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Gender-related effects of co-operative learning in a mathematics curriculum for 12–16-year-olds

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This project investigated an instructional model for middle school education in mathematics: the AGO model. Earlier research revealed significant differences in learning outcomes for students following a programme designed according to the AGO model in comparison with learners following a more traditional (individual) form of mathematics education. The research question is: What are the differential effects for boys and girls of co-operative learning in mathematics? The AGO curriculum does improve the mathematical achievement of girls compared with more traditional (individual) methods of instruction. However, girls do not profit more from co-operative learning than boys. No interactions between gender and condition were found. The AGO model has only slight effects on the affective outcomes. There was a tendency towards lessened differences between boys and girls in comparison with the control condition. In a multi-level analysis differential effects of gender were found on two affective outcomes variables: Pleasure and Relevance of Mathematics. The learning environment variable Task-orientation perceived by the students plays a crucial role in the explanation of gender-level effects on Relevance of Mathematics. No gender-level effects on achievement in mathematics were found.

Background

Girls still leave secondary education with fewer opportunities for pursuing higher education or entering the job market (Bennet and LeCompte 1990, Sikes 1992). The issue of underrepresentation of girls in mathematics and science has received a great deal of attention (e.g. Brush 1985, Chipman and Wilson 1985, Eccles *et al.* 1985, Eccles *et al.* 1986). As well as focusing attention on gender differences in educational choices, researchers have also investigated gender differences in performance (e.g. Eccles 1987, Open University 1987). In a meta-analysis carried out on 100 investigations into gender differences in mathematics performance for widely varying groups

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of pupils and school types, Hyde *et al.* (1990) found that men in general perform slightly better than women in mathematics. There appeared to be no gender differences in problem solving in elementary school and middle school but boys did outperform girls in high school and college. Taken across the whole population, however, the differences are rather small. There is, however, cross-national variation in gender differences in mathematical performances. Hanna *et al.* (1990) compared achievement in mathematics for boys and girls in 15 different countries using data from the IEA Second International Mathematics Study. Although boys perform better on average than girls in practically every country, the differences are not always the same in size. Using the same data, Baker and Perkins Jones (1993) found that, although there is a clear pattern of national differences in gender effects on achievements, the absolute size of gender difference favours neither boys nor girls. A possible explanation for these different results may be age. In the study by Hanna *et al.* (1990) pupils in the last grade of secondary school were compared; in Baker and Perkins Jones's (1993) study the data were from 8th-grade mathematics.

Hanna *et al.* attribute the differences between countries to teacher gender, students' stereotypical attitudes towards gender, the degree to which students aspire to more education, gender-specific support from parents for their children's education, and the degree of parents' support. The last factor – the degree of parental support for their children's education – offered the only significant difference between the three countries with the largest and the smallest gender differences in learning outcomes.

Baker and Perkins Jones used a more explicitly sociological perspective to explain the gender differences they found: school and family factors leading to higher mathematical performance are less stratified by gender when women have more equal access to jobs and higher education.

The Netherlands is one of those countries in which there is a gender inequality in mathematics achievements in favour of boys (Ten Dam *et al.* 1992; see also Baker and Perkins Jones 1993). Moreover, comparatively few girls in the second stage of secondary education choose mathematics. In order to explain this inequality several studies have been carried out (see Volman *et al.* 1993). It was found that the gender of the teacher was less important than the teacher being aware of the problem. It could not be shown that girls receive less attention in the classroom than boys but it is evident that teachers do more often expect boys to achieve better results than girls (e.g. Kuyper and Van der Werf 1991). In other words, there does not seem to be an unequivocal answer to the extent to which the content of mathematics and science influences choices and achievement. A mathematics programme which was expected to have a positive effect on girls, because it put mathematics in an everyday context, resulted in not only more girls choosing mathematics but also more boys choosing mathematics. The difference between girls and boys in levels of achievement also did not seem to be reduced (e.g. Van der Werf 1988).

The results of the Dutch research carried out into the relationship between school characteristics and the choices and achievements of girls in mathematics and science can be summarized as follows: what is favourable to pupils' careers in general – involvement of the school principal in the style and content of the education provided, reasoned maintenance of discipline, a positive image of pupils' efforts, emphasis on both achievement and personal development – also proved to be effective in furthering the choices and achievement of girls in mathematics and science. Activities specifically aimed at the creation of equal opportunities, e.g. career counselling and personnel policy in schools, were found to have no effect (e.g. Dekkers 1985, Kristensen and Jenneskens 1990).

Internationally, many researchers have focused attention on the learning environment in order to explain gender inequality in educational choices and achievements – for example in research into the role of teachers (e.g. Rodgers and Mahon 1987, Fennema and Leder 1990), interactive processes in the classroom (e.g. Fennema and Leder 1990), the nature of the subject as a possible explanation of gender differences in performance (Hyde *et al.* 1990), and into the nature of examinations or test items (e.g. Marshall and Smith 1987, Domoney 1988). Relatively few studies focus on the *instructional* process. In schools, however, teachers have tried to develop approaches to mathematics instruction that are more suited to (the presumed) interests of girls and their ways of working. Group work occupies an important place in the projects undertaken (Burton 1990). In this article we explore the connection between gender inequality in mathematics and a curriculum design based on theories about co-operative learning.

Theoretical background

A relatively new development in research into gender and mathematics is the development and testing of intervention programmes which are supposed to have a positive effect on the achievement and attitudes of girls (Kelly 1987). In descriptions of innovative teaching practices girls' and women's appreciation of working in groups is often reported (e.g. Barnes and Coupland 1990, Marr and Helme 1990, Isaacson 1990, Rodgers 1990). Although group work as an instructional method appears to be promising, the effect of group work on the choices and achievement of girls in mathematics has rarely been tested empirically. The question is: To what extent does working in small groups contribute to a decrease in gender differences in achievement and attitudes towards mathematics?

In this paper we describe work on the gender-related learning effects of group work. We assume that group work positively influences achievement, in particular for female pupils, thus contributing to a decrease in gender differences. The justification for this assumption lies, first, in the fact that research in this area shows that women – in contrast with men – have little affinity with competitive and individual ways of working. Co-operative styles of working are more suitable for women, and it is precisely in small groups that there is room for co-operation (see also Burton 1987, Fennema and Peterson 1987, Open University 1987). Furthermore, group work offers more possibilities for mutual interaction. Interaction gives women the opportunity to use their verbal skills effectively (Maccoby and Jacklin 1974, Halpern 1992). In addition, research has shown that interaction in small groups is a facilitating factor in learning since it stimulates pupils and helps them clarify their ideas (Webb 1982). Group work can also improve pupils' self-confidence, which is of particular importance for female pupils (see Taylor 1990). As mentioned earlier, however, clear findings are lacking in this area, as are findings concerning the possible interrelationship between working in small groups and achievement and attitudes of boys and girls. This was the goal of the study to be reported here.

The AGO model

The AGO model (AGO is a Dutch acronym for 'Adaptive Instruction and Co-operative Learning') combines aspects of co-operative learning and adaptive instruction. The model is based on cognitive theories about co-operative learning (Freudenthal 1973a, b, Terwel 1986, 1990). The various instructional strategies are designed to develop higher-order thinking. The AGO model tries to create a balance between, on the one hand, basic skills and concepts developed through whole-class instruction and, on the other hand, problem solving developed by guided discovery in co-operative groups. In the model arrangements are made to adapt teaching to differences in aptitude between students. The AGO model is designed for the middle grades and consists of the following seven instructional stages:

- whole-class introduction of a mathematics topic;
- small-group co-operation in groups of four students;
- teachers' assessments: tests and observations;
- alternative learning paths depending on assessments. These paths result in two different modes of activity:
  (*a*) individual work with the possibility to consult other students;
  (*b*) opportunities to work in remedial groups under direct guidance and supervision of the teacher;
- individual work in heterogeneous groups with possibilities to help each other;
- whole-class reflection and evaluation of the topic;
- an achievement test and evaluation of individual progress in mathematics.

The AGO model has proved to be feasible in practice. Pupils who have worked with AGO materials show higher achievement than those who have never worked with AGO materials. To put it differently, group work has an accelerating effect on pupils' learning processes. No AGO effect was found for pupils' attitudes (Herfs *et al.* 1991). In this paper we will report a secondary analysis of an existing database to investigate whether teaching based on the AGO model leads to reduced gender differences in achievement and attitudes in the area of school mathematics.

Research questions

The general research question is: What are the (differential) effects on boys and girls of co-operative learning in a mathematics curriculum? From this general question we derive three specific questions:

(1) What are the effects of co-operative learning for girls? The literature on gender differences in mathematical achievement and on the characteristics of the AGO model lead us to the hypothesis that instruction according to the AGO model would have a positive effect on (cognitive and affective) learning outcomes of girls when compared with girls in a more traditional (individualistic) condition.

(2) In addition we will look for differential effects. Do girls benefit *more than* boys from co-operative learning in mathematics? To put it differently, is co-operative learning a strategy for reducing gender differences?

(3) Given a multi-level perspective the research problem can be refined further. From earlier research we know that the individual level as well as the class level are important in explaining differences in learning. We can ask whether or not 'social group gender' is a relevant level. Girls and boys within a class can be viewed as a subgroup of a special kind. In schools different attitudes and capabilities are ascribed to them. Moreover, teachers are inclined to treat girls and boys differently. Is there a relevant contribution of the gender group (level) to the learning in mathematics – in addition to the effects at the individual level and the class level? And if there are, how can these effects be explained?

Design

The data were obtained from six secondary schools, including the newly created 'integrated' schools and middle schools. The sample consisted of 289 boys and 283 girls distributed over 23 classes. The design is a quasi-experimental, pre-test – post-test design in which the effects of the AGO model are compared with a more traditional instruction method (mainly without group work). An existing Dutch mathematics curriculum (*Wiskunde Lijn*) was reconstructed in accord with the AGO model. The mathematical content and goals were identical in both conditions. The pre-test consisted of an aptitude test in mathematical reasoning. The post-test was a test in mathematical achievement.

In addition, questionnaires for affective variables were administered, based on the attitude scale for mathematics developed by Martinot *et al.* (1988). This scale consists of four subscales, measuring *Pleasure, Anxiety, Motivation* and *Relevance*. Pupils were asked to give their rating on a five-point scale. This scale had to be filled in twice, before and after the research period. At the end of the experimental period the pupils were given a questionnaire on their perceptions of the learning environment. In this paper we present only the analysis of the variable *Task-orientation* from the questionnaire.

Finally, in a questionnaire given after the research period, the teachers were asked to provide information about the amount of individual guidance they had given to each pupil.

All testing instruments proved to be reliable and valid. For a more detailed description of these instruments, as well as their psychometric characteristics, we refer to the original report (Herfs *et al.* 1991). Data were analysed by means of the SPSS analyses of variance program. For the multi-level analyses, the VARCL program (Longford 1988) was used.

Results: analysis of variance

Means and standard deviations for the whole sample are presented in table 1. One-way analysis of variance in the whole sample revealed no significant effects of gender in the cognitive domain (Aptitude and Achievement). However, in the affective domain all the differences between boys and girls were significant. Boys' attitude scores are higher than the scores for girls, before and after the experiment. All differences are small (eta-squared values between 2 and 7%). Guidance also shows a small but significant difference for gender: girls receive more guidance from the teacher than boys.

The descriptive statistics for the experimental group are presented in table 2. One-way analysis of variance between girls and boys in the experimental group leads to the same conclusions as in the whole sample: no significant differences in the cognitive domain were found in contrast with the small but significant differences in the affective domain. Girls received more guidance than boys.

The descriptive statistics for the control group are presented in table 3. In the control group, one-way analysis of variance leads to almost the same conclusions as for the whole sample and the experimental group: no significant differences in the cognitive domain were found. In addition, small but significant differences were found in the affective domain except for *Motivation* at the pre-test point. For Guidance no significant difference between boys and girls was found.

Cognitive results

Analysis of variance did not reveal any statistically significant difference between boys and girls in mathematical aptitude, nor did it show a significant difference between the conditions. We may therefore conclude that students in both conditions are comparable in aptitude at the beginning of the experiment and that this holds true for boys and girls.

For the post-test a factorial analysis of variance was carried out (ANCOVA, with the pre-test Aptitude score as a covariate and gender and condition as independent factors). This enables us to test effects of (*a*) condition, (*b*) gender, and (*c*) the interaction of condition and gender. The results are reported in table 4.

A significant effect for gender and for condition was found (respectively $F = 7{\cdot}39, p < 0{\cdot}05$ and $F = 52{\cdot}91, p < 0{\cdot}00$). Boys outperformed girls and AGO students scored higher on post-test achievement than students in the control condition. No interactions between gender and condition were found.

Table 1. Mean (SD) of the variable for boys ($n = 289$) and girls ($n = 283$).

Variable	Boys	Girls
Math aptitude1	53·02 (6·82)	54·10 (6·71)
Math achievement2	23·45 (9·12)	22·63 (9·18)
Pleasure1	3·42 (0·81)	3·02 (0·85)
Anxiety1	3·64 (0·67)	3·35 (0·74)
Motivation1	3·09 (0·61)	2·89 (0·68)
Relevance1	3·91 (0·58)	3·59 (0·56)
Pleasure2	3·37 (0·88)	2·96 (0·90)
Anxiety2	3·65 (0·67)	3·32 (0·72)
Motivation2	3·05 (0·70)	2·86 (0·68)
Relevance2	3·94 (0·63)	3·57 (0·65)
Guidance	2·95 (1·10)	2·87 (1·03)

Standard deviations are in parentheses.
1, Before experiment; and 2, after experiment.

Table 2. Mean (SD) of the variables, experimental group (n boys = 187, n girls = 194).

Variable	Boys	Girls
Math aptitude1	53·47 (7·00)	54·37 (6·71)
Math achievement2	25·56 (9·56)	24·27 (9·75)
Pleasure1	3·41 (0·84)	3·00 (0·85)
Anxiety1	3·62 (0·71)	3·31 (0·74)
Motivation1	3·03 (0·62)	2·82 (0·70)
Relevance1	3·87 (0·60)	3·54 (0·55)
Pleasure2	3·36 (0·90)	3·00 (0·88)
Anxiety2	3·67 (0·68)	3·32 (0·71)
Motivation2	3·00 (0·72)	2·83 (0·66)
Relevance2	3·91 (0·64)	3·56 (0·65)
Guidance	2·34 (1·07)	2·86 (1·04)

Standard deviations are in parentheses.
1, Before experiment; and 2, after experiment.

Table 3. Mean (SD) of the variables, control group (n boys = 102, n girls = 89).

Variable	Boys	Girls
Pre-test math	52·19 (6·44)	53·52 (6·72)
Post-test math	19·59 (6·76)	19·04 (6·53)
Pleasure1	3·45 (0·76)	3·06 (0·85)
Anxiety1	3·69 (0·60)	3·44 (0·73)
Motivation1	3·19 (0·59)	3·03 (0·60)
Relevance1	4·00 (0·54)	3·71 (0·55)
Pleasure2	3·39 (0·85)	2·86 (0·92)
Anxiety2	3·62 (0·65)	3·33 (0·75)
Motivation2	3·14 (0·67)	2·92 (0·72)
Relevance2	3·98 (0·62)	3·58 (0·65)
Guidance	3·04 (0·99)	2·89 (0·99)

Standard deviations are in parenthesis.
1, Before experiment; and 2, after experiment.

Table 4. Analysis of variance: achievement in mathematics by gender and condition as independent factors with aptitude as covariate ($n = 575$).

Source of variation	Sum of squares	DF	Mean square	F	Significance of F
Covariates:					
Aptitude	11966·980	1	11966·980	208·742	0·000*
Main effects:	3381·727	2	1690·864	29·494	0·000
Gender	423·349	1	423·349	7·385	0·007*
Condition	3033·007	1	3033·007	52·905	0·000*
Two-way interactions					
Gender × condition	6·670	1	6·670	0·118	0·731ns
Explained	15355·467	4	3838·867	66·692	0·000
Residual	32505·527	567	57·329		
Total	47860·993	571	83·820		

* Significant $< 0·05$.

We cannot conclude, therefore, that there are differential effects of co-operative learning for boys and girls.

Girls do, however, benefit from co-operative learning and adaptive instruction. Girls who followed the AGO model scored higher, on average, than the girls who participated in the more traditional form of mathematics instruction. The mean score on the post-test achievement of the girls in the experimental group is 24·3, for the girls in the control group it is 19·0 (tables 2 and 3). A t-test showed that this difference is significant ($t = 4·60$, $p < 0·01$). A similar result was found for boys. When we compared the girls in the AGO condition with the boys in the control condition, a significant difference was found in favour of the girls ($t = 4·33$, $p < 0·01$).

Affective results

Some well-known empirical findings were reconfirmed with regard to the affective variables. In respect of the affective variables at the beginning of the experiment, an analysis of variance with gender and condition as independent factors revealed that boys do have less Anxiety for mathematics than girls ($F = 24·25$, $p < 0·001$). No significant effects of condition or of interaction between gender and condition were found. A similar pattern was found for Pleasure. Boys have more Pleasure in mathematics than girls ($F = 32·68$, $p < 0·001$) at the pre-test. No significant effects of condition or of interaction between gender and condition were found. Gender differences were also found on the variable Motivation. At the pre-test boys showed more Motivation towards mathematics than girls ($F = 12·58$, $p < 0·001$). In respect of this variable we found an effect of condition; the subjects in the control condition showed more Motivation towards mathematics than the subjects in the AGO condition ($F = 10·25$, $p < 0·01$). The interaction between gender and condition was not statistically significant.

Finally, boys considered mathematics to have more Relevance than girls at the pre-test ($F = 43·68$, $p < 0·001$). Subjects in the control condition saw mathematics as having more Relevance than the subjects in the AGO condition ($F = 9{\cdot}18$, $p < 0{\cdot}01$). However, no significant interaction effect between gender and condition was found.

For the post-test measures we performed analyses of covariance (ANCOVA), with the corresponding pre-test measure as covariate and gender and condition as independent factors. An ANCOVA for Pleasure, with gender and condition as independent factors, did not reveal any significant differences or a significant interaction effect.

A significant effect was found ($F = 6{\cdot}76$, $p = 0{\cdot}01$) for the variable Anxiety. Boys still had less Anxiety for mathematics than girls. Neither a significant effect of condition nor a significant interaction was found. We did not detect any significant differences on the variable Motivation.

For the variable Relevance there was a significant effect of gender ($F = 13{\cdot}57$, $p < 0{\cdot}001$). Boys still regarded mathematics as having more Relevance than girls. No significant effect of condition was found nor was the interaction between gender and condition significant.

When the girls were compared separately, no statistically significant differences could be detected on these affective measures between the AGO condition and the control condition. Apparently, education according to the AGO model does not lead to a change in girls' attitudes towards mathematics.

Finally, teachers in the AGO condition were inclined to guide girls more than boys. In the control group we saw no difference in guidance between the sexes. Table 5 summarizes *F*'s, as found by AN(C)OVAs for the learning measures, the affective variables and the amount of guidance.

Following Hyde's (1981) recommendations, we computed the effect size, *d*, for all our variables. This measure is appropriate for analysing the magnitude of the differences.[1] In table 6 the *d*'s for the whole sample are presented, and in tables 7 and 8 the *d*'s for the separate conditions are given.

A magnitude of $d = 0{\cdot}16$ was found for the initial difference between boys and girls in mathematical Aptitude in favour of the girls. The difference between boys and girls in achievement after the experiment is also small, $d = 0{\cdot}09$, reflecting an even smaller gender difference, but this time it is in favour of the boys. We may conclude that in the whole sample boys outperformed girls in achievement (see also the conclusion from the analysis of covariance in table 4). For the separate conditions we found the same tendency in the achievement scores for boys and girls (tables 2 and 3). The AGO treatment does not have the effect of reducing the differences between boys and girls in the cognitive domain. Boys and girls both profit from AGO but boys seem to gain more than girls.

On the variable Pleasure, in the pre-test as well as in the post-test, we found near-medium effects. On Anxiety we found a medium effect in the post-test and a small effect in the pre-test. On Motivation we found small effects in the pre-test as well as in the post-test. On Relevance we found medium effects in the pre-test as well as in the post-test. A small effect for guidance was also found. The effect sizes remained quite stable. It is striking, however, that within the AGO condition, with the exception of Anxiety, the effect sizes of the affective variables decrease while in the control condition the effect sizes increase.

Table 5. *F*'s from the An(c)ovas, with regard to gender differences.

Variable	Before	After
Mathematics	3·40*	7·39**
Pleasure	32·68***	2·88**
Anxiety	24·25***	6·76**
Motivation	12·58***	1·91
Relevance	43·68***	13·57***
Guidance		13·41**

$*p < 0{\cdot}10$; $**p < 0{\cdot}05$; $***p < 0{\cdot}01$.

Table 6. Effect-sizes, expressed as *d*'s (whole sample, $n = 572$).

Variable	Pre-test	Post-test
Mathematics	0·16	0·09
Pleasure	0·48	0·46
Anxiety	0·41	0·47
Motivation	0·31	0·27
Relevance	0·56	0·58
Guidance		0·25

Table 7. Effect-sizes expressed as *d*'s for AGO condition (*n* boys = 187, *n* girls = 194).

Variable	Before	After
Mathematics	0·13	0·13
Pleasure	0·48	0·40
Anxiety	0·42	0·50
Motivation	0·32	0·25
Relevance	0·57	0·49
Guidance		0·49

Table 8. Effect-sizes expressed as *d*'s for the control condition (*n* boys = 102, *n* girls = 89).

Variable	Before	After
Mathematics	0·20	0·08
Pleasure	0·48	0·60
Anxiety	0·37	0·41
Motivation	0·27	0·31
Relevance	0·48	0·62
Guidance		0·15

Multi-level analysis: perspective and results

In the database each class has been decomposed into the two gender levels, boys and girls. These gender levels play a crucial role in the multi-level analysis, due to the guiding notion that gender groups are relevant in teaching and learning mathematics. Moreover, we presume that gender differences can take different forms, depending on the educational environment. Before presenting the results of the multi-level analysis we shall discuss this view of 'gender' in educational practice.

In most research on gender differences in education gender is perceived as a more or less definitive characteristic of pupils. Although gender differences are viewed as the result of pre-school socialization processes and current social relationships, such as the gendered division of labour, in general researchers assume that gender has developed its special significance by the time pupils enter school. The origins of 'femininity' and 'masculinity' are ascribed to processes on an individual level, whether or not these events are situated in a larger social context. This approach views education as the context in which female students act, rather than seeing schooling as a socializing institution (Volman *et al.* 1993).

During the second half of the 1980s, however, a new development in the approach to gender differences and inequality in education took place. It was suggested, especially in constructivist quarters, that education should not be conceptualized as an institution where gender inequality is reproduced and pre-school socialization is maintained. Rather, schooling is one of the producers of gender inequality. Here gender is not interpreted first and foremost as a characteristic of individual pupils or teachers with the same meaning inside and outside the school. It is assumed that gender differences are (partly) dependent on the school context, such as the type of school or a particular class (Ten Dam and Volman 1991). Thus, in this second approach the achievement and attitudes of girls and boys in mathematics are induced from the organization of the curriculum or the instructional style of the teacher. Central to this notion of 'gender as a social construction' is the idea that students are offered different identities in schools. In our society these school identities are almost always gender-specific. Walkerdine (1989), for example, shows how achievement in mathematics for girls ultimately always turns out to be lower than that for boys. The teachers she spoke to interpreted the achievement of girls in terms of hard work and following rules, whereas creativity and insight were accredited to boys.

To sum up, from the perspective elaborated above, we assume that (a) education is not gender-neutral, (b) different attitudes and capabilities are attributed to girls and boys in schools (e.g. by teachers or pupils), and (c) within the same formal curriculum (in our case the AGO model) girls and boys as part of distinguished gender groups experience different environments (treatments). It is self-evident that this reading of possible gender effect goes further than the view of gender as a mere statistical group, comparable to whether or not pupils wear sneakers.

Multi-level analysis is a research method which makes it possible to decompose the total variance in a sample into components at three levels: the individual level, the gender-group level and the class level. At each level

Table 9. Descriptives of the variables for the multi-level analysis ($n = 572$).

Variable	Mean	SD	Minimum	Maximum
Achievement	23·04	9·16	1·00	43·00
Aptitude	53·55	6·78	32·00	76·00
Pleasure1	3·23	0·85	1·00	5·00
Anxiety1	3·50	0·72	1·00	5·00
Motivation1	2·99	0·65	1·00	4·63
Relevance1	3·76	0·59	1·00	5·00
Pleasure2	3·17	0·91	1·00	5·00
Anxiety2	3·49	0·71	1·00	5·00
Motivation2	2·96	0·69	1·00	4·75
Relevance2	3·76	0·66	1·50	5·00
Gender	1·49	0·50	1·00	2·00
Task-orientation	3·06	0·51	2·12	4·23

Table 10. Multi-level analysis: overview of the distribution of the variances among the three levels, separately for each dependent variable.

Variable	Individual	Gender	Class
Math achievement	8·48 (48)	0 (0)	41·75 (52)
Pleassure	0·70 (86)	0·03 (4)	0·08 (10)
Anxiety	0·48 (95)	0 (0)	0·02 (5)
Motivation	0·41 (87)	0·01 (1)	0·06 (12)
Relevance	0·42 (95)	0·01 (3)	0·01 (2)

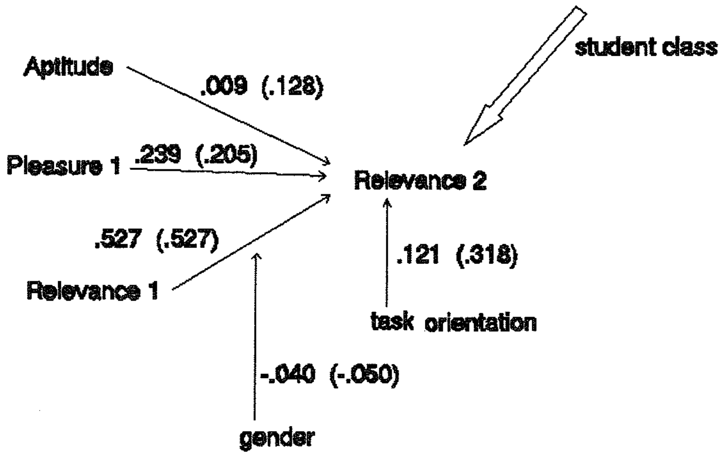
Note: Percentages are given in parentheses.

variables are at work. Introduction of these variables into the multi-level model may explain differences in the dependent variables.

After this discussion of the problem of gender from a multi-level perspective, we now turn to the statistical analysis and results. The relevant descriptive statistics are given in table 9.

Initially we opted for a multi-level analysis at three levels: individual, gender and class. First, we decomposed the variance at each level. In table 10, the distribution of the variance between the levels is given. Gender group turns out to be a relevant social classroom factor in the learning of mathematics on the pupil level, although the influence is rather slight. The within-class gender group is neither relevant with respect to post-test achievement nor with respect to Motivation and Anxiety. Here only class differences exercise an influence. The gender group is relevant only with respect to Pleasure and Relevance. The between-gender group differences in the scores of Pleasure and Relevance are very small but significant. In the case of the variable Relevance the class is not relevant. We conclude that the gender level seems to be relevant only with respect to the dependent variables Pleasure and Relevance.

Pleasure as a dependent variable shows, apart from the individual regressions, remaining variance decomposition both on the gender and class level. Neither the gender variance nor the class variance can be explained by



*Weighted coefficients of the individual variables are calculated by:

$$\frac{\text{Original coefficient * mean of independent variable}}{\text{Mean dependent variable (Relevance 2)}} =$$

Weighted coefficients of gender level variables are calculated by:

$$\frac{\text{Original coefficient * product of the independent variables}}{\text{Mean dependent variable (Relevance 2)}} =$$

Figure 1. Multilevel results from tables 11(a) and (b), model 5, in a graph with Relevance 2 as dependent variable. Weighted coefficient in parentheses.

the level-specific variables concerned. The ratio is 86%, 4% and 10% respectively. It turns out that a small part of Pleasure in mathematics is on the gender-group level, but without any explanation in terms of its characteristics. A reasonable, higher percentage is on the class level (10%), but here too class characteristics provide no explanation.

Relevance is the most interesting dependent variable from the point of view of the research problem of this paper. The variance of Relevance can be decomposed into various levels: 95% on the pupil level, 3% on the gender group level and a non-significant 2% on the class level. The outcome of the multi-level analysis are given in tables 11a and b.

Relevance depends on Aptitude, Pleasure 1 and Relevance 1 (table 11a, model 5). There is only a between-gender group variance with respect to the intercept and the slope of Pleasure 1. The between-slope differences can be explained by the gender of the gender group (gender), as expected in the main hypothesis above – independently of class. The effect is negative, which means that there is a negative effect of girls (due to the score 2 = girls). The between-intercept differences can be explained by Task-orientation of the gender group.

In figure 1 this outcome is shown graphically. It is worth mentioning here that in this figure the original coefficients (table 11a) are presented, as well as the weighted coefficients (in parentheses). The weighted coefficients in figure 1 enable us to compare the relative strengths of the effects. The most important contribution is offered by Relevance (0·527 change points),

Table 11(a). Fixed part of the exploratory multi-level analysis with Relevance2 as a dependent variable.

	Model 1		Model 2		Model 3		Model 4		Model 5	
Respondent effect:										
Mean	3·754		0·488		0·570		0·610		0·364	
Aptitude			0·009	(0·003)	0·007	(0·003)	0·009	(0·003)	0·009	(0·003)
Pleasure1			0·162	(0·034)	0·161	(0·037)	0·205	(0·039)	0·239	(0·035)
Motivation1			0·086	(0·043)	0·083	(0·042)	0·094	(0·42)		
Relevance1			0·538	(0·040)	0·537	(0·040)	0·512	(0·041)	0·527	(0·040)
Gender effect:										
intercept variance explained by:										
Task-orientation									0·121	(0·048)
Slope variance of Pleasure										
Explained by Gender							− 0·042	(0·013)	− 0·040	(0·013)

Irrelevant non-significant coefficients are omitted ($p < 0{\cdot}05$). The figures in parentheses are the standard errors of the coefficients concerned.

Table 11(b). Random part of the exploratory multi-level analysis with Relevance2 as a dependent variable.

	Model 1		Model 2		Model 3		Model 4		Model 5	
Pupil level:										
Variance	0·417		0·235		0·229		0·226		0·226	
Gender level:										
variance of:										
Intercept	0·015	(0·060)	0·009	(0·045)*	0·008	(0·036)	0·007	(0·037)	0·006	(0·038)
Pleasure1					0·009	(0·034)	0·008	(0·035)	0·009	(0·035)
covariance of intercept with:										
Pleasure1					− 0·009	(0·003)	− 0·008	(0·003)	− 0·007	(0·003)
Class level:										
variance:										
Intercept	0·008	(0·067)*	0·006	(0·048)*	0·004	(0·040)*	0·004	(0·039)	0·002	(0·045)*
Deviance	1146·754		819·449		810·214		799·903		798·699	

Irrelevant non-significant coefficients are omitted. The figures in parentheses are the standard errors, which have to be related to the root of the coefficients concerned. Deviance is a measure of the goodness of fit.

* Relevant non-significant coefficients.

followed by Pleasure (0·205 change points), whereas the smallest contribution is made by Aptitude (0·128). The total effect of the gender characteristic of the gender group (*gender*) on the influence of Pleasure on Relevance is very slight (−0·050). The effect of the gender group characteristic Task-orientation on the mean of Relevance per gender group amounts to 0·318.

Conclusions and discussion

This paper addresses the question of whether girls and boys benefit differentially from (co-operative) learning in a secondary mathematics curriculum. The following conclusions can be drawn.

First, as regards the effects of the experimental curriculum, especially for girls, no significant differences were found on the pre-test (mathematical Aptitude) between the girls in either condition. The post-test results for achievement in mathematics showed remarkable differences. Girls in the AGO group significantly outperformed girls in the control group. The score on the post-test was 24·3 for the AGO girls, and 19·0 for the girls in the control group. No positive AGO effects were found in the affective domain for girls.

Second, although we can see that AGO girls performed significantly better in mathematics than non-AGO girls, and may therefore conclude that co-operative learning is effective for girls compared with more traditional forms of instruction, we cannot say that girls benefit *more than boys* from co-operative learning. Both boys and girls profit from co-operative learning. Within the experimental group there is no decrease in the difference in the cognitive domain between the gender groups.

Third, in respect of the effects for boys and girls in the whole sample, the following conclusions can be drawn. On the post-test, covariance analyses–with the pre-test as a covariate–revealed significant effects of gender and condition. Boys outperformed girls, and the AGO group scored higher than the control group. No differential effects for boys and girls were found (i.e. there were no interactions between gender and condition).

As regards the affective variables, some well-known earlier findings were confirmed. At the start of the experiment boys had less anxiety towards mathematics, boys showed more pleasure in mathematics, boys showed more motivation towards mathematics and boys considered mathematics to have greater relevance than girls.

At the end of the experiment, while controlling for initial differences, two gender effects still exist (Anxiety and Relevance) and no effects of condition or of interactions of condition and gender were found. No interaction between condition and gender means no differential effects for boys and girls in the affective domain.

Finally, we used multi-level analysis, given the premise that gender differences are (partly) dependent on the educational context. Multi-level analyses were carried out in order to investigate the effects of the gender level in greater detail. The basic idea behind this analysis is that boys and girls experience different learning environments (treatments) while going through the same formal curriculum. These different learning environments may result in differential effects for boys and girls. The multi-level analysis is aimed at the investigation of the sources of variance at the individual, gender and class levels. In this analysis the gender level contributes slightly to the explanation of two dependent variables in the affective domain: Pleasure in mathematics and the Relevance of mathematics. No gender-level effects on achievement in mathematics were found. With regard to the effects of the gender group on Relevance 2, two conclusions can be drawn. First, the gender of the gender group (boys or girls) has a negative effect on the transformation from Relevance 1 to Relevance 2 (slope effect). This means that there is a differential effect for boys and girls in favour of the boys. Mathematics becomes relatively less relevant for girls during the process of implementation of the curriculum. Second, task-orientation as perceived by the students plays a crucial role in the explanation of gender level effects on Relevance of mathematics (intercept effect). Probably this is a reflection of the fact that girls have a significantly lower perception of Task-orientation than boys. Consequently here we also see a negative effect for girls.

We will now discuss the findings and attempt to offer some explanations. If we look to the positive effects of the experimental model on the achievement of girls compared with the girls in the control group (the first conclusion), the following explanations can be given. These explanations are general ones, which can be applied to the differences between girls in the two conditions.

According to theories of cognition it is to be expected that working in groups accelerates the learning process. The causes of the positive effects of group work may be found in various factors inherent in this type of learning environment. Pupils in small groups are confronted by their fellow pupils in the group with different solutions and points of view. This may lead to socio-cognitive conflicts, which are accompanied by feelings of uncertainty. This may cause a willingness in pupils to reconsider their own solutions from a different perspective. The resulting processes stimulate higher cognitive skills. In principle pupils can also conquer the uncertainty caused by different points of view together with the other members of the group, particularly where difficult or complicated assignments are involved. Those small groups offer group members the opportunity to profit from the knowledge available in the group as a collective. This may take the form of knowledge, skills and experiences which not every member of the group possesses. Pupils use each other as 'resources' under those circumstances. Leechor (1988) calls this 'resource sharing'.

Collaboration in small groups means that pupils are forced to verbalize their thoughts. Such verbalizations facilitate understanding through cognitive reorganization on the principle that 'He or she who teaches learns the most'. Offering and receiving explanations enhances the learning process. Group members not only profit from the knowledge and insights transmitted through 'peer tutoring', they can also internalize effective problem-solving strategies by participating in the collective solution procedures.

Positive effects of group work can also be expected on the basis of motivation theory. Co-operation intensifies the learning process: 12–16-year-olds are strongly orientated towards the peer group and very interested in interaction with their peers.

We now turn to the differences between boys and girls. In our introduction to the AGO model we argued that group work is most important characteristic of this type of curriculum design. Although girls do benefit in terms of achievement, the model has not proved very effective in reducing gender inequalities. Here we have a phenomenon which we encounter quite often in education research. It may be summed up as follows: what is good for girls, is good for boys as well. By way of example, we referred to the work of Van der Werf (1988) which shows that teaching mathematics in real-life contexts not only had the intended effect for girls; boys, too, more often chose mathematics and performed better. Also, the learning materials which have been developed by teachers in the last few years to meet the interests of girls and their ways of working, and which give an important place to group work, were also appreciated by boys who worked with them (see, e.g. Barnes and Coupland 1990). Does this warrant the conclusion that girls are worse at dealing with 'bad teaching' than boys? For the moment we will seek an explanation in a different direction.

Few data were available for our analysis with regard to interactive classroom processes. We knew something about the amount of assistance given to boys and girls by teachers. Girls received more help than boys but we had no information about the nature of this assistance. Nor did we have any data about the small-group interactions which had taken place between the pupils themselves. What were task divisions like? Did gendered division of labour occur? Because of the lack of information in these areas little can be said about the gender context in which the AGO instruction model was implemented. To put it another way, whereas in the 'formal' curriculum attention was paid to the elements which could have special significance for girls and whose gender-specific effects were subsequently examined, an observational investigation specifically on the within-class gender level of the 'operational' curriculum was not undertaken.

In this context of ignorance about possible gender-specific processes and interactions, we would raise a question: Do attempts to reduce differences between boys and girls require a more comprehensive approach? Changes in the content of school mathematics (e.g. changes to real-life contexts) or changes in teaching methods, however useful, may simply be insufficient. In this connection we should mention a particular school project, which is being conducted under the auspices of the Dutch Ministry of Education and Science to influence pupils' choices positively in favour of science subjects and mathematics. The starting point for the project was the idea that girls choose fewer science and mathematics subjects and perform less well in those subjects as a consequence of low motivation. In order to increase girls' motivation the project works on four fronts simultaneously: learning materials are used which are tailored to the (assumed) special interests of girls: teaching methods contain elements which are assumed to promote the participation of girls in scientific subjects (among other things by means of group work): there are separate classes for boys and girls; and career choice and professional orientation are explicitly included in the curriculum (Coornhert 1990). Evaluation research into the effects of the project on the choices, performance and attitudes of boys and girls is still under way.

In conclusion, we want to draw attention to one remarkable result of our multi-level analysis. Contrary to our theoretical assumption that the gender group is a relevant entity in explaining the variance in learning achievement and attitudes, it turns out that by far the greatest part of the variation found can be attributed to the pupil and class level. This result of our research might mean that the gender group is of little relevance in the explanation of gender differences. However, this conclusion seems premature. The aim of the original AGO project was not to reduce differences between boys and girls, but to improve learning processes and outcomes for all (compared with traditional mathematics education). Consequently, in this particular investigation the teachers were not specially trained in applying differential treatments to reduce differences between boys and girls. It is conceivable that the gender group will turn out to be an important explanatory factor once teachers consciously apply different treatments to boys and girls with a view to reducing gender inequality. In further theorizing about the place of gender in curriculum theory and practice it will be important to examine the effect of differential treatment for each gender group on gender differences in learning achievements and attitudes.

Notes

1. The effect size d is expressed as the difference in means between two samples, divided by the pooled standard deviation ($d = (m_1 - m_2)/\text{SD}$). According to Cohen (1969), $d = 0{\cdot}20$ is a small effect, $d = 0{\cdot}50$ is a medium effect, and $d = 0{\cdot}80$ is a large effect.

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