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Lower secondary school students' conceptions about their effort in mathematics education

Lovisa Sumpter [1]*, Astrid Pettersson [1], Samuel Sollerman [1]

[1] Department of Teaching and Learning, Stockholm University, Stockholm, SWEDEN
***Corresponding Author:** lovisa.sumpter@su.se

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ABSTRACT

Previous research has shown the importance of affect when seeking knowledge about students' achievements. However, there are surprisingly few studies looking at students' expressed effort on a longer time scale. Using data spanning over almost three decades, in this paper, we analyze Swedish lower secondary school students' responses to items in relation to large-scale assessments in 1992, 2003, and 2019. The two general results were that students express a lower level of goal-directed motivation, whereas the responses regarding students' motivation as an evaluation of effort, most students state that they do not give up when facing a difficult task, that they would learn more and do better if they put more effort into their studies, and that they are happy with their achievement. Looking at changes between the different years, several items show a significant difference in the Swedish students' answers between 1992 and 2003 and no difference by 2019. The results might explain the changes in achievement that took place between 1992 and 2003.

Keywords: evaluation of effort, large-scale assessment, lower secondary school, mathematics, motivation

INTRODUCTION

The importance of affect such as conceptions, self-beliefs, motivation, and attitudes as a factor for students' mathematical achievement has been in focus for studies for decades (e.g., Guimond & Roussel, 2001; Hannula, 2006; Pajares, 2003; Ryan & Deci, 2000; Stage & Kloosterman, 1995; Valentine et al., 2004; Zimmerman et al., 1992). The conclusion can be reduced to 'what you think about yourself and your ability to play part when solving mathematical problems'. The impact works in both directions: positive attitude can boost performance, and negative conceptions can function as an obstacle and contribute to low performance (Capuno et al., 2019). A detailed analysis of students' arguments illustrates how impactful affective constructs can be, including how to decide on which strategy choice to use based on what can be considered safe and determine what is possible to do with respect to motivation (Sumpter, 2013). Furthermore, students with positive intrinsic motivation are inspired, expressing a wish and a strive to learn (Ryan & Deci, 2000): the feeling of success or failure is important for motivation and related conceptions since emotions are the most direct link to motivation, manifested either in positive or negative feelings (Hannula, 2006; Sumpter & Sollerman, 2023). When adding that students' conceptions reflect their experiences of mathematics education (Pehkonen, 2001), the conclusion is that how you perceive an educational situation with respect to your motivation and your emotions sets the arena for the individual learner. Thus, it is relevant to study different aspects of students' affective world to gain knowledge on how students perceive mathematics education.

Research about affect is also important since affect is seldom static and often culturally bounded, meaning that it changes between cultures but also within a culture (Niemivirta et al., 2024; Sumpter & Sollerman, 2023). Hence, there are patterns in affect where some are general, cross-cultural, some national, and some related to micro-climates. Looking at some general patterns, we find studies from different countries, such as the Philippines (Capuno et al., 2019), Kazakhstan (Karjanto, 2017), and Turkey (Sirmaci, 2010) that signal that there is a positive correlation between the attitudes of the students and their achievement in mathematics meaning that some aspects appear to be general over the borders. One example is the research into students' interest in and motivation for mathematics, where results show that it is inversely proportional to years of schooling (e.g., Blomqvist et al., 2012; Hannula, 2006). However, to our best knowledge, many of these studies are often small, and few look at patterns over a large number of years. Studies of this kind are often qualitative, with few respondents, and the larger studies on affective factors like emotion primarily cover teenagers or adults (Dowker et al., 2019), where most studies tend to focus on anxiety (e.g., Batchelor et al., 2019; Lewis, 2013; Valiente et al., 2012). A study from Finland shows that key aspects of students' mathematics motivation decreased over time and across different age cohorts (Metsämuuronen, 2013). Another study, also over a relatively shorter timeframe (four years), looking at Swedish students using data from TIMSS shows that negative emotions, including negative motivations, increased with age, and there were gender differences (Sumpter & Sollerman, 2023). The results indicated that girls might be more likely to form negative emotional directions towards mathematics between grades 4 and 8, and more so compared to boys. Again, although these studies used data from different years that have some age differences, these two studies are still within a few years of data collection, relatively speaking. Batchelor et al. (2019) concluded in 2019 that few studies can explain if and how these phenomena develop over a long period of time. In our review, we have not found one single study spanning over a longer period of time.

At the same time, over the years, many countries have seen a decline in mathematics performance in recent years (OECD, 2019; von Davier et al., 2024), making it relevant to study students' interests using large-scale data to see if the results can function as an explanation model for the decline of performance. It is, therefore, of interest to study students' conceptions within a cultural context for a long period of time to see what stable/static and what changes is. The aim of the present study is to study lower secondary school students' conceptions about their effort in mathematics. The research questions are as follows:

1. How do students express their effort in mathematics as aspects of motivation?
2. How do students' expressed conceptions about their effort change over time?

BACKGROUND

A commonly used definition of conceptions in mathematics education research is the one provided by Thompson (1992), who describes conceptions as "conscious or subconscious beliefs, concepts, meanings, rules, mental images, and preferences" (Thompson, 1992, p. 132). Similar ontological and epistemological roots can be found in the definition suggested by Philipp (2007), who refers to Thompson's (1992) work when saying that conception is "a general notion or mental structure encompassing beliefs, meanings, concepts, propositions, rules, mental images, and preferences" (Philipp, 2007, p. 259). We follow this description, and conception is defined here as an abstract or general idea with both affective and cognitive dimensions, inferred or derived from specific instances. Hence, students' conceptions consist of their belief systems, preferences, and so forth, reflecting their experiences. Here, we are interested in conceptions about effort, meaning that their expressed conceptions mirror different aspects of motivation. Motivation can be framed theoretically in many ways, but a common starting point is to relate it to some goal (Nyman & Sumpter, 2019). Motivation is generally categorized into two main types: extrinsic and intrinsic motivation (Ryan & Deci, 2000). Within these categories, several subscales have been identified (Sumpter, 2013). For extrinsic motivation, we can distinguish between two types: outward motivation and compensation (Amabile et al., 1994). Outward motivation refers to social gains, while compensation involves personal gains. On the other hand, intrinsic motivation can be further divided into cognitive and emotional subscales (Nyman & Sumpter, 2019; Sumpter, 2013). In this context, motivation as a theoretical construct is closely linked to emotions. Each of the first three categories can be associated with specific emotions, whereas the fourth category–goals–can also be considered an emotion as a category itself. For example, one might say, "I am doing this because it is fun," or "I am doing this because it makes me happy." Then, the motivation expressed as a goal is based on an emotion. In the present study, we focus on students' conceptions of effort. Therefore, we interpret motivation as "the process whereby goal-directed activity is instigated and sustained" (Schunk et al., 2010, p. 4). Then, conceptions about effort reflect how an individual has experienced this particular process, including the goal itself.

As stated earlier, previous research on students' conceptions (or related constructs in affect) shows how and in what ways the impact can be. A qualitative study of Swedish upper secondary school students found three themes of indicated beliefs that often were expressed as arguments for choices made during task solving (Sumpter, 2013). The first theme was beliefs about safety, such as thinking that certain algorithms are safe to use, whereas constructing your own solutions strategy is not. The second theme was about different expectations, for instance, saying, 'I'm supposed to solve this task with this algorithm'. The third theme was beliefs about motivation, often negative ones, for instance, the idea that 'I can't construct my own reasoning'. Combining qualitative results such as these with results from quantitative studies showing that students doing well in mathematics most often have a positive attitude towards mathematics, and vice versa (e.g., Fredrickson et al., 2018; Garofalo & Lester, 1985; Valentine et al., 2004) signal the impact of affect. However, studies on this topic often focus on upper secondary school students and university students and not students in compulsory schooling, meaning that we need more information on students at lower secondary levels of education.

One study focusing on lower secondary school students is Sirmaci (2010), who got the responses from 190 students in grade 9. The results were significant when analyzing the relationship between students' attitudes and their performance in mathematics. A similar connection is confirmed by Capuno et al. (2019), who asked 177 grade 9 students about their study habits and attitudes toward mathematics. Their results showed that those respondents who expressed positive attitudes towards mathematics also expressed a more neutral conception when asked about self-confidence, enjoyment, and motivation in mathematics. However, their study reported a weak positive correlation between how mathematics is valued and academic performance in math, but the main conclusion of the results is that students' attitudes are linked to their performance. Concerning effort and the impact of stated effort and achievement, it has been shown that effort can explain between 32 and 38 percent of the variation when looking at countries participating in PISA (Zamarro et al., 2019). The researchers concluded that non-cognitive aspects such as affect capture important information that can function as a guide for policymakers if wanting to make changes in mathematics education.

METHODS

We will first present data collection, including the instruments that were used. Then, we present how the data was analyzed.

Data Collection

The data comes from three surveys: two national surveys in mathematics took place in 1992 and 2003, and one was part of TIMSS in 2019. The two national (Swedish) surveys were answered by grade 9 students (age–15-16 years old), whereas TIMSS was done at the end of grade 8 when students are around 15 years old; the average age of the Swedish cohort for TIMSS 2019 was 14.8 years. Since there is only a minor age difference, it is considered neglectable, and the assumption is that a comparison between results is possible. However, interpretations of the results should be done with care. The comparison is possible because of the opportunity to add national survey items to TIMSS. This entails two things:

(1) the items have been tested and validated several times and

(2) the long period means there have been four different curriculums in Sweden.

It should be stressed that the present paper does not try to measure the outcome of these different curricula; it is not within the scope of this study. The data is unique since the implementation of the items in TIMSS was only this specific year. Hence, we do not know of any other large-scale assessment in mathematics education that has generated such data.

We selected the items that were used in the three surveys and analyzed them using the revised definition of motivation for each of the items (e.g., Schunk et al., 2010). Four of the items measured evaluation of effort, and one item measured goal. The items that were selected for the study are presented in **Table 1**, here given the codes Q1-5, including the theoretical underpinning:

Table 1. Item and motivational dimension

Question	Item	Dimension of effort
Q1	I would like to learn more mathematics in school.	Goal-directed
Q2	Most of the time, I give up when I face a difficult mathematical task.	Evaluation of effort
Q3	I would have been better at mathematics if I tried harder.	Evaluation of effort
Q4	I have done my very best to learn mathematics.	Evaluation of effort
Q5	I am satisfied with my achievement in mathematics.	Evaluation of effort

Given that the items were used in all three items will allow us to compare the results. The exception is item Q4 that was used in 1992 and 2019 but not in 2003. It was included given it would allow comparison between two years.

When asking students to evaluate these items using the Likert-scale, we get information about their conceptions about their perceived effort (e.g., Philipp, 2007). One limitation of the present study is that the item 'I have done my best to learn mathematics' was not part of the 2003 national survey, and therefore, the analysis and the results have to be discussed with this in mind. Another limitation is the description of scale differs between the two national surveys and the TIMSS 2019 survey, see **Table 2**.

Table 2. The scales used in the different surveys

Test/scale	Most positive			Most negative
National survey 1992	Instämmer helt [Fully agree]	Instämmer i stort sett [Largely agree]	Instämmer delvis [Partly agree]	Instämmer inte alls [Fully disagree]
National survey 2003	Stämmer mycket bra [Fully agree]	Stämmer i stort sätt bra [Largely agree]	Stämmer ganska dåligt [Partly disagree]	Stämmer mycket dåligt [Fully disagree]
TIMSS 2019	Instämmer helt [Agree a lot]	Instämmer i stort sett [Agree a little]	Instämmer delvis [Disagree a little]	Instämmer inte alls [Disagree a lot]

The assumption is that although the scales are not using the exact same phrases, the underlying word (in Swedish: 'stämmer/instämmer' i.e., correct/agree) is more or less the same. In addition, the scale with a dichotomy with two positive and two negative options means that the two main directions (positive or negative) are the same in the three surveys. Here, we will refer to the four steps as 'fully agree, mostly agree, partly agree, and do not agree'. The number of students that answered the two national surveys were 9,500 (1992) and 6,788 (2003). The TIMSS 2019 survey was completed by 216 students. Even though the skewed number of responses for the 2019 survey compared to the previous ones, it is enough data to compare patterns in conceptions given that the 2019 sample is representative, a stratified representative sample.

Methods of Analysis

For the surveys 2003 and 2019 data is calculated in percentages to allow comparisons, given that different numbers of students replying to each item. For the 1992 survey, the proportions of responses in each category were converted into absolute frequencies based on the group sizes due to a lack of individual data. The results are summarized in a table to compare the descriptive results, including the absolute frequencies and percentages. To determine whether the distribution of responses to the five different questions differed significantly across three survey years (1992, 2003, and 2019), Chi-square tests for independence were conducted (e.g., Agresti, 2018). Given the three pairwise comparisons for each of the four questions Q1, Q2, Q3, and Q5 and one pairwise comparison for Q4, gives the total number of Chi-square tests that were performed to 13 tests. These tests compared the observed distributions of responses on an ordinal Likert scale. "Fully agree," "largely agree," "partly agree," and "fully disagree") between pairs of survey years for each question. The Chi-square statistic (χ^2) was calculated, and the corresponding p-value was obtained. A significance level of 0.05 was used to determine statistical significance. The results are summarized in a table, including the Chi-square value, degrees of freedom, p-value, and whether the result was statistically significant. The data has been presented earlier, in Pettersson and Sollerman (2023), however, without the theoretical underpinnings as in the present paper and with no statistical analysis. Then, the focus was on a different curriculum (see Pettersson & Sollerman, 2023 for a longer discussion).

RESULTS

We will first present the descriptive results, before presenting the results of the statistical analysis. In **Table 3**, we have the absolute frequencies and proportion of responses to each item for each year:

Table 3. The proportion of responses for the five questions, n (%) (total n = 9,500; 6,788; 216)

Item	Grade/year	Fully agree	Mostly agree	Partly agree	Do not agree
Q1 (goal-directed): I would like to learn more mathematics in school.	Grade 9/1992	1,045 (11%)	1,805 (19%)	3,800 (40%)	2,850 (30%)
	Grade 9/2003	1,222 (18%)	2,036 (30%)	2,444 (36%)	1,086 (16%)
	Grade 8/2019	37 (17%)	63 (29%)	76 (35%)	42 (19%)
Q2 (evaluation of effort): Most of the time, I give up when I face a difficult mathematical task.	Grade 9/1992	475 (5%)	950 (10%)	3,610 (38%)	4,465 (47%)
	Grade 9/2003	747 (11%)	1,832 (27%)	2,851 (42%)	1,358 (20%)
	Grade 8/2019	28 (13%)	55 (25%)	85 (39%)	50 (23%)
Q3 (evaluation of effort): I would have been better at mathematics if I had tried harder.	Grade 9/1992	2,375 (25%)	2,280 (24%)	3,610 (38%)	1,235 (13%)
	Grade 9/2003	1,629 (24%)	2,918 (43%)	1,629 (24%)	611 (9%)
	Grade 8/2019	65 (30%)	89 (41%)	46 (21%)	17 (8%)
Q4 (evaluation of effort): I have done my best to learn mathematics.	Grade 9/1992	2,850 (30%)	3,800 (40%)	2,185 (23%)	665 (7%)
	Grade 9/2003	-	-	-	-
	Grade 8/2019	50 (23%)	96 (44%)	61 (28%)	11 (5%)
Q5 (evaluation of effort): I'm happy/ content with what I have achieved in mathematics.	Grade 9/1992	1,615 (17%)	3,420 (36%)	2,945 (31%)	1,520(16%)
	Grade 9/2003	1,562 (23%)	2,987 (44%)	1,697 (25%)	543 (8%)
	Grade 8/2019	41 (19%)	83 (38%)	65 (30%)	28 (13%)

As we can see in **Table 3**, for all survey years, the majority of pupils indicated that they do not want to learn more mathematics at school (Q1), that they usually give up when they encounter a difficult mathematical problem (Q2), and that they are satisfied with their performance in mathematics (Q5). When asked whether students think they would be better at mathematics if they tried harder (Q3), the results for 1992 are relatively split between positive and negative. For the two later years, 2003 and 2019, there is a greater proportion expressing answers in a positive direction. The item that asks the students whether they did their best to learn mathematics (Q4) was only included in 1992 and 2019. In both cohorts, most students gave answers in a positive direction.

The next results come from the analysis, where we wanted to examine whether the distributions of responses differed between the studies. To do so, we used Chi-square tests; see the results in **Table 4**.

Table 4. Results from pairwise Chi-square tests

Question	Years	χ2	df	p	Significance
Q1	1992 vs. 2003	680.06	3	0.0000	Yes
	2003 vs. 2019	1.69	3	0.6400	No
	1992 vs. 2019	27.35	3	0.0000	Yes
Q2	1992 vs. 2003	1,682.23	3	0.0000	Yes
	2003 vs. 2019	2.25	3	0.5227	No
	1992 vs. 2019	99.75	3	0.0000	Yes
Q3	1992 vs. 2003	746.08	3	0.0000	Yes
	2003 vs. 2019	4.28	3	0.2324	No
	1992 vs. 2019	47.58	3	0.0000	Yes
Q4	1992 vs. 2019	7.80	3	0.0620	No
Q5	1992 vs. 2003	387.91	3	0.0000	Yes
	2003 vs. 2019	11.40	3	0.0097	Yes
	1992 vs. 2019	2.10	3	0.5527	No

As shown in **Table 4**, Q1 has a higher result, meaning that the students indicated that they would like to learn more mathematics to a higher degree in 2003 than in 1992. However, there is no difference in the levels between 2003 and 2019. This pattern, with a change in indicated levels between 1992 and 2003, and then showing no significant difference with the results in 2019, also applies to Q2 and Q3. The proportion of students who indicated that they gave up when faced with a difficult mathematics task and the proportion who indicated that they would have done better if they had tried harder increased between 1992 and 2003, but not between 2003 and 2019. Item Q4, where students indicated to what extent they did their best, was only included in the surveys in 1992 and 2019. The distributions do not show a significant difference, although the proportion of students who strongly agree with the statement has decreased from 30% to 23%. When asked if students are satisfied with their performance in mathematics, Q5, the responses given are at the same level in 1992 as in 2019. However, they were higher in 2003.

Interpreting the items from different aspects of motivation, we see that Q1 is the only one measuring goal-directed motivation, and items Q2-Q5 measure students' motivation as an evaluation of the effort. Given the differences in items, only indications can be reported. As such, students' indicated goal-directed motivation increased between 1992 and 2003, and has since been on the same level. Looking instead at students' motivation as an evaluation of effort, we see two patterns. One is similar to the indicated goal-directed motivation; there has been an increase between 1992 and 2003 in the responses to Q2 and Q3, and since 2003 it has been on the same level. However, whereas Q3 measure a positive change, Q2 measure a negative change. Therefore, we cannot say that the motivation with respect to effort is neither positive nor negative based on these two items. Looking at Q4 and Q5, we see no significant differences between 1992 and 2019. When trying to combine the results, it appears that students from 1992 and 2019 more or less expressed similar motivation as an evaluation of effort, with the notation of increased knowledge that they would have done better if they tried harder and that it appears that they more easily give up if a mathematical task is harder in 2019 compared to 1992.

DISCUSSION

The aim of the present study was formulated as following: to study lower secondary school students' conceptions about their effort in mathematics. By using unique data, using the possibility to add specific items to TIMSS, we analyzed students´ responses over a time frame of 27 years. The first research question was about how students perceive their effort in mathematics as an aspect of motivation. The results of the analysis show that students express, in general, a lower level of goal-directed motivation; that is, most students reply with a more negative reply. Looking instead at students' motivation as an evaluation of effort, most students state that they do not give up when facing a difficult task, that they would learn more and do better if they put more effort into their studies, and that they are happy with their achievement. Comparing this with previous research signaling that a positive attitude can increase performance, whereas a negative affect can contribute to low performance (e.g., Capuno et al., 2019; Valiente et al., 2012), the results are good news. Overall, Swedish students express positive conceptions about their effort and motivation. Given the great body of research indicating the correlation between positive affect and positive learning in mathematics (e.g., Guimond & Roussel, 2001; Hannula, 2006; Pajares, 2003; Ryan & Deci, 2000; Stage & Kloosterman, 1995; Valentine et al., 2004; Zimmerman et al., 1992), and that students' conceptions reflect their experiences of mathematics education (Pehkonen, 2001), the conceptions appear to be a good start for mathematics learning. One implication, when applying the two theoretical dimensions of motivation (e.g., Schunk et al., 2010) to the results, is that students' motivation is multi-faceted but, in general, positive, meaning that teachers and researchers should have that in mind when discussing Swedish students' expressed affect.

However, it is in the second research question where some interesting patterns occur. The second research question focuses on how students' conceptions about their efforts change over time. The results show some general patterns. First, several items show a significant difference in the Swedish students' answers between 1992 and 2003 and no difference by 2019. As such, Swedish students appear to have a different pattern compared to Finnish students (e.g., Metsämuuronen, 2013). This can, of course, be due to several reasons, some general and some cultural/contextual, and due to the risk of speculation, we will refrain from trying to provide some answers. One reflection, though, is that this coincides with the pattern of Swedish results in mathematics in the TIMSS study (von Davier et al., 2024). The scores of Swedish students in mathematics dropped between 1992 and 2003 from 540 points to 499 points and then remained at about the same level until 2019 (503 points). Given the conclusion by Zamarro et al. (2019), who found that effort can explain a relatively large portion (32-38 %) of the variation in achievement, some of the changes in stated effort might explain the changes in achievement and vice versa. In addition, since affect is often dynamic as well as culturally bounded, meaning that results from different cultures cannot easily be transferred given intra-cultural and inter-cultural differences (e.g., Niemivirta et al., 2024; Sumpter & Sollerman, 2023), we would like therefore to encourage other researchers interested in mathematics (or other subjects) and large-scale assessments to conduct further research to see if this pattern can be observed in other countries. If so, we will be able to see if the theory 'effort can explain a relatively large portion of the variation in achievement' is a global pattern also in a longer time period (e.g., Batchelor et al., 2019).

Another suggestion for further studies is to do a similar design but, as an addition, to apply gender theory. Given that previous research shows that there are gender differences in different aspects of students' affect and mathematics (e.g., Stage & Kloosterman, 1995; Sumpter & Sollerman, 2023), it is of interest to see if an analysis of conceptions of effort, both as goal and evaluation of effort, generate any differences. The results would provide insight into why we have gender differences in career choices in relation to mathematics.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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