THE EFFECT OF ACHIEVEMENT, GENDER AND CLASSROOM CONTEXT ON UPPER SECONDARY STUDENTS' MATHEMATICAL BELIEFS

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The influence of achievement, gender and classroom context on students' mathematical beliefs were analysed from survey data from 1436 Finnish upper secondary school students. The results indicate that students of the same class tend to have similar effort, enjoyment of mathematics and evaluation of teacher. Students' mathematical confidence is influenced by gender while their perception of their competence mainly relates to their achievement in mathematics.

Keywords: beliefs, gender, secondary school, multilevel analysis

INTRODUCTION

Mathematical beliefs are on the one hand considered as individual constructs that are generated by individual experiences. On the other hand, beliefs are considered to be constructed socially, in a shared social context of a classroom. Which is more important? Are all beliefs constructed in the same way or are some beliefs socially constructed while some others are purely individual?

In Finnish research on affect in mathematics education the focus has clearly been on the level of human psychology, and only a few studies have explored also the social level (Hannula, 2007). One reason for this is most likely that differences between schools and geographic regions are low and the social variables have generally less pronounced effect on achievement in mathematics in Finland than in most other countries (OECD-PISA, 2004). Finland is also culturally rather homogeneous. Hence, it is not surprising that comparative studies between different groups of students within Finland have not been popular, gender being an exception to the rule. One study on regional effects indicated that students in capital province choose advanced syllabus more often than students in another province (Nevanlinna, 1998). This indicates that geographical differences in mathematics related beliefs may exist.

A general international trend has been that gender differences in mathematics achievement are disappearing. Gender differences in overall achievement of 15-year olds have disappeared also in Finland, but robust gender differences still exist in their affect towards mathematics (Hannula, Juuti & Ahtee, 2007). When attitude towards mathematics has been constructed as a single variable, studies generally have found boys to hold a more positive attitude towards mathematics (e.g. Saranen 1992). However, when different dimensions of attitude have been separated, interesting variations have been found. For example, all studies have not found gender differences in 'liking of mathematics' (Kangasniemi, 1989). Gender difference has been clearer in how difficult mathematics is seen (Kangasniemi, 1989) and quite robust in students' self-confidence in mathematics (Hannula & Malmivuori, 1997; Kangasniemi, 1989; Hannula, Maijala, Pehkonen & Nurmi, 2005). Class-level factors are seen to influence students' self-confidence, and these seem to be more relevant to girls' than to boys' self-confidence (Hannula & Malmivuori 1997).

Although Finland scored to the top in PISA achievement scores, Finland was also characterised by less favourable results on the affective measures. Finnish students lack interest and enjoyment in mathematics, they have below average self-efficacy, and low level of control strategies. As a more positive result, levels of anxiety were also low. In Finland affect was an important predictor of achievement. Mathematical self-concept was the strongest predictor of mathematics performance, and this correlation was strongest among countries in the study. The study also revealed that gender differences favouring males in affect were larger in Finland than in OECD on average. (OECD-PISA, 2004)

In a study of elementary and secondary teachers' beliefs Pekka Kupari identified two types of mathematics teachers, traditional and innovative teachers. The traditional teacher emphasises basic teaching techniques and extensive drill, while the innovative teacher emphasises student thinking and deeper learning. (Kupari, 1996)

Moreover, Riitta Soro (2002) found out in her study that most mathematics teachers held different beliefs about students based on student's gender. Girls were seen to employ inferior cognitive skills and succeed because of their diligence, while boys were seen to be talented in mathematics but lacking in effort. However, there were also teachers who did not hold such gendered beliefs.

As there are quite different teachers, one would expect this to have an effect on beliefs of their students. If this is the case, then we are likely to find significant amount of variation of students' beliefs to be attributable to the class they study in. Moreover, this variation might be different for male and female students.

In this report we shall explore more deeply which aspects of mathematical beliefs are most affected by shared classroom context or gender, and which seem to be individual constructs, for which gender and class are poor predictors of the belief.

THEORETICAL FRAMEWORK

In the literature, beliefs have been described as a messy construct (Pajares, 1992). There are many variations for characterisations of belief concept (Furinghetti & Pehkonen, 2002). In this article we consider mathematical beliefs as "an individual's understandings and feelings that shape the ways that the individual conceptualizes and engages in mathematical behavior" (Schoenfeld 1992, 358). Op 't Eynde, De Corte and Verschaffel (2002) provide a framework of students' mathematics-related beliefs. Constitutive dimensions are object (mathematics education), self, and context (class), which further lead to several sub-categories:

1) Mathematics education (mathematics as subject, mathematical learning and problem solving, mathematics teaching in general),

2) Self (self-efficacy, control, task-value, goal-orientation), and

3) The social context (social and socio-mathematical norms in the class,). With regard to the social context, Op 't Eynde & DeCorte (2004) found out later that the role and functioning of one's teacher are an important subcategory of it.

In an earlier study (Rösken, Hannula, Pehkonen, Kaasila and Laine, 2007), we have explored the structure of mathematical beliefs among upper secondary school students. Our studies confirmed partially the aspects of mathematical beliefs that Op ‘t Eynde and his colleagues had suggested.

It is generally assumed that there is a link between teachers’ and their students’ affect towards mathematics (e.g. Cockroft, 1982). However, few studies seem to confirm this relationship. For example, the review of PME research on affect (Leder & Forgasz, 2006) does not mention any such study. As an example of research relating teacher and student beliefs we can take Crater and Norwood’s (1997) study of seven teachers and their 138 students, where they found out that this group of teachers’ beliefs influences their practices and what their students believed about mathematics

These different findings can be summarised on a model where there the three levels of gender, classroom context and individual are differentiated in the process of belief development (Figure 1).

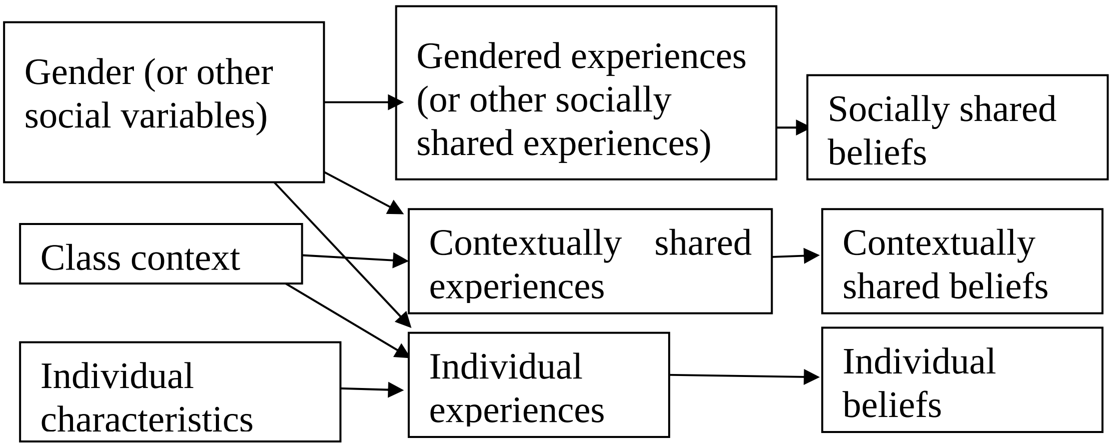

Figure 1. A model for generation of mathematical beliefs.

One origin of different student beliefs are the individual life histories that each student brings into the classroom. These life histories influence the way the students position themselves in the classroom, the way they engage with mathematics, teacher and peers and the way they interpret their experiences in the classroom. On the other hand, there are contextual factors that students of the same class share with each other. These are, for example, the personality of the teacher, the physical classroom and the implemented curriculum. These influence all students in a class and are the origin of shared experiences. Moreover, also students’ individual experiences are partly shaped by the shared events in the classroom. This is illustrated with an arrow from classroom context to individual experiences.

On the most general level there are experiences that people of the same social background (e.g. ethnicity, social class, hobbies, and social subcultures) share. One of such subsets is generated by students' gender. Gender is seen to play a significant part in the experiences in the classroom and in the beliefs that students develop (e.g. Hannula et. al, 2008). Also most teachers' have different beliefs about boys and girls as mathematics learners (Soro, 2002). Therefore it is reasonable to make the claim that individual experiences in mathematics classrooms are not the same for male and female students. Moreover, as teachers and classes are different, these gendered experiences may vary from one class context to another. Therefore, there are arrows from gender to both contextual and individual experiences.

METHODS

Instrument and Participants

The view of mathematics indicator has been developed in 2003 as part of the research project "Elementary teachers' mathematics" financed by the Academy of Finland (project #8201695). It has been applied to and tested on a sample of student teachers and was slightly modified for the present sample. That is, items addressing specifically aspects of teaching mathematics like View of oneself as mathematics teacher (D1-D6) and Experiences as teacher of mathematics (E1-E7) were removed. More information about the development of the instrument can be found e.g. in (Hannula Kaasila, Laine & Pehkonen, 2006).

The participants in our study came from fifty randomly chosen Finnish-speaking upper secondary schools from overall Finland, including classes for both, advanced and general mathematics. The respondents were in their second year course for mathematics in grade 11. Altogether 1436 students from 65 classes (26 general and 39 advanced) filled in the questionnaire and gave it back. The response rate was higher among advanced mathematics courses.

Through an exploratory factor analysis we obtained a seven-factor solution that counts for 59 % of variance and provides factors with excellent internal consistency reliability (Table 1). We related three factors to personal beliefs since a clear self-relation aspect regarding competence (F1), effort (F2) and confidence (F7) can be found. Two factors were related primarily to social context variables, namely teacher quality (F3) and family encouragement (F4), one to more emotional expressions concerning enjoyment of mathematics (F5) and one to mathematics as a subject; that is, difficulty of mathematics (F6). A description of factor analysis as well as all components and their loadings can be found in another report. (Rösken et. al, 2007)

A GLM univariate analysis was performed on SPSS. The seven belief factors were the dependent variables, gender was a fixed factor, and class a random factor.

Mathematics grade was a covariant. Students of advanced and general mathematics courses were analysed separately, and partial η^2 is used as a measure of effect size. It should be noted that although partial η^2 is a reliable estimate within a sample, it does not provide reliable estimate for the whole population. Because all variables did not confirm with the assumptions of normality, we made also a nonparametric Kruskal Wallis test to test the statistical significance of the grouping effect.

Name of the component	Sample item	Number of items	Cronbach's alpha
Competence	Math is hard for me	5	0.91
Effort	I am hard-working by nature	6	0.83
Teacher Quality	I would have needed a better teacher	8	0.81
Family Encouragement	My family has encouraged me to study mathematics	3	0.80
Enjoyment of Mathematics	Doing exercises has been pleasant	7	0.91
Difficulty of Mathematics	Mathematics is difficult	3	0.82
Confidence	I can get good grades in math	5	0.87

Table 1. The 7 principal components of students' view of mathematics.

RESULTS

The GLM univariate analysis indicated several statistically significant effects (Table 2 and Table 3). However, the assumption of equal variance did not hold true in all cases and nonparametric tests were necessary to confirm results (see below).

	General mathematics											
	Grade			Gender			Group			Gender x Group		
	F	Sig.	η^2	F	Sig.	η^2	F	Sig.	η^2	F	Sig.	η^2
Competence*	326,16	,000	,35	,12	,729	,00	1,58	,111	,61	,97	,507	,04
Effort	172,22	,000	,27	3,10	,087	,09	2,03	,041	,67	1,15	,278	,06
Teacher Quality	41,86	,000	,08	10,37	,003	,22	2,95	,004	,75	,92	,577	,05
Family Encouragement	,75	,388	,00	2,20	,147	,06	1,05	,456	,51	1,08	,359	,06
Enjoyment of Mathematics	196,65	,000	,30	2,94	,096	,08	1,65	,107	,62	1,00	,470	,05
Difficulty of Math*	194,80	,000	,30	4,73	,036	,12	1,90	,057	,65	,94	,550	,05
Confidence*	86,40	,000	,16	23,29	,000	,41	1,06	,444	,51	1,02	,433	,05

Table 2. GLM univariate analysis for general mathematics students (gender*group, grade as covariate). η^2 is partial η^2. *) variance in groups was not equal (Levene's Test of Equality of Error Variance)

Most of the mathematical beliefs were related to the mathematics grade the student had. A simple correlation was calculated to determine the direction of the correlation

(correlation table is not reprinted here). All correlations were positive, except of correlation between grade and perceived difficulty of mathematics.

Regarding gender differences, the GLM Univariate analysis indicated that for both advanced and general syllabus female students were less confident and they perceived teacher quality lower and mathematics more difficult than male students. The effect was strongest in self-confidence.

The analysis indicated a strong group effect for teacher quality. In groups of general mathematics there was also a strong group effect on effort and in groups of advanced mathematics a strong group effect on enjoyment. Moreover, there was a gender and group interaction effect for enjoyment among advanced mathematics courses, indicating stronger group effect for female students.

	Advanced mathematics											
	Grade			Gender			Group			Gender x Group		
	F	Sig.	η^2	F	Sig.	η^2	F	Sig.	η^2	F	Sig.	η^2
Competence*	332,61	,000	,30	1,09	,301	,02	1,63	,077	,63	1,08	,355	,05
Effort*	254,72	,000	,25	,13	,717	,00	1,02	,479	,51	1,13	,278	,05
Teacher Quality*	53,34	,000	,07	5,83	,019	,10	7,26	,000	,88	1,14	,274	,05
Family Encouragement	1,20	,274	,00	,34	,561	,01	1,50	,116	,61	,73	,877	,03
Enjoyment of Mathematics	175,78	,000	,18	,30	,591	,01	2,41	,005	,71	1,49	,036	,06
Difficulty of Mathematics	254,08	,000	,24	34,27	,000	,40	1,67	,066	,63	1,24	,160	,05
Confidence	115,86	,000	,13	75,07	,000	,60	1,29	,228	,57	1,28	,132	,05

Table 3. GLM univariate analysis for advanced mathematics students (gender*group, grade as covariate). η^2 is partial η^2. *) variance in groups was not equal (Levene's Test of Equality of Error Variance)

Because all variables did not confirm with the assumptions of normality, we made separate analysis to confirm some of the disputable results above (Table 4). Unfortunately this analysis did not allow a simple means to control for effect of achievement. The results confirmed the group effects partially. For students of general mathematics the statistically significant group effects were different for male and female students. For male students, groups had an effect on competence and effort, whereas for female students the group effect was found on teacher quality and confidence. This confirms the group effect on effort for male students and teacher quality for female students. The observed group effects on competence and confidence may actually be effects of grade.

For advanced mathematics a statistically significant group effect was found for teacher quality, effort, and enjoyment. This confirms the results of GLM Univariate analysis. Moreover, for female students only, a group effect on confidence was found.

Kruskal Wallis Test Statistics for group differences									
Course, Gender		Compe-tence	Effort	TQ	FE	Enjoy	Difficulty	Confidence
General, male	χ^2	36,39	46,10	27,053	21,96	25,16	26,56	20,38
	df	25	25	25	25	25	25	25
	Asymp. Sig.	,066	,006	,353	,638	,453	,378	,727
General, female	χ^2	30,64	24,70	66,369	47,61	31,12	23,41	43,72
	df	25	25	25	25	25	25	25
	Asymp. Sig.	,201	,479	,000	,004	,185	,554	,012
Advanced, male	χ^2	35,25	58,61	96,81	38,20	51,06	56,99	39,51
	df	36	36	36	36	36	36	36
	Asymp. Sig.	,504	,010	,000	,370	,049	,014	,316
Advanced, female	χ^2	40,71	52,04	140,12	33,8	99,700	47,43	54,14
	df	35	35	35	35	35	35	35
	Asymp. Sig.	,233	,032	,000	,523	,000	,078	,020

Table 4. Kruskal Wallis Nonparametric Test for the group effect on mathematical beliefs among male and female students in general and advanced mathematics courses. TQ = Teacher quality, FE = Family encouragement

CONCLUSIONS

The results of these analysis confirmed that there is a certain level of agreement in certain mathematical beliefs among students of same class. Most pronounced this was for perceived teacher quality. In our earlier studies on teacher education students (e.g. Hannula et. al, 2006) we were not sure whether the variation in respondents' beliefs about their teacher's quality was an effect of their own mathematical achievement or if it reflected actual differences in the teaching they had received. This study confirms that students' belief of their teacher's quality is shared among students of the same class and therefore it is likely to be generated by shared experiences in the classroom context. Yet, also student's gender and achievement had an effect on this evaluation of the teacher. This provides evidence for the suggested interaction between levels in the model (Figure 1).

Shared classroom context seemed to have an effect also in students' effort (general mathematics) and enjoyment (advanced mathematics). This is indicating that through choices in instruction, it is possible to create a 'culture' in the classroom that is motivating or enjoyable. However, we can not rule out the possibility that these differences between classes be effect of geography or some other variable that differentiates these groups.

An interesting finding was that there was a gender and group interaction effect for enjoyment among advanced mathematics courses, indicating stronger group effect for female students. This might relate to the anecdotes that students still occasionally tell about chauvinistic mathematics teachers they have had. The small effect size (6%) indicates that this is not a major problem on the level of educational system. However, for those female students who have to suffer through these classes it may be a big problem. Alternatively, this might indicate that there are such teachers in Finnish upper secondary schools that are able to create lessons that female students find especially enjoyable.

It is worth to note that gender had a stronger influence on confidence in mathematics than mathematics grade. The same is true also for and perceiving mathematics difficult in advanced course. In this sense these beliefs are truly gendered beliefs.

The findings provide support for the presented model and give indication to the origin of the measured beliefs (Figure 2). The effects of context and gender were surprisingly strong and the results support the hypothesis of social origin of beliefs.

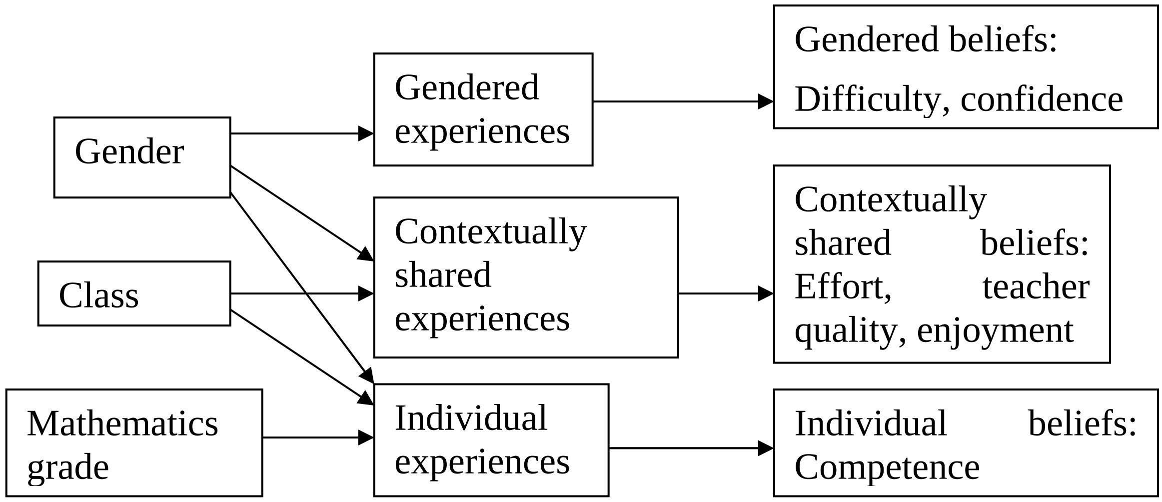

Figure 2. Empirically confirmed gendered, contextual and individual beliefs.

Enjoyment of mathematics, self-confidence in mathematics and self-efficacy beliefs are often considered as closely related aspects of attitude towards mathematics. This study highlights the different origin of these three aspects of attitude towards mathematics. Hence, it seems worthwhile to separate these different aspects also in future studies.

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