i.e. meetings and discussions, development of teaching materials, classroom observations and feedback by peers and researchers, interviews with researchers, seem to have their specific value.

Physics instruction is embedded in a much broader frame. One might ask, whether teachers and schools alone, particularly at the upper secondary level, are able to overcome the gender specific outcomes of physics instruction. For example, our results show that parents' attitudes toward physics and their expectations of own child's ability in physics are significantly correlated with children's attitudes and achievements in physics. The improvement of teaching and learning physics is only one part of a larger 'gender jig-saw puzzle' that includes many different parts of school, family and society. To investigate these different parts and factors and their influences on physics instruction remains an important research question. It needs more intervention studies to examine strategies in the classroom, in the school, in the family and in teacher education for a more gender-balanced physics instruction.

Acknowledgements

The co-operation and the engagement of the physics teachers and their students are gratefully acknowledged. The work has been supported by the Swiss National Science Foundation, Grant No. 4035-039811.

References

AMTHAUER, R. (1973) *Intelligenz-Struktur-Test (IST70)* (Göttingen: Hogrefe).

BAUMERT, J. and LEHMANN, R. (1997) *TIMSS - Mathematisch-naturwissenschaftlicher Unterricht im Vergleich* (Opladen: Leske and Budrich).

BEATON, A. E., MARTIN, M. O., MULLIS, I., GONZALEZ, E. J., SMITH, T. A. and KELLY, D. L. (1996) *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS)* (Chestnut Hill, MA: TIMSS International Study Centre, Boston College).

BLK-MODELLVERSUCH RHEINLAND-PFALZ (1993) *Mädchen und Jungen in der Schule: Kompetenzen entwickeln - die eigene Rolle finden* (Koblenz, Germany: Ministerium für Bildung und Kultur).

BROPHY, J. (1985) Interactions of Male and Female Students with Male and Female Teachers. In L. Wilkinson and C. B. Marrott (eds) *Gender Influences in Classroom Interaction* (Orlando: Academic Press), 115-142.

BYRNE, E. M. (1993) *Women and Science: The Snark Syndrom* (London: Falmer).

ECCLES, J. S. and JACOBS, J. E. (1986) Social forces shape math attitudes and performance. *Signs: Journal of Women in Culture and Society*, 11, 367-380.

ENDERS-DRÄGESSER, U. and FUCHS, C. (1989) *Interaktionen der Geschlechter. Sexismusstrukturen in der Schule* (Weinheim: Juventa).

GERBER, C. (1998) *Methodisch-didaktische und interaktionelle Aspekte des koedukativen Physikunterrichts* (Dissertation, Universitaet Bern).

GREENFIELD, T. A. (1995) An exploration of gender participation patterns in science competitions. *Journal of Reserach in Science Teaching*, 32, 735-748.

GUZZETTI, B. J. and WILLIAMS, W. O. (1996) Gender, text, and discussion: examining intellectual safety in the science classroom. *Journal of Research in Science Teaching*, 33, 5-20.

HAGGERTY, S. M. (1995) Gender and teacher development: issues of power and culture. *International Journal of Science Education*, 17, 1-15.

HARDING, J. and PARKER, L. H. (1995) Agents for change: policy and practice towards a more gender-inclusive science education. *International Journal of Science Education*, 17, 537-553.

HARMON, M., SMITH, T. A., MARTIN, M. O., KELLY, D. L., BEATON, A. E., MULLIS, I. V., GONZALES, E. J. and ORPWOOD, G. (1997) *Performance Assessment in IEA's Third International Mathematics and Science Study* (Chestnut Hill, MA: TIMSS International Study Centre, Boston College).

HÄUSSLER, P. (1987) Measuring students' interest in physics - design and results of a cross-sectional study in the FRG. *European Journal of Science Education*, 9, 79-92.

HÄUSSLER, P., HOFFMANN, L., LANGEHEINE, R., ROST, J. and SIEVERS, K. (1998) A typology of students' interest in physics and the distribution of gender and age within each type. *International Journal of Science Education*, 20, 223-238.

HERZOG, W. (1994) Von der Koedukation zur Koinstruktion. *Die Deutsche Schule*, 86: 78-95.

HERZOG, W. (1996) Motivation und Naturwissenschaftliche Bildung - Kriterien eines 'mädchengerechten' koedukativen Unterrichts. *Neue Sammlung*, 36, 61-91.

HERZOG, W., LABUDDE, P., NEUENSCHWANDER, M., P. VIOLI, E. and GERBER, C. (1997a) *Koedukation im Physikunterricht - Schlussbericht zuhanden des Schweizerischen Nationalfonds zur Förderung der wissenschaftlichen Forschung* (Universität Bern: Abteilung Pädagogische Psychologie, Abteilung für das Höhere Lehramt).

HERZOG, W., LABUDDE, P., NEUENSCHWANDER, M. P., VIOLI, E. and GERBER, C. (1997b) *Koedukation im Physikunterricht - Erhebungsinstrumente (Forschungsbericht 13)* (Universität Bern: Abteilung Pädagogische Psychologie).

HERZOG, W., LABUDDE, P., NEUENSCHWANDER, M. P., VIOLI, E., GERBER, C. and BÄRTSCHI, S. (1997c) *Koedukation im Physikunterricht - Entwicklung und Analyse der Erhebungsinstrumente (Forschungsbericht 14)* (Universität Bern: Abteilung Pädagogische Psychologie).

HOFFMANN, L., HÄUSSLER, P. and PETERS-HAFT, S. (1997) *An den Interessen von Mädchen und Jungen orientierter Physikunterricht* (Kiel: Institut für die Pädagogik der Naturwissenschaften).

JOHNSON, S. (1987) Gender differences in science: parallels in interest, experience and performance. *International Journal of Science Education*, 9, 467-481.

KAHLE, J. B. (1988) Gender and Science Education II. In P. Fensham (ed.) *Development and Dilemmas in Science Education* (London: Falmer), 249-265.

KELLER, C. (1997) Geschlechterdifferenzen: Trägt die Schule dazu bei? In U. Moser, E. Ramseier, C. Keller, and M. Huber (eds) *Schule auf dem Prüfstand - Eine Evaluation der Sekundarstufe I auf der Grundlage der 'TIMSS'* (Chur, Zürich: Rüegger), 137-179.

KELLY, A. (1988) Sex stereotypes and school science. A three year follow-up. *Educational Studies*, 14, 151-163.

KENWAY, J. and WILLIS, S. (1990) *Hearts and Minds: Self-esteem and the Schooling of Girls* (London: Falmer).

LABUDDE, P. (1993) *Erlebniswelt Physik* (Bonn: Dümmler).
LABUDDE, P. (1996) *Alltagsphysik in Schülerversuchen*, 3rd edn. (Bonn: Dümmler).
LABUDDE, P. (1997a) Selbstständig lernen - eine Chance für den Physikunterricht. *Naturwissenschaften im Unterricht-Physik*, 37, 4-9.
LABUDDE, P. (1997b) Physiklernen als Sprachlernen: Wie in der Wissenschaft so im Unterricht. In H. E. Fischer (ed.) *Handlungsorientierter Physik-Unterricht Sekundarstufe II* (Bonn: Dümmler), 56-80.
LABUDDE, P. (1999) Mädchen und Jungen auf dem Wege zur Physik. *Naturwissenschaften im Unterricht-Physik,* 49, 4-10.
LABUDDE, P. and PFLUGER, D. (in press) Physikunterricht in der Sekundarstufe II - eine Empirische Analyse der Lern-Lehr-Kultur und ihrer Wirkungen. *Zeitschrift für Didaktik der Naturwissenschaften,* 1999/2.
MULLIS, I. V., MARTIN, M., BEATON, A., GONZALEZ, E., KELLY, D. and SMITH, T. (1998) *Mathematics and Science Achievement in the Final Year of Secondary School. IEA's Third International Mathematics and Science Study* (Chestnut Hill, MA: TIMSS International Study Center, Boston College).
PARKER, L. H., RENNIE, L. J. and FRASER, B. J. (eds) (1996) *Gender, Science and Mathematics - Shortening the Shadow* (Dordrecht, Boston, London: Kluwer Academic).
PFUNDT, H. and DUIT, R. (1994) *Bibliography: Students' Alternative Frameworks and Science Education*, 4th edn. (Kiel: Institut für die Pädagogik der Naturwissenschaften).
RÄSÄNEN, L. (1992) Girls and the learning of physical concepts. *European Education,* 167-217.
ROYCHOUDHURY, A., TIPPINS, D. J. and NICHOLS, S. E. (1995) Gender-inclusive science teaching: a feminist-constructivist approach. *Journal of Research in Science Teaching*, 32, 897-924.
SJØBERG, S. and IMSEN, G. (1988) Gender and Science Education. In P. Fensham (ed.) *Development and Dilemmas in Science Education* (London: Falmer Press), 218-248.
SPEAR, G. M. (1985) Teachers' attitudes towards girls and technology. In J. Whyte, R. Deem, L. Kant and M. Cruickshank (eds) *Girl friendly schooling* (London: Methuen), 36-44.
UHLENBUSCH, L. (1992) *Mädchenfreundlicher Physikunterricht. Motivationen, Exempla, Reaktionen* (Frankfurt/M.: Lang).
WEINBURGH, M. (1995) Gender differences in student attitudes toward science: a meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching*, 32, 387-398.