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Collaborative problem solving in Finnish lower secondary mathematics classrooms and its effect on mathematics-related affect

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Problem solving is widely considered as a mean to learn mathematics deeply that has a positive impact on pupils' mathematics-related affect. Despite the positive results from research, problem solving is rarely used as a regular part of classroom activities in mathematics. This paper reports from a 1-year intervention study where collaborative problem solving was used as the central teaching and learning method in mathematics lessons. During the intervention, the global pandemic closed the schools for two months that also influenced the results. The results show that the pupils' view of themselves as learners of mathematics developed negatively during the intervention year. Possible reasons to the negative development are discussed and suggestions on further studies are given in the discussion.

Keywords: Collaborative problem solving, mathematics related affect, lower secondary school.

Introduction

Finnish lower secondary school pupils are known for their low affect in mathematics. For instance, Trends in International Mathematics and Science Study (TIMSS) showed that on grade 8, at the age of 14-15, no less than 57% of the Finnish pupils reported not liking learning mathematics (international average 41%), and only 9% reported very much liking learning mathematics (international average 20%) (Mullis et al., 2020). The same trend was visible also on grade 4. Preventing the development of negative attitudes and self-efficacy beliefs in mathematics is crucial, as they might have an impact on pupils' future studies and career choices.

Previous studies have shown how problem solving has a positive impact on pupils' affect. For instance, Tuohilampi and colleagues (2015) showed that already one monthly problem-solving lesson stopped the negative trend that the Finnish pupils have in mathematics-related affect. This result made me think of the possibilities that daily problem-solving activities could have on Finnish pupils' mathematics-related affect. Internationally, interventions with daily collaborative problem-solving activities in mathematics have been promising (see Liljedahl, 2021).

The intervention

To address the Finnish pupils' negative mathematics-related affect and to study the potential influence that a daily problem solving might have on pupils' mathematics related affect, I conducted a 1-year problem-solving intervention in six lower secondary mathematics classrooms during the academic year 2019-2020. During the intervention, pupils worked collaboratively with problem-solving tasks. Each lesson started with a mathematical problem that pupils solved in visibly random groups, standing, writing their solutions on vertical white boards. These methods have shown to increase pupils' engagement and enthusiasm in mathematics classrooms, persistence, and eagerness to start working on mathematical tasks (Liljedahl, 2014; 2019; 2021), among other things.

During the academic year 2019-2020 the world faced its first modern pandemic. After seven months of the intervention, the schools were closed in Finland, and the learning processes moved from the classroom environment to pupils' homes. Whereas the pupils had been learning to collaborate and solve mathematical problems in groups during the previous seven months, they were now shut down into their homes, working on mathematical tasks on their own for the remaining two months of their school year. The very limited data that I have from the time of the lockdown suggests that the distance teaching did not support collaboration between the pupils. A year later, a large-scale national study showed that the connection between pupils' mathematical skills and attitudes in mathematics has weakened and that pupils' self-efficacy beliefs in mathematics have lowered especially in high-performing pupils (Metsämuuronen & Nousiainen, 2021).

Theoretical framework and research questions

In this study, pupils' mathematics-related affect is studied through pupils' views of themselves as learners of mathematics (Rösken et al., 2011). This view is individual (cf. psychological affective traits in Hannula, 2012), reflecting the impact that the social problem-based learning processes have on individual pupils' mathematics-related affect. This view is considered important also according to the Finnish national core curriculum (Finnish National Board of Education, FNBE, 2016) which states that one of the key tasks in mathematics teaching is to support pupils' positive attitude and self-image in mathematics.

Interesting in this study is to examine the joint impact of the problem-solving intervention and the school lockdown to the pupils' mathematics-related affect. Based on previous research on collaborative problem solving, the hypothesis would be that the pupils' mathematics-related affect develops positively during the academic year (cf. Liljedahl, 2021; Tuohilampi et al., 2015). However, previous research shows that the global pandemic, and the school lockdown, might have had a negative impact on pupils' mathematics-related affect (cf. Metsämuuronen & Nousiainen, 2021).

To study the joint impact of the intervention and the school lockdown on pupils' mathematics-related affect, the following research questions are placed: (1) How do the pupils view themselves as learners of mathematics in the beginning and in the end of their school year? and (2) How do the pupils' view of themselves as learners of mathematics develop in the context of the problem-solving intervention and the school lockdown over the span of one school year?

Methods

The problem-solving intervention started at the beginning of the school year in mid-August 2019. During the first seven months pupils worked collaboratively in each mathematics lesson, solving mathematical problem-solving tasks in visibly random groups on vertical non-permanent surfaces (see Liljedahl, 2021). In mid-March 2020, the global pandemic closed the schools, and the pupils were forced to study home, alone with the online support that the teachers gave during the distance schooling. After two months of the school lockdown, in mid-May 2020, the pupils returned to their classrooms for the remaining two weeks of the school year. During this time, the pupils had to keep physical distance to each other, and no visitors were allowed to the schools.

Participants

The data used in this paper are from two grade 8 classes ($N=29$) and two grade 9 classes ($N=19$). In Finland, pupils in grade 8 are 14-15-year-olds and pupils in grade 9 are 15-16-year-olds. Only pupils that answered to both pre- and post-questionnaire are included in the sample.

Data collection

The data to this paper were collected through pre- and post-questionnaires. Pupils answered the pre-questionnaire during the first week of the school year (mid-August 2019) and the post-questionnaire during the last two weeks of the school year (end of May 2020, directly after the pupils returned to classrooms after the school lockdown). The pupils answered to the questionnaires individually during their mathematics lessons. The pre- and post-questionnaires were otherwise identical, but the post-questionnaire included some open questions considering the time while the schools were closed due to the pandemic. The questions connected to the school lockdown are not used in this paper.

For this paper, I will look at the questions related to pupils' views of themselves as learners of mathematics (Rösken et al., 2011). In their study, Rösken et al. (2011) found seven dimensions of students' views of themselves as learners of mathematics: ability, effort, teacher quality, family encouragement, enjoyment of mathematics, difficulty of mathematics, and success. From these dimensions, I used questions only from the dimensions that are directly connected to the learners, that is, I excluded dimensions teacher quality and family encouragement from the study. The data is collected through a Likert-scale from 1 = Fully disagree to 5 = Fully agree.

Data analysis

Since the sample size is so small, the data are analysed through descriptive statistics and correlations. Reliability of the sum variables was tested using Cronbach's alpha. Significance of the descriptive statistics was tested using paired samples t-test.

Results

According to the literature (Rösken et al., 2011), the data for this paper can be divided into five categories: ability, effort, enjoyment of mathematics, difficulty of mathematics, and success. First, the data of these sum variables will be reported, followed by the results from the individual statements.

Sum variables

Pupils' view of their ability in mathematics was studied through four statements: *I am no good at math*, *I am not the type to do well in math*, *Math has been my worst subject*, and *I have made it well in math*. The sum variables for ability were highly reliable (Pre: $\alpha=.83$, Post: $\alpha=.90$, the three negative statements inverted). The results show that the pupils on average do not agree with these negative statements but the development on their ability in mathematics has developed negatively between the pre- and the post-tests. The development is statistically fairly significant (Pre: $M=3.40$, $SD=.861$, Post: $M=3.02$, $SD=1.125$, $t(48)=2.647$, $p<.05$).

Pupils' view of their effort in mathematics was studied through four statements: *I am hard-working by nature*, *I have not worked hard enough*, *I have worked hard to learn math*, and *I always prepare*

myself carefully for exams. The sum variables for ability were highly reliable (Pre: $\alpha=.82$, Post: $\alpha=.76$, the negative statement inversed). The results show that on average, the pupils put effort to their work in mathematics. The development is slightly negative, but not statistically significant (Pre: $M=3.29$, $SD=.853$, Post: $M=3.16$, $SD=.784$).

Pupils' enjoyment of mathematics was studied through six statements: *It has been boring to study mathematics*, *Doing exercises has been pleasant*, *Mathematics is a mechanical and boring subject*, *I have enjoyed pondering mathematical exercises* (the same statement was asked twice, both being part of the analysis; Pre- and post-study correlations .884 and .887 respectively, both correlations highly significant $p<.001$), *Mathematics has been my favourite subject*, and *Mathematics has been the most unpleasant part of studying*. The sum variables for enjoyment were highly reliable (Pre: $\alpha=.93$, Post: $\alpha=.90$, the three negative statements inversed). Overall, pupils seem not to enjoy mathematics. The development is negative on a fairly significant level (Pre: $M=2.66$, $SD=.966$, Post: $M=2.41$, $SD=0.865$, $t(48)=2.181$, $p<.05$).

Pupils' view on the difficulty of mathematics was studied through two statements: *Mathematics is difficult*, and *Learning mathematics requires a lot of effort*. The sum variables for difficulty were highly reliable (Pre: $\alpha=.80$, Post: $\alpha=.79$). Pupils' view on the difficulty of mathematics is negative, and the negative development is statistically significant (Pre: $M=3.29$, $SD=1.056$, Post: $M=3.70$, $SD=1.005$, $t(48)=-3.242$, $p<.01$).

Pupils' view on success in mathematics was studied through four statements: *I can get good grades in math*, *I am sure that I can learn math*, *I know I can do well in math*, and *I think I could handle more difficult math*. The sum variables for difficulty were highly reliable (Pre: $\alpha=.77$, Post: $\alpha=.73$). On average, pupils view on success is positive. Yet again, the development is negative on a statistical level (Pre: $M=3.36$, $SD=.746$, Post: $M=3.07$, $SD=.757$, $t(48)=2.794$, $p<.01$).

See the results on sum variables in Table 1.

Table 1: Descriptive statistics, sum variables

	Mean		Median		Mode		St. Deviation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ability	3.40	3.02*	3.5	3.0	3.8	3.0	0.861	1.125
Effort	3.29	3.16	3.5	3.0	3.0,3.75	3.0	0.853	0.784
Enjoyment	2.66	2.41*	2.9	2.4	3.14	1.4,2.0,2.43	0.966	0.865
Difficulty	3.29	3.70**	3.0	4.0	3.0	4.0	1.056	1.005
Success	3.36	3.07**	3.5	3.0	3.0	3.0	0.746	0.757
* Difference is fairly significant, $p<.05$ (2-tailed); ** Difference is significant, $p<.01$ (2-tailed)								

Individual statements

In this part, I will look more closely to the individual statements, starting with ability. Pupils' view of their ability in mathematics was studied through four statements (see Table 2). The results show that the pupils' view on their ability in mathematics has developed negatively across all the four statements. Although still on the positive side, the development is significantly negative with the statement *Math has been my worst subject* (Pre: $M=2.04$, $SD=1.148$, Post: $M=2.71$, $SD=1.597$, $t(46)=-2.985$, $p<.01$). The development with the statement *I am no good in math* has shifted from the positive to the negative side with a moderate significance rate (Pre: $M=2.90$, $SD=1.026$, Post: $M=3.33$, $SD=1.155$, $t(47)=-2.601$, $p<.05$).

Pupils' view of their effort in mathematics was studied through four statements (see Table 2). The results show that the pupils think that they have worked relatively hard on mathematics but their effort between the pre- and the post-questionnaire has decreased. However, similarly as with the sum variable, the differences between the pre- and post-questionnaire are not significant. In fact, the statement *I have not worked hard enough* does not even correlate significantly between the two measurements, indicating that the possible changes were highly dependent on the individuals.

Pupils' enjoyment of mathematics was studied through six statements (see Table 3). The development during the school year has been negative across all the six statements. The negative change has been

Table 2: Descriptive statistics: ability and effort

Ability	Mean		Median		Mode		St. Deviation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
I am no good at math	2.90	3.33*	3	3	3	3	1.026	1.155
I am not the type to do well in math	3.00	3.23	3	3	3	2	1.052	1.225
Math has been my worst subject	2.04	2.71**	2	2.5	1	1	1.148	1.597
I have made it well in math	3.58	3.29	4	3	4	4	1.007	1.080
Effort	Mean		Median		Mode		St. Deviation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
I am hard-working by nature	3.51	3.39	4	3	4	3	1.043	1.096
I have not worked hard enough	2.57	2.60	2	2.5	2	2	0.979	1.047
I have worked hard to learn math	3.21	2.94	3	3	3	3	1.020	0.966
I always prepare myself carefully for exams	2.96	2.87	3	3	3	3	1.129	0.969
* Difference is fairly significant, $p<.05$ (2-tailed); ** Difference is significant, $p<.01$ (2-tailed)								

fairly significant with the statements *Mathematics is a mechanical and boring subject* (Pre: $M=3.16$, $SD=1.143$, Post: $M=3.55$, $SD=1.209$, $t(48)=-2.395$, $p<.05$) and *Mathematics has been my favourite subject* (Pre: $M=1.96$, $SD=1.079$, Post: $M=1.55$, $SD=0.818$, $t(48)=2.369$, $p<.05$). However, the statement *Mathematics has been my favourite subject* does not correlate between the two measurements indicating that the change, even though significant, was not very linear.

Table 3: Descriptive statistics: enjoyment, difficulty, and success

Enjoyment	Mean		Median		Mode		St. Deviation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
It has been boring to study mathematics	3.48	3.73	3	4	3	3,4,5	1.031	1.031
Doing exercises has been pleasant	2.80	2.59	3	2	3	2	1.118	0.998
Mathematics is a mechanical and boring subject	3.16	3.55*	3	4	3	4	1.143	1.209
I have enjoyed pondering mathematical exercises	2.63	2.53	3	2	3	2	1.074	1.120
	2.63	2.51	3	2	3	2	1.149	1.043
Mathematics has been my favourite subject	1.96	1.55*	2	1	1	1	1.079	0.818
Mathematics has been the most unpleasant part of studying	2.78	3.06	3	3	2	4	1.295	1.375
Difficulty	Mean		Median		Mode		St. Deviation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mathematics is difficult	3.12	3.59**	3	4	3	4	1.130	1.189
Learning mathematics requires a lot of effort	3.42	3.82*	3.5	4	4	4	1.164	1.014
Success	Mean		Median		Mode		St. Deviation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
I can get good grades in math	3.80	3.38*	4	3	4	3,4	0.935	1.123
I am sure that I can learn math	3.76	3.50	4	4	4	4	0.969	0,825
I know I can do well in math	3.28	2.96	3	3	4	3	1.057	1.083
I think I could handle more difficult math	2.56	2.42	3	2	3	2	0.956	1.028

* Difference is fairly significant, $p<.05$ (2-tailed); ** Difference is significant, $p<.01$ (2-tailed)

Pupils' view on the difficulty of mathematics was studied through two statements (see Table 3). Pupils experienced that mathematics is difficult and requires a lot of effort. Their view developed negatively between the pre- and post-questionnaire (Pre: $M=3.12$, $SD=1.130$, Post: $M=3.59$, $SD=1.189$, $t(48)=-3.036$, $p<.01$; and Pre: $M=3.42$, $SD=1.164$, Post: $M=3.82$, $SD=1.014$, $t(47)=-2.276$, $p<.05$ respectively), the development being significant and fairly significant, respectively.

Pupils' view on success in mathematics was studied through four statements (see Table 3). The pupils thought that they can get good grades in mathematics (Pre: $M=3.80$, $SD=0.935$, Post: $M=3.38$, $SD=1.123$), and they were sure they can learn mathematics (Pre: $M=3.76$, $SD=0.969$, Post: $M=3.50$, $SD=0.825$). However, they did not believe they could handle more difficult mathematics (Pre: $M=2.56$, $SD=0.956$, Post: $M=2.42$, $SD=1.028$). The changes were negative across all the statements but only *I can get good grades in math* was fairly significant ($t(47)=2.275$, $p<.05$). However, it did not correlate significantly between the measurements indicating that the change was not very linear.

Discussion

The results on pupils' view of themselves as learners of mathematics show that, on average, pupils view their ability, effort, and success in mathematics as slightly positive, but mathematics is seen as difficult, and the pupils do not enjoy it. These results are in line with previous research that shows Finnish pupils' very negative mathematics-related affect (Mullis et al., 2020; Metsämuuronen & Nousiainen, 2021). Unfortunate is the development of these views: pupils' views developed negatively over the span of the school year. Most significantly descended their views on the difficulty of mathematics and success in mathematics. Pupils' view on their ability in and enjoyment of mathematics developed negatively as well, but their effort remained statistically on the same level. These results indicate that, unlike previous research results (Liljedahl, 2021; 2014; 2019), the intervention was not successful in transforming the negative, descending trend of Finnish pupils' attitudes in lower secondary school (see Metsämuuronen & Tuohilampi, 2014).

What makes the study interesting, is the effect of the pandemic. During the last two months of the study, the schools were closed. The second measurement was directly after the pupils returned to their schools. A recent national study indicates that after the school lockdown, pupils' self-efficacy beliefs in mathematics lowered especially in high-performing pupils (Metsämuuronen & Nousiainen, 2021). However, the same study shows also that pupils like mathematics slightly more than before the pandemic. Furthermore, the participating teachers in the problem-solving intervention reported that the collaborative problem-solving had had a positive influence on their pupils' learning and affect (see Viitala, 2022). Unfortunately, the data does not tell if the teachers misinterpreted their observations or was the effect of the intervention indeed positive until the exceptional circumstances caused by the pandemic. The negative effect of the lockdowns on young people's wellbeing is well recognised. Hence, the remaining question is, how much did the pupils' fresh experiences from the lockdown influence the results? This question requires further studies with new intervention groups.

This study has some further limitations than the effect of the pandemic. Another limitation is that there were no control groups in the study. Furthermore, as improving pupils' learning and affect in mathematics are in the centre of the project aim, pupils should be interviewed regularly throughout the intervention. To address these limitations, a new intervention with control groups and a shift in

focus is needed. The reported study was a pilot study with a main objective to study the teachers and their professional development. In future reports, the questionnaires on pupils' mathematics-related affect will be analysed from the viewpoints of goal orientations and group work, and their mathematics performance will be evaluated from pre- and post-tests.

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