THE RESTRICTED YET CRUCIAL IMPACT OF AN INTERVENTION ON PUPILS' MATHEMATICS-RELATED AFFECT

Laura Tuohilampi, Liisa Näveri, Anu Laine
University of Helsinki

Past research clearly indicates that students' mathematics-related affect develops destructively during school years. However, not many efficient interventions have been done. The efficiency of the interventions may become minor if other factors dominate the development of affect structures. Also the methods in order to measure the impact might be insufficient. However, the negative development of affect must be taken seriously. Especially the most harmful consequences, such as girls' unnecessarily poor self-efficacy, needs to be tackled. Here, we present a three-year intervention designed to improve primary school pupils' problem solving skills, and consequently mathematics-related affect. The impact was restricted but crucial: girls' affect regarding mathematics decreased less in the intervention group.

Key words: Mathematics-related affect, Gender differences, Development of affect, Intervention

BACKGROUND

Numbers of studies show that students end up having an unnecessary negative affect towards mathematics when they leave school (Lee, 2009; Tuohilampi & Hannula, 2013; Hirvonen, 2012). In addition, affect develops destructively: children tend to have very positive affect (e.g. they view the learning subjects enjoyable, and see themselves very capable) when they come to school (Tuohilampi, Hannula, & Varas, 2014; Harter, 1999), but during the school years the affect turns negative (the enjoyment turns into dislike, the feelings of capability decreases) and harmful for learning (Tuohilampi, Hannula, Laine & Metsämuuronen, 2014). Especially girls suffer from having negative emotions towards mathematics already after first three years of schooling. Also girls' self-efficacy has been noticed to be unnecessary low: even when performing well, a girl might feel incapable in mathematics (Tuohilampi, Hannula, Laine & Metsämuuronen, 2014). The presented development is to some extent natural, as it is indeed necessary for children to get social responses, including negative ones, in order to be able to modify their self-concept. After an almost omnipotent view of the self in the childhood (Harter, 1999), a certain number of negative, significant responses contribute to a more realistic self-view. When it comes to mathematics, the worrying thing is that the students do not become only realistic, but also remarkably negative. Unfortunately, having negative affect towards mathematics makes people avoid such future choices where mathematics is included (Tuohilampi & Hannula, 2013). Further, there is some evidence that negative affect connects with poor participation with other students and learning activities (Kirshner, 2014). In addition, students' poor wellbeing, such as a negative self-concept in mathematics or disaffection (see Lewis, 2014), should be significant per se.

Tuohilampi, Hannula, Laine & Metsämuuronen (2014) noticed in their recent study of Finnish students that the deterioration of mathematics-related affect begins very early, already after 3rd school year. It is particularly interesting that this happens in Finland that has a reputation of a remarkable performance level acknowledged by national studies (e.g. Metsämuuronen, 2013), and by international studies (PISA-studies, see e.g. OECD 2010): this makes Finnish primary school pupils an interesting population when it comes to examine how to prevent the deterioration. Letting the affect become negative in the first place is particularly problematic, as repairing it has noticed to be hard work (Hannula, 2006). Also, cumulative disappointments can lead to the cycles of failure, fear, the expectancies of failure and test anxiety (Pekrun, 2006). This is why it would be wise to concentrate on maintaining the affect as positive as possible throughout the school years, with a special focus on the early school years.

Most mathematics-related interventions seem to concentrate on performance or cognitive problems, such as dyscalculia (see a review of mathematics-related interventions in Dowker, 2009). Fewer interventions have been done to improve affect. These interventions have had a focus on students' self-control, and social interaction. For example, in an intervention by Rimm-Kaufman et al (2014) there was a Responsive Classroom approach (RC) in use, aimed to foster relationships in the classroom and support students' self-control to enhance student achievement. This goes in line with the studies of Pekrun (2006), who has introduced control to be one of the defining elements of optimal affect structure and its development. For example, Pekrun (ibid.) argues that when the learning demands exceed pupil's individual capacities, she/he loses her/his control over the activity. This may lead the pupil to reduce the value of the activity in question, and make the experience boring. Finally, boredom may reduce the pupil's engagement with the activity by decreasing the effort one puts in an activity, consequently reducing future success.

Having control over the action (action-control expectancies) and trusting that the action will lead to the expected outcome (action-outcome expectancies) are the key elements in Pekrun's (e.g. 2006) control-value theory of achievement emotions. When it comes to mathematics, one cannot always see the path to the outcome at the beginning. Thus, in mathematics a certain degree of resilience and tolerance towards mistakes might be necessary. However, the pupils should experience their actions effective. This can be done by allowing the pupils to proceed through small and various steps. Pupils should have the expectation that their efforts are worth to be done. If the tasks would allow different strategies in order to find the solution, many of the pupils' efforts would be beneficial. That is how they can have action control expectancies. On the contrary, there are less action-control expectancies if the pupils just either know or do not know the only possible solution. The expectancies the pupils have also connect with the amount and quality of responses the pupils get from their significant others. If it is a clear cut that a pupil either knows or does not know the solution, the evaluation the pupils make about themselves may become very polarized. Some pupils can make it, some pupils cannot. If, on the other hand, there are plenty of possibilities to proceed within the tasks, and the steps are small enough, it should be more likely that every once in a while even the weakest pupils succeed, and the strongest pupils make an incorrect effort. In such circumstances, the peer evaluation becomes versatile, and the responses the pupils get from their efforts diverse. That in turn plays a role on pupils' affect structure construction.

In addition to control and social interaction, improving mathematical understanding may be one path to achieve more positive affect: in a longitudinal study of Tuohilampi & Hannula (2013), high performance was the biggest cause of positive affect in future. These three elements connected with the optimal affect structure development suggest that an intervention could, or even should include the following goals: 1) minimize negative responses that are unconstructive, 2) give students possibilities to control their actions and 3) support students' understanding about the content of learning. However, even a good intervention faces a challenge of affect structure's resilience, as the dispositions of the students are noticed to be fairly robust. Chapman (2002) for example has shown that there is a need for open conflict that is meaningful to the holder before a change in the affect structure is likely.

One way to reach the presented three intervention goals is to use open ended problems. In such problems, more than one solution can be possible, and to find a solution, pupils need a linear or a cycling problem solving process where they use their resources, heuristics, beliefs, and abilities of monitoring and self-regulation (Schoenfeld, 2012). Because of the nature of the open ended problems, there are usually many opportunities where to start and how to proceed. Following that, there is typically at least something a pupil can initiate and perform. In addition, because of the several options of how to find an answer (or answers), the pupils' own actions ought to produce a positive outcome in most cases. Thus, using open ended problems should lead to high action-control expectancies, as well as high action-outcome expectancies (Pekrun, 2006), and consequently, the possibilities to control actions and learning is guaranteed to the pupils (the intervention goal number 2). These elements, on the other hand, widen the strategy options and thus decrease the number of ”wrong choices”. Following that, the negative responses from significant others regarding pupils' actions could be minimized (the intervention goal number 1). Open ended problems may also enhance pupils' understanding as they allow connections to several or untypical contexts. A traditional instruction, wherein specific learning content is mostly connected with the same, isolated context makes pupils' knowledge structures fragmented, and does not help pupils to generalize their thinking. In their study about students' conceptions Saglam, Karaaslan, and Ayas (2010) show that fragmented, isolated knowledge structures, produced by restricted contexts, cause students to fall short in solving problems across contexts. Thus, the use of open ended problems having less limited contexts may help pupils to create deeper and more applicable understanding (the intervention goal number 3). In this study, we report how an intervention that is built around open ended problems, guaranteeing the three intervention goals presented above impacts primary school pupils' affect structure development.

INTERVENTION

Here, we examine a three-year intervention from 3rd to 5th grade which included a monthly activity with a mathematical problem. The problem was in most cases an open ended and they were selected or developed by the research group. The teachers were allowed and instructed to execute the problem solving sessions according to their preferences. In most cases, the teachers used collective activities wherein pupils were allowed to discuss the problems, to move, and to work collaboratively.

We will introduce two of the problems that were used during the intervention. The first one to be presented is ”Divide a square: Make such a division to a square that makes the two parts of the square totally equal. How many different solutions can you find?” This problem was implemented in the 3rd grade and it was the second problem in the project. In the pupils' solutions, five levels of thinking were present: level 0 = no solution; level 1 = the two most obvious solutions (two triangles and two rectangles); level 2 = division by a straight line that is not diagonal, nor passes the middle points of the sidelines of the square; level 3 = the thinking of level 2, replacing the straight line with a curve; and level 4 = clearly understanding the central symmetry of the task (Laine, Näveri, Pehkonen, Ahtee, Heinilä & Hannula, 2012). Because of the five levels of understanding, the active nature of the task (a pupil could easily just use a pen to figure out the solutions), and the collaboration the pupils were allowed to have during the task, the intervention goals presented above were fulfilled. The second problem to be presented here is ”*Etana-Elli (= a snail called Elli): Etana-Elli climbs up a wall very slowly. During some of the days she gets up 10 cm, during some of the days 20 cm, during some days she sleeps and does not move, and during some days she is in a very deep sleep and descends 10 cm. The wall is 100 cm high. After ten days of climbing, Etana-Elli is on a halfway of the wall (which means that she has mounted 50 cm).What could have happened during the first 10 days? Describe as many scenarios that are possible.*” This problem was implemented in 4th grade being the 7th problem in the project. Also in Etana-Elli -problem the pupils could easily initiate actions, and several solutions were possible. Thus the intervention goals got fulfilled within the problem.

METHOD

The data used in this study was gathered within a research project that aimed to develop mathematics learning and affect structure among pupils in Finland and Chile (see further description of the project in Laine, Näveri, Pehkonen, Ahtee, Heinilä & Hannula, 2012). Here, we focus on Finnish pupils' data, wherein the number of pupils that participated either the pre-test, the post-test or both tests was 320. The pre-test data was collected in regions near to Helsinki at the beginning of the academic year 2010-2011 during September-October 2010. The post-test data was collected within the same classes at the end of the academic year 2013-2014 during April-May. The schools are fairly uniform in Finland (see OECD, 2010, p. 87), so the data can be considered representative to urban pupils in Finland. In the pre-test, there were 25 classes involved. 10 out of these classes were intervention groups, the rest of them being control groups. In the post-test, six control groups were not reached and three intervention groups had left the project (they quit doing the tasks, but yet participated in the post-test). Among the three classes that quit, one had participated in the project for two years whereas the other two had participated only one year. We decided to include the class that had participated for two years (i.e. more than 50 % of the intervention tasks) but exclude the classes that had been participating just one year (i.e. less than 50 % of the tasks). Moreover, there was a teacher change in two of the included intervention groups, and some movement regarding the pupils had happened, as there were pupils in the pre-test but not in a post-test and vice versa: those pupils' data were excluded from the analysis. In sum, we included in the data pupils who had participated in all the intervention tasks or at least 2/3 of them, and that had participated both of the measurements, but might have had a new teacher during the intervention.

The following factors of affect were measured in the questionnaire: self-competence, (spice item: "I have made it well in mathematics"), self-confidence ("I am sure that I can learn math"), the difficulty of mathematics, referred to as DoM ("Mathematics is difficult") representing cognitive dimension; the enjoyment of mathematics, referred to as EoM ("I have enjoyed pondering mathematical exercises") representing emotional dimension; mastery goal orientation, referred to as MGO ("On every lesson, I try to learn as much as possible") representing motivational dimension; and effort ("I always prepare myself carefully for exams") representing behavior. The purpose of the instrument was to catch the trait aspect of affect (see discussion on the cognitive, emotional and motivational dimensions, and the state - the trait aspects of affect in Hannula 2011). The instrument was a shortened and simplified version of the instrument used by Hannula & Laakso (2011) to measure 4th grade Finnish pupils. The instrument worked well in that context and seemed suitable for measuring mathematics-related affect within Finnish population. In the instrument there was a 3-point Likert scale in use ("true", "partly true", "not true"). Bearing in mind that the pupils were just 9-year old in the pre-test it was justified to use only three points, as this makes the instrument simpler. The scale is an ordinal scale, as the middle option, "partly true", may situate differently between the two ends depending on the examinee. In the questionnaire some of the items were direct (e.g. "I have made it well in mathematics"), while some were indirect (e.g." I am not very good in mathematics"). For the analysis, the items that had an inverse content were recoded to share the same direction with directly stated items.

Before starting the analysis, we constructed a sum variable of all the questionnaire items regarding both measurements. The reliabilities (measured by Cronbach alpha's) were satisfactory: $\alpha = .895$ in the pre-test and $\alpha = .858$ in the post-test. To find out the answer to our research problem, we calculated the distributions of pupils' affect within both measurements. A paired sample t-test was used to compare the means of the distributions regarding the two measurements and an independent sample t-test was used to compare the means of the distributions regarding intervention and control groups and genders.

RESULTS

In Table 1, there are the distributions of all items' sum variable regarding all pupils, intervention group, and control group.

	Group	Positive	In between	Negative	N
Pre-test, all items	All pupils	168 (75,3%)	54 (24,2%)	1(0,4%)	223 (100%)
Post-test, all items	All pupils	90 (32,4%)	186 (66,9%)	2(0,7%)	278 (100%)
	Intervention group	41 (33,9%)	80 (66,1%)	0 (0%)	121 (100%)
	Control group	49 (31,2%)	106 (67,5%)	2 (0,4%)	157 (100%)

Table 1: Distributions regarding all pupils, intervention group, and control group

The mean of all items for all pupils in the pre-test was 1,37 (1 = positive, 3 = negative), and the standard deviation was 0,30. In the post-test, the mean of all items for all pupils was 1,64, the standard deviation being 0,29. In a paired samples' t-test there was a statistically significant difference between the pre-test and post-test regarding all the pupils ($t(193) = -11.88$; $p < .000$), the intervention group ($t(108) = -9.72$; $p < .000$), and the control group ($t(84) = -6.98$; $p < .000$). The results indicate that there is a remarkable decline in pupils' affect regarding mathematics from the beginning of the 3rd to the end of the 5th grade in both the intervention group and control group.

When it comes to the differences between the intervention and the control group, no statistically significant difference was found with respect to all items in post-test ($t(276) = -.67$; $p = .505$). Looking further at the differences between the groups factor by factor in post-test did not change the picture: $t(287) = -.06$, $p = .954$ regarding self-competence; $t(294) = -.79$, $p = .433$ regarding self-confidence; $t(290) = -1.50$, p

= .134 regarding the difficulty of mathematics; $t(290) = 0.62$, $p = .533$ regarding the enjoyment of mathematics; $t(294) = -.57$, $p = .571$ regarding mastery goal orientation; and $t(290) = .62$, $p = .536$ regarding effort. Besides the non-significance between the groups, no trend was found regarding the minor differences regarding the different variables, as with respect to one variable the mean could be lower for the control group, but with respect in another the mean could be lower for the intervention group.

When it comes to the gender differences, we still did not find any significant differences in either of the tests (gender difference in pre-test: $t(122) = 1.05$, $p = .295$; gender difference in post-test: $t(140) = 1.57$, $p = .118$). However, when testing the control group's and intervention group's difference in the post-test separately to genders, a statistically significant difference was found regarding girls' development (girls: $t(67) = 2.08$, $p < .05$; boys: $t(87) = .42$, $p = .634$). The mean of the control group girls in the post-test was 1.82, and for the intervention group girls 1.65. This means that the girls had benefitted from the intervention, but not boys. The significance in the development came through two factors: self-confidence (t(729 = 2.39, $p < .05$), and EoM ($t(72) = 2.47$, $p < .05$).

DISCUSSION

We have reported the impacts of a three-year intervention aimed to improve primary school pupils' mathematics-related affect through focusing on pupils' control on their learning, social interaction, and mathematical understanding. According to our results, the impact was not as strong and widespread as one would have hoped. For the sake of future interventions sharing the same goal, it is necessary to gain knowledge about why it had such a minor impact. Even the effects of a well-designed intervention may become disguised by other features in school, more significant to the pupils. As Chapman (2002) has shown, a significant conflict is needed to allow affect structure to become reorganized. The pupils in an intervention may get positive experiences, yet those experiences might be less significant than school expectancies, peers' perceptions, or teacher's actions effect. The other perspective is the method used here. Perhaps a questionnaire based quantitative data does not reveal all the possible nuances that might have been affected during an intervention. A mixed method approach could be advisable. However, as there was no significant difference between the whole intervention and control groups, it seems likely that a stronger change in the practices is needed. In our intervention, there was a monthly problem solving class for three years. Maybe the amount of doing was too little for the pupils, or maybe such classes would need different school culture to be more effective. For example, pupils in Finland do not rate their learning environment as positive as their mates in other cultures do (Tuohilampi, Laine, Hannula, & Varas, submitted). Thus, pupils in Finnish classes might need support to become effective with working socially among problem solving. The intervention presented here would possibly have become more efficient if there had been more support for pupils to become socially active.

The benefit for girls in the intervention related to their self-confidence and enjoyment of mathematics. This is extremely critical, as girls suffer poor and unrealistic mathematical self-confidence worldwide (Syzmanowics & Furham, 2011) and in Finland (Tuohilampi & Hannula, 2013). This makes girls avoid mathematics in future (ibid.), so even the impact was restricted on girls, it was extremely welcome. Girls' emotions towards mathematics have also been critical (ibid.), and it is delighting that the intervention could help girls to maintain their emotions more positive. Hannula, Kupari, Pehkonen, Räsänen & Soro (2004) have presented that collaborative atmosphere and learning methods connect with increasing self-confidence and mathematical performance especially regarding girls. This seems natural, as while girls feel less confident with mathematics in general, they might find it helpful to work in co-operation with others. Thus the benefit for girls might have come through the increase in collaboration. To give some critique, one has to be reminded that making several t-tests may lead to misleading statistical significances raised just by a coincidence. However, what the girls benefit is in line with their needs, and the p-values were very near to $p < .01$.

This study has given us the insights of the possibilities and the restrictions an intervention may have. We continue to work with the rich data collected during the research project to contribute our knowledge of the development of mathematics-related affect in even more nuanced ways.

REFERENCES

Chapman, O. (2002). Beliefs structure and inservice high school mathematics teacher growth. In G. C. Leder, E. Pehkonen & G. Törner (Eds.), *Beliefs: A Hidden Variable in Mathematics education?* (pp. 177-193). Kluwer Academic Publishers, The Netherlands.

Dowker, A. (2009). What Works for Children with Mathematical Difficulties? Univeristy of Oxford. Retriewed from: http://www.nationalnumeracy.org.uk/resources/22/index.html

Hannula, M. S. (2006). Affect in mathematical thinking and learning. In J. Maasz, & W. Schloeglmann (Eds.), *New mathematics education and practice* (pp. 209-232). Sense Publishers, Netherlands.

Hannula, M. S. (2011). The structure and dynamics of affect in mathematical thinking and learning. In M. Pytlak, T. Rowland, & E. Swoboda (Eds.), *Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education* (pp.34-60). Rzeszów, Poland: ERME.

Hannula, M. S., Kupari, P., Pehkonen, L., Räsänen, P., & Soro, R. (2004). Matematiikka ja sukupuoli. In P. Räsänen, P. Kupari, T. Ahonen, & P. Malinen (Eds.), Matematiikka – näkökulmia opettamiseen ja oppimiseen. Jyväskylä, Finland: The Niilo Mäki Institute.

Hannula, M. S. & Laakso, J. (2011). The structure of mathematics related beliefs, attitudes and motivation among Finnish grade 4 and grade 8 students. In B. Ubuz (Ed.), *Proceedings of the 35th conference of the international group for the psychology of mathematics education, Vol. 3*, (pp. 9–16). Ankara, Turkey: PME.

Harter, S. (1999). *The construction of the self. A developmental perspective*. New York, NY: The Guildford Press.

Hirvonen, K. (2012). *Onko laskutaito laskussa? Matematiikan oppimistulokset peruskoulun päättövaiheessa 2011*. Helsinki, Finland: The Finnish National Board of Education.

Kirshner, D. (2014). The remarkable pedagogy of Chistopher Healy. In: P. Liljedahl & C. Nicol (Eds.) *Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education, Vol. 5.* (). Vancouver, Canada: PME.

Laine, A., Näveri, L., Pehkonen, E., Ahtee, M. Heinilä, L., & Hannula, M.S. (2012). Third-graders' problem solving performance and teachers' actions. In T. Bergqvist (ed.)*: Proceedings of the ProMath meeting in Umeå*, (pp. 69–81). University of Umeå.

Lee, J. (2009). Universals and specifics of math self-concept, math self-efficacy, and math anxiety across 41 PISA 2003 participating countries. *Learning and Individual Differences 19*, 355-365.

Lewis, G. (2014). The incidence of disaffection with school mathematics. In: P. Liljedahl & C. Nicol (Eds.) Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education, Vol. 4. (122-129). Vancouver, Canada: PME.

Metsämuuronen, J. (2103). Matemaattisen osaamisen muutos perusopetuksen luokilla 3-9. In: J. Metsämuuronen (Ed.). Perusopetuksen matematiikan oppimistulosten pitkittäisarviointi vuosina 2005−2012. National board of education. Finland.

OECD (2010), *PISA 2009 Results: What students know and can do – Student performance in reading, mathematics and science (Volume I).* Retrieved from: http://www.oecd.org/pisa/pisaproducts/48852548.pdf

Pekrun, R. (2006). The Control-Value Theory of Achievement Emotions: Assumptions, Corollaries, and Implications for Educational Research and Practice. *Educational Psychology Review (18)*, 315-341.
DOI: 10.1007/s10648-006-9029-9

Rimm-Kaufman, S. E., Larsen, R. A. A., Baroody, A. E., Curby, T. W., Ko, M., Thomas, J. B., Merritt, E. G., Abry, T., & Jamie DeCoster, J. (2014). Efficacy of the Responsive Classroom Approach: Results From a 3-Year,

Longitudinal Randomized Controlled Trial. *American Educational Research Journal 51*(3), 567–603.
DOI: 10.3102/0002831214523821

Saglam, Y., Karaaslan, E. H., & Ayas, A. (2010). The impact of contextual factors on the use of students' conceptions. *International Journal of Science and Mathematics Education (9)*, 1391-1413.

Schoenfeld, A. H. (2012). How we think: a theory of human decision-making, with a focus on teaching. 12th International Congress on Mathematical Education. Retrieved from:
http://www.icme12.org/upload/submission/1900_f.pdf

Syzmanowicz, A. & Furnham, A. (2011). Gender differences in self-estimates of general, mathematical, spatial and verbal intelligence: Four meta analyses. *Learning and Individual Differences 21*(5), 493–504.

Tuohilampi, L. & Hannula, M. (2013). Matematiikkaan liittyvien asenteiden kehitys sekä asenteiden ja osaamisen välinen vuorovaikutus 3., 6. ja 9. luokalla. In J. Metsämuuronen (Ed.). *Perusopetuksen matematiikan oppimistulosten pitkittäisarviointi vuosina 2005−2012.* National board of education. Finland.

Tuohilampi, L., Hannula, M. S., Laine, A., & Metsämuuronen, J. (2014). Examining mathematics-related affect and its development during comprehensive school years in Finland. In: P. Liljedahl & C. Nicol (Eds.) *Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education, Vol. 5.* (281-288). Vancouver, Canada: PME.

Tuohilampi, L. & Hannula, M., & Varas, L. (2014). 9-year old students' self-related belief structures regarding mathematics: a comparison between Finland and Chile. In M. Hannula, A. Laine (Eds.): *Proceedings of the 18th Conference of the Mathematical Views*. Helsinki, Finland: MAVI.

Tuohilampi, L., Laine, A., Hannula, M., & Varas, L. (submitted). A comparative study of Finland and Chile: The culture-dependent significance of the individual and the interindividual level of mathematics-related affect. Submitted to: *International Journal of Science and Mathematics education*.