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The Association Between Attitudes Towards Mathematics, Students' Background and TIMSS Mathematics Achievement

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Abstract: The overall aim of this study is to examine the association between Swedish students' attitudes towards mathematics, mathematics achievement as measured by the Trends in Mathematics and Science Study (TIMSS), socioeconomic status (SES), and educational background variables. A further aim is to investigate whether students' attitudes towards mathematics have a mediating role between their mathematics achievement and their background. Several indicators of students' SES and background, taken from both the TIMSS 2015 database and from Swedish official registers, were used. The overall results show that there were differences in attitudes towards mathematics in relation to the different SES and educational background measures. There are also associations between students' SES and both TIMSS mathematics achievement and their attitudes towards mathematics. The students' attitudes towards mathematics only had a small mediation role between the students' backgrounds and TIMSS mathematics achievement. Finally, although the mediation models had a better fit when including other information, the mediation effect was lower. Practical implications of the obtained results are discussed.

Keywords: *Mediation analysis, national test results, school grades, SEM, SES.*

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Introduction

In studies undertaken in several different countries, it has been concluded that students with a high social economic status (SES) tend to have higher educational achievements, in terms of grades or test performance, than students with low SES (e.g., Erberber et al., 2015; Gustafsson et al., 2018; Jurdak, 2014; Sirin, 2005; Wang et al., 2014; Yang Hansen & Gustafsson, 2019). As regards the subject of mathematics, S. Hwang and Son (2021) and Ajisuksmo and Saputri (2017) concluded that there is a positive relationship between attitudes towards mathematics and mathematics achievement. To better understand the relationship between SES and educational achievement, researchers have examined potential mediating factors (see, e.g., Liu et al., 2015; Nilsen et al., 2022; Rjosk et al., 2014). In line with these research studies, this study will therefore not only examine the association between the students' educational background, including SES, and the students' mathematics achievement, but also examine whether students' attitudes towards mathematics have a mediating role between students' SES and their mathematics achievement as measured by the Trends in Mathematics and Science Study (TIMSS).

TIMSS is a large-scale international assessment programme for mathematics and science in school years 4 and 8. TIMSS also collects information about the students' SES and the students' views and attitudes towards school and the subjects of mathematics and science. Students from different countries who have high SES, in terms of having more educated parents and attending more socioeconomically advantaged schools, tend on average to perform better than students with low SES in both TIMSS mathematics (see, e.g., Kaleli-Yilmaz & Hanci, 2016; Schiller et al., 2002) and TIMSS science (see, e.g., Caponera & Losito, 2016). However, there are many different definitions of SES (National Forum on Education Statistics [NFES], 2015) and in TIMSS, SES is measured by several student self-reported variables, including home possessions (e.g., having a computer at home, internet connection, a study desk, or an own room), but also number of books at home, parental level of education, and language spoken at home (Broer et al., 2019; Mullis & Martin, 2013).

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Different variables from TIMSS have been used to describe SES. For example, Reimer et al., (2018) used parents' level of education. The home resources learning scale, which has a positive association with TIMSS mathematics achievement, has been used as a proxy for SES in TIMSS studies in Norway, Turkey, and Sweden (e.g., Bergem et al., 2016; Ersan & Rodriguez, 2020; Swedish National Agency for Education, 2016b). In several TIMSS studies, students' SES, measured by home possessions and number of books at home, has a stronger association with the students' achievement than school-level factors (e.g., Chiu & Xihua, 2008; Wiberg, 2019). Wiberg and Rolfsman (2023) concluded that the TIMSS measures number of books at home and the home educational resources (HER) index correlated well when compared with official register SES measures collected by the Swedish authorities. Furthermore, they suggested that these two measures could be used as proxies for parents' education, as both correlated highly with information from national registers and had a low number of missing values as compared to other SES measures. High correlations were also found between national test scores, grades, and TIMSS achievement measures. The authors suggested that when available, information from multiple data sources, such as national registers that provide information about the students' previous performance (grades, national test results), and parents' educational level, should also be used together with data from the TIMSS home resources for learning scale, and number of books at home. A limitation of their study was that no information was included about the students' self-reported views towards the subject of mathematics. Therefore, students' views should be considered, as SES together with parents' expectations on their child or teachers' attitudes, have been shown to be significant for students' performance on TIMSS (Badri et al., 2019; Geesa et al., 2019; Mensah et al., 2013).

Attitudes towards mathematics are included in the TIMSS assessment in the student questionnaire. As previously mentioned, a positive attitude towards mathematics has been shown to be associated with higher TIMSS mathematics achievements (see, e.g., Berger et al., 2020; Geesa et al., 2019; J. Hwang et al., 2017). However, the relationship between attitudes toward mathematics and performance is not entirely clear (see, e.g., S. Hwang & Son, 2021). Note that the percentage of students who dislike mathematics or do not feel confident in mathematics is higher among students in school year 8 as compared to students in school year 4 (Mullis, Martin, Foy & Hooper, 2016). Furthermore, when TIMSS data is aggregated to the country level, top-performing countries exhibit larger percentages of students, in comparison with low-performing countries, reporting that they do not do well in mathematics, a phenomenon known as 'the enjoyment–achievement paradox' (Mullis, Martin & Loveless, 2016). In addition, there are students with low SES who are successful even though they have a disadvantaged background, sometimes referred to as resilient students (see, e.g., Rouse, 2001). Resilience, in an educational context, denotes a capacity to adapt and to pursue high performance despite the circumstances and adversity (Aydın & Erdem, 2023). In line with research on resilience, students' attitudes towards mathematics may be linked to the association between SES and students' achievement.

In mediation analysis, mediating factors are used to weaken, strengthen, or explain relationships, such as the relationship between SES and educational achievement. The most commonly explored factors for mediating school and classroom SES effect on achievement are school climate, instructional quantity, and quality (Rjosk et al., 2014). These factors were used by Gustafsson et al. (2018) when examining the moderating power within schools across 50 countries participating in TIMSS 2011. One limitation of their study is that they only used the first plausible value to describe the students' achievement, which is known to be a serious problem as the obtained results are not completely correct (Laukaityte & Wiberg, 2017). Other studies have examined the mediating power of underlying family processes in the relationship between SES and school performance (Chao & Willms, 2002; Guo & Harris, 2000). The mediation effect of student self-efficacy between teaching approaches and science achievement has also been studied with TIMSS US data (Gao et al., 2020). Østbø and Zachrisson (2021) examined student motivation and parental attitude as mediators for SES on TIMSS 2015 mathematics achievement in school year 4 in Norway. They used single-level models and concluded that students' self-concept accounted for a small but statistically significant portion of SES effects on achievement. As students' self-concept is connected to the students' attitudes (see, e.g., Metcalfe, 1981), we hypothesize that attitudes towards mathematics have a mediating role between SES and TIMSS mathematics achievement in Sweden. Recently, Albayrakoğlu and Yıldırım (2022) studied the mediating role of school characteristics between school SES and mathematics achievement in TIMSS 2015 and concluded that in some educational systems there was a mediation effect. However, there has not yet been a study examining students' attitudes towards mathematics in Sweden as a mediating factor between TIMSS mathematics achievement and SES measures within a multilevel framework. Note that Mittal (2019) used mediation analysis when examining TIMSS science achievement among students from Sweden and Ukraine using TIMSS 2011 data. However, although she used structural equation models with several mediators, some of her methodology choices are unclear. Our study differs from that study in two important aspects. First, Mittal (2019) examined science achievement, while our focus is on mathematics achievement. Second, we used TIMSS 2015 data together with official Swedish register data, while the study by Mittal (2019) is limited to TIMSS 2011 data. Summing up, we are not aware of any study that examines Swedish students' backgrounds, including SES, and the mediating role of students' attitudes in TIMSS mathematics school year 8, and that also uses information about the students' backgrounds from other register data sources than TIMSS, which is important to examine, as academic gain may vary between countries. It is therefore important to also apply a country-specific context (Aydın & Erdem, 2023).

The overall aim of this study is to examine the association between Swedish students' attitudes towards mathematics, mathematics achievement measured by TIMSS, SES, and educational background variables. A further aim is to investigate

whether students' attitudes towards mathematics have a mediating role between their mathematics achievement and their background.

The following research questions are examined:

1. Is there a difference in attitude towards mathematics among students in relation to different SES and educational background measures?
2. How do students' educational background, including SES, directly associate with students' TIMSS mathematics achievement and with students' attitudes towards mathematics?
3. How do students' attitudes towards mathematics directly associate with students' TIMSS mathematics achievement?
4. Do students' attitudes towards mathematics mediate the relationship between the students' educational backgrounds, including SES, and students' TIMSS mathematics achievement?
5. Do we get stronger effects if we include other information about students' backgrounds than the information from the TIMSS database when conducting mediation analysis?

Based on the literature, we hypothesize that there are differences in attitudes towards mathematics depending on the students' SES and educational background. We also believe that there are strong associations between students' SES and both TIMSS mathematics achievement and the students' attitudes towards mathematics. Furthermore, we believe that there is a strong association between students' attitudes towards mathematics and TIMSS mathematics achievement, although we are aware of the results showing that there is a decline among students over the years regarding their interest in learning mathematics. We hypothesize that the students' attitude towards mathematics is a significant mediator between the students' background, including their SES, and TIMSS mathematics achievement, as this was shown to be a significant mediator when examining TIMSS science (Mittal, 2019). Finally, we hypothesize that we get stronger effects in the mediation analysis when other sources of information about students' backgrounds than only those provided by the TIMSS database are used, as Wiberg and Rolfsman (2023) obtained stronger results when they included other data sources than only TIMSS data.

Methodology

Participants

We used TIMSS 2015 data for Swedish students from school year 8 (International Association for the Evaluation of Educational Achievement [IEA], 2017). Following TIMSS 2015 protocol, 4,090 Swedish students from 150 participating schools were randomly selected in a two-stage procedure. Schools were selected first, and then classes, to ensure that the sample was representative of Swedish students in school year 8. The students' response rate on TIMSS 2015 in Sweden was high, and only about five per cent of the students, all of whom were absent from school on the test day, did not respond to any of the TIMSS items.

When TIMSS 2015 was distributed, the Swedish National Agency of Education collected the participating students' social security numbers, which opened a unique opportunity to link the information in TIMSS with official Swedish register data collected by the authorities. This study has an ethical review approval 2017/42-31, so we were allowed to use the students' social security numbers to connect some official register data with the students' TIMSS 2015 data. The data used from Swedish official register data were information about the students' national school achievement measures (mathematics grades from school year 6 and students' mathematics grades on national tests in school year 6), and the students' parental educational level.

Variables Used from TIMSS and Official Registers

Only a limited number of assessment items are given to each student in TIMSS, to limit the time and effort required for the students. The students' scores on these items are then transformed into five plausible values for each student. The plausible values in mathematics are imputed values, which represent the students' mathematics achievement on the entire TIMSS assessment if they would have received all items. The conducted statistical analyses were performed for each plausible value following the suggested methods and procedures for TIMSS 2015 in general (Martin et al., 2016), as suggested by von Davier et al. (2009) for secondary analyses and by Laukaityte and Wiberg (2017) on how to use plausible values in TIMSS in multilevel analyses. We also used students' home background variables from TIMSS and from the official registers as well as information from TIMSS describing students' attitudes towards mathematics.

The Swedish TIMSS sample had 2,104 (52%) boys and 1,975 (48%) girls. As a measure of SES, we used number of books at home (*books*), the home educational resources index (*HER index*), and highest parental education (*PEdR* from official register data) as suggested by Wiberg and Rolfsman (2023). Number of books at home is a category variable coded from 1 to 5 depending on the number of books the student's home has, where 1 represents few or no books and 5 represents many books. Highest parental education was coded from 1 to 6 depending on the highest education of the parents, where

1 represents the lowest educational category (did not complete upper-secondary education) and 7 represents the highest category (a university doctoral degree). The *HER index* contains a number of books at home, a number of home study aids (in terms of own room and internet connection), and the highest level of education of either parent (refer to Mullis, Martin, Foy, and Hooper (2016) for more details about this index). Digital home possessions were not included, as most Swedish students have them.

To measure the students' attitudes towards mathematics, we used items from the Students Like Learning Mathematics scale (Mullis, Martin, Foy, & Hooper, 2016). For the mediating models, we used the item 'I like mathematics', with the recoded scale 1–4, where 1 represents 'disagree a lot' and 4 represents 'agree a lot'. Although other items from the Students Like Learning Mathematics scale could have been used, we chose to use the item with the average highest correlation with the plausible values for mathematics (0.41). When using the structural equation models (SEM), we used five items from the Students Like Learning Mathematics scale: M1 – 'I enjoy learning mathematics', M2 – 'I learn many interesting things in mathematics', M3 – 'I like mathematics', M4 – 'I look forward to mathematics class', and M5 – 'Math is one of my favorite subjects'. These items are coded as the 'I like mathematics' item. Most students in the sample were born in Sweden with Swedish parents (78%, 3205) and only 22% of the students were either not born in Sweden (9%, 361) or had both parents not born in Sweden (11%, 453).

Students' Grades and National Tests

We used information about the students' mathematics grades from school year 6 (*G6*). The overall aim of subject grades in Sweden is to provide a measure of students' subject knowledge. The Swedish grades are criterion-referenced, and thus specific criteria are used to determine a student's grade. The grading scale comprises six levels: A–F, where A is the highest grade and F is failed. Grades A–E are different levels of pass. The teachers set the grades at the end of a school semester based on all given tests and assignments that the student has done. If there is too little information about a student's knowledge, the student does not receive a grade in that subject, and this is denoted with a line (-). The letter grades are also transferred to the following numeric scale: A=20, B=17.5, C=15, D=12.5, E=10, and F=0.

Swedish national tests aim to assess parts of the curriculum of a core subject and are given to students in school years 3, 6, and 9. The aim of the national tests is to support a fair and equal grading process and to provide information about how knowledge demands are reached on a national and a school level (Swedish National Agency for Education, 2016a). The results of the national tests are given on the same grading scale as the students' grades. In this study, we had access to students' mathematics national test results from school year 6 (*NT6*).

Note that national tests and grades deviate in an important way. The national test results come from a single or a few tests given on a single occasion, which tests several parts but not the complete curriculum. Grades are instead an overall judgment of the student that are usually based on several assessments and occasions and cover the entire curriculum.

Statistical Analyses

The basic statistical analyses were conducted using SPSS version 26. Correlation analyses were conducted using the IEA International Database Analyzer (Version 5) (IEA, 2018) and were used to examine students' attitudes towards mathematics and their grades, national tests and TIMSS mathematics achievement. We used pairwise deletion to handle missing data, as was done by Wiberg and Rolfsman (2023). The mediation analysis was conducted with Mplus version 8.7 (Muthén & Muthén, n.d.) and we used a full information maximum likelihood procedure to deal with missing data. The distributions among the different SES measures within each mathematics attitude level were compared using Pearson χ^2 tests (categorical variables) and ANOVA F-tests (continuous variables). We used both single-level and multilevel mediation analyses (Hayes, 2013) to examine if attitude towards mathematics is a mediator variable for the strength of the association between TIMSS mathematics and the students' background (i.e., SES or the two school achievement measures – mathematics grades and mathematics national test results). We also used SEM and multilevel SEM to be able to use more items from the attitude scale. In the mediation analyses, we assumed that all confounders were examined. Note, that our mediation analyses are based on observational data and thus do not imply causal relationships. We chose not to adjust our main analyses for other SES variables as we were interested in a general effect of SES, not a specific education effect.

A Basic Single-Level Mediator Model

First, we examined a single-level mediation model (Model 1) in which all variables were treated as continuous. Variable *X,* which is called the *initial variable* in mediation analysis, is the independent variable (e.g., ***books***, ***HER index***, ***PEdR***, *G6*, or *NT6*), *M* is the mediator ('I like mathematics'), and Y is the dependent variable (the five plausible values of TIMSS mathematics achievement). The path diagram for the described model is presented in Figure 1.

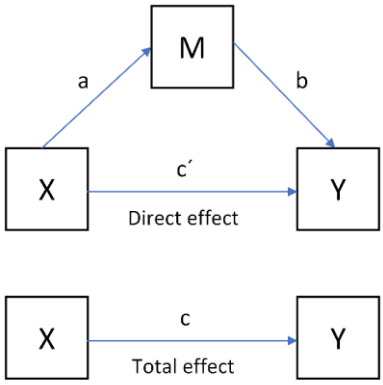


Figure 1. A Path Diagram Describing the Single-level Mediation Model.

In Figure 1, the direct effect of students' SES to mathematics achievement *c'* is presented as the path from *X* to *Y*. X are student home background variables (books, HER index, PedR, G6, or NT6), M is whether the student likes mathematics, and Y is the TIMSS mathematics achievement. The indirect effect, *ab*, is the product of the path from *X* to *M*, *a*, and the path from *M* to *Y*, *b*. The total effect, *c*, is the sum of direct and indirect effects. Mediation is complete when variable *X* no longer affects *Y* after controlling for *M*, i.e., path *c'* becomes zero. Mediation is partial if the path from *X* to *Y* is reduced in absolute size but is still different from zero when controlling for *M* (James & Brett, 1984). Partial mediation indicates that additional mediators should be included in the model.

The two most popular measures of effect size for mediation, according to Preacher and Kelley (2011), are the mediation ratio and the R_M ratio proposed by Sobel (1982), and these were used here. The mediation ratio, P_M, is the ratio between the indirect effect and the total effect:

$$P_M = \frac{ab}{ab + c'}.$$

R_M is the ratio between the indirect effect and the direct effect:

$$R_M = \frac{ab}{c'}.$$

For analysis of TIMSS complex assessment data in Mplus, we chose an approach that is obtained by specifying TYPE=COMPLEX in the ANALYSIS command. To make valid estimates and inferences, we used the overall student sampling weight specified by WEIGHT=TOTWGT, and indicated cluster, or in this case school, membership by CLUSTER= IDSCHOOL in the VARIABLE command. To analyse plausible value datasets correctly, we specified TYPE=IMPUTATION in the DATA command. The Mplus code used can be obtained upon request from the corresponding author.

Multilevel Mediation Models

To consider TIMSS hierarchical nature, we used multilevel models. There are different possible multilevel mediation designs, and in our study, we used a 1-1-1 two-level design. The three numbers indicate the level at which the initial variable, the mediator, and the dependent variable are measured. In this case, all variables are level-1 (student-level) variables. TIMSS student and school sampling weights were included in all multilevel models, as suggested by Laukaityte and Wiberg (2018).

We compared two multilevel models in Figure 2, where X_w are student home background variables (*books*, *HER index, PEdR, G6*, or *NT6*), X_b are aggregated student home background variables, M is whether the student likes mathematics, and Y is the TIMSS mathematics achievement. The first of the multilevel models (Model 2), similarly to Model 1, contains only level-1 variables (see Fig. 2A). Several studies (e.g., Ersan & Rodriguez, 2020; Laukaityte & Rolfsman, 2020) have shown the existence of a strong relationship between school SES and student achievement. Thus, the second multilevel model (Model 3) additionally contains an aggregated (contextual) SES variable at level 2 (see Fig. 2B). We examined the direct and indirect effects and the lower and upper confidence limits for the indirect effects. To evaluate which model should be preferred, we used the Akaike information criterion (AIC) as well as the Bayesian information criterion (BIC). Models with the lowest values of AIC and BIC were chosen.

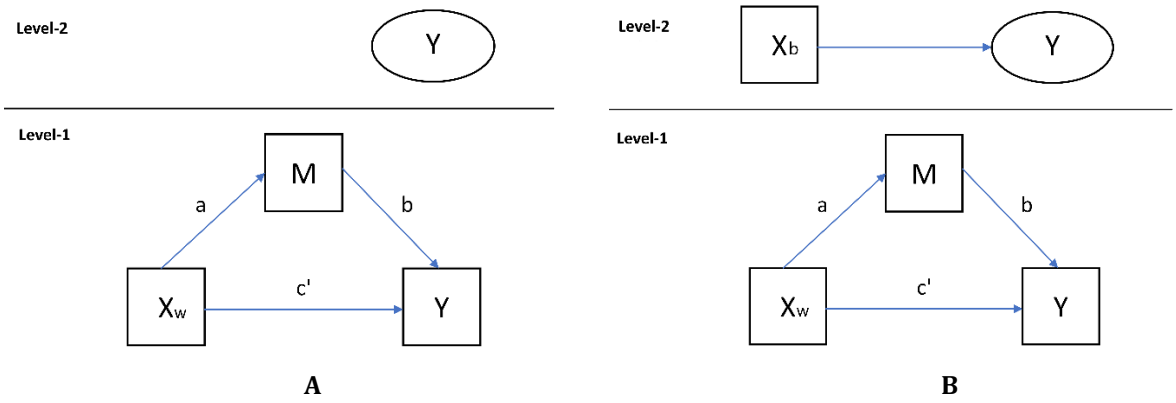
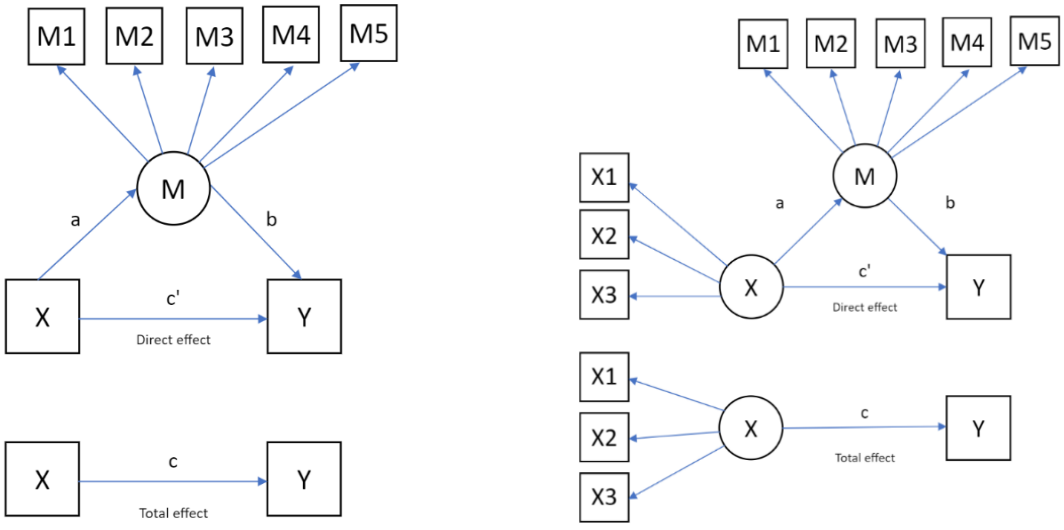


Figure 2. Path Diagrams Describing the Two-level Mediation Models 2 (left) and 3 (right).

SEM and SEM Multilevel Mediation Models

In the single- and multilevel analyses above, we assessed students' positive attitude towards mathematics using a single item, 'I like mathematics', and measured SES through the *HER index* available in the TIMSS dataset. In these models, we assume that the constructed predictor variables are perfectly reliable, which is not very realistic (Hox, 2013). To mitigate this assumption, we could employ structural equation models (SEM) that can include a measurement model for the predictor variables. Thus, we could treat the mediation and *HER* variables as latent variables. Latent variables cannot be directly observed but are measured indirectly using other observable variables (VandenBos, 2015). In our case, the latent variable 'students' positive attitude towards mathematics' was, as previously mentioned, measured by five items from the Students Like Learning Mathematics scale. Similarly, we let the latent *HER* variable be described by three items: *books*, *the number of home resources*, and *the highest educational level of parents* obtained from the TIMSS dataset.

SEM and SEM multilevel mediation models share similarities with the single- and multilevel models described previously, except for the treatment of latent variables. In the case of SEM, two path diagrams are utilized for the single-level mediator model, as illustrated in Figure 3. The first diagram (SEM Model 1a) includes only one latent variable – the mediator, where variable *X* can represent *books*, *PEdR*, *G6*, or *NT6*. The second diagram (SEM Model 1b) is similar to SEM1 but is employed when variable *X* represents the latent *HER* variable.



SEM model 1a SEM model 1b

Fig. 3. SEM Model 1a when X is books, PedR, G6, NT6. SEM Model 1b when X is HER (X1 – books, X2 – the Highest Parental Education from TIMSS, X3 – Number of Home Resources). M1 – 'I Enjoy Learning Mathematics', M2 – 'I Learn Many Interesting Things in Mathematics', M3 – 'I Like Mathematics', M4 – 'I Look Forward to Mathematics Class', M5 – "Math is One of My Favorite Subjects'. Y is the TIMSS Mathematics Achievement.

Path diagrams for SEM multilevel mediation models closely resemble those of multilevel Models 2 and 3 presented in Figure 2, differing only in the inclusion of either a single latent mediator (SEM Models 2a and 3a) as seen in SEM Model 1a or both a latent mediator and a latent *X* variable (SEM Models 2b and 3b), as seen in SEM Model 1b.

Results

First, we examined the correlation between the item 'I like mathematics' and the five plausible values for mathematics. The average correlation was reasonably high (0.41). Next, we examined the correlation between TIMSS mathematics achievement and grades from school year 6 (*G6*; 0.68), and national test results from school year 6 (*NT6*; 0.68), which were both very high. We also examined the correlation between TIMSS mathematics achievement and parental education from registers (*PEdR*; 0.39), the home educational resources index (*HER index*; 0.42), and books at home *(books*; 0.41). These were reasonably high, although lower for the educational background measures. Correlations were also examined between 'I like mathematics' and grades from school year 6 (*G6*;0.36), national test results from school year 6 (*NT6*; 0.36), and parental education from registers (*PEdR*; 0.13), the home educational resources index (*HER index*; 0.17), and books at home *(books*; 0.16). Again, the highest correlations were found with the educational background measures compared with the TIMSS SES measures, which were substantially lower.

Table 1 shows descriptive statistics for students' attitudes towards mathematics in terms of 'I like mathematics' and the students' different background levels. From this table, it is evident that all student SES measures have a clear relationship with the students' attitudes towards mathematics. As for the registered educational background measures from school year 6 (*G6* and *NT6*), the average results were higher for those who liked mathematics. The chi-squared tests and the F-test confirmed that there were statistically significant differences between students with different attitudes towards mathematics and their SES background as well as their school performance.

Table 1. Descriptive Statistics by the Students' Mathematics Attitude and Different SES Levels

	I like mathematics					
books	1 (disagree)	2	3	4 (agree)	Total	χ^2/p
1 (few)	155	176	145	84	560	
2	150	263	270	128	811	
3	182	327	375	203	1087	
4	100	188	257	173	718	
5 (many)	78	191	251	219	739	134.25
Total	665	1145	1298	807	3915	<.0001
PEdR						χ^2/p
1 (low)	5	17	23	36	81	
2	18	30	32	16	96	
3	140	198	178	83	599	
4	179	293	266	108	846	
5	112	211	225	163	711	
6	202	360	513	357	1432	
7 (high)	5	29	42	31	107	156.07
Total	661	1138	1279	794	3872	<.0001
HER Index						F/p
Mean	10.75	11.06	11.29	11.57	11.19	37.60
N	668	1145	1298	808	3919	<.0001
G6						F/p
Mean	11.76	13.43	14.91	16.18	14.19	139.04
N	639	1113	1235	765	3752	<.0001
NT6						F/p
Mean	12.08	13.56	15.33	16.73	14.54	148.83
N	615	1101	1216	745	3677	<.0001

books = Number of books at home (TIMSS), PEdR = Parents' highest education (Register), HER index = Home educational resources index, G6 = Mathematics grade 6, NT6 = National test in mathematics from school year 6, *p*-values from Pearson's χ^2 test (categorical variables) and ANOVA F-tests. N = Number of students.

Table 2 summarizes the conducted mediation analyses with the three different mediating models. The indirect effects were statistically significant at the $p<0.01$ level in all studied models. Mediation ratio P_M varied from 9% to 19%, and R_M varied from 9% to 24%, with the highest ratios in models with SES represented by *books* and the *HER index*. The R^2 varied between 0.25 and 0.56 and was highest when using grade or national test result as predictor (0.56) and lower when other predictors were used. The goodness-of-fit measures AIC and BIC indicate that the Model 2 models (values marked in bold in the table) fitted the data best regardless of which variable was used as indicator of SES. The mediation effect size was, however, lower for these measures and higher when *HER index* or *books* were used. Summing up, students' attitudes towards mathematics appear to have a smaller mediation role between TIMSS mathematics achievement and SES, and the effect is larger when using *HER index* or *books* than when using students' educational background measures.

Table 2. Mediating Models with 'I Like Mathematics' as a Mediator and TIMSS Plausible Values for Mathematics as Y and Different X Variables

Model	X	Total	Direct	Indirect	LI	UI	AIC	BIC	R^2	P_M	R_M
1	books	20.62 (1.81)	17.78 (1.72)	2.84 (0.72)	1.66	4.01	27890.0	27929.2	0.27	0.14	0.16
2	books	18.03 (1.86)	15.00 (1.82)	3.04 (0.70)	1.88	4.19	**27615.2**	**27660.0**	**0.29**	0.17	0.20
3	books	16.66 (1.83)	13.48 (1.79)	3.18 (0.80)	1.87	4.49	34580.0	34647.5	0.26	0.19	0.24
1	HER index	23.94 (2.18)	20.83 (2.04)	3.10 (0.90)	1.63	4.58	27891.8	27931.0	0.27	0.13	0.15
2	HER index	20.76 (2.52)	17.10 (2.31)	3.66 (0.91)	2.16	5.16	**27645.0**	**27689.9**	**0.28**	0.18	0.21
3	HER index	18.36 (2.49)	14.87 (2.27)	3.49 (0.95)	1.93	5.05	33866.7	33934.1	0.25	0.19	0.23
1	PEdR	20.21 (1.98)	18.47 (1.96)	1.74 (0.56)	0.82	2.66	27725.9	27765.2	**0.30**	0.09	0.09
2	PEdR	16.18 (1.73)	14.19 (1.62)	1.99 (0.64)	0.93	3.04	**27541.1**	**27586.0**	**0.30**	0.13	0.14
3	PEdR	13.25 (1.81)	11.82 (1.63)	6.83 (3.57)	0.38	2.49	34732.1	34799.5	0.25	0.11	0.12
1	G6	10.29 (0.44)	9.08 (0.43)	1.21 (0.18)	0.92	1.50	25820.6	25859.6	0.51	0.12	0.13
2	G6	9.75 (0.41)	8.57 (0.40)	1.18 (0.19)	0.87	1.49	**25551.0**	**25595.6**	**0.56**	0.12	0.14
3	G6	9.63 (0.43)	8.51 (0.41)	1.13 (0.19)	0.82	1.43	38993.8	39061.3	0.51	0.12	0.13
1	NT6	10.09 (0.46)	8.83 (0.44)	1.26 (0.18)	0.97	1.55	25175.3	25214.1	0.53	0.12	0.14
2	NT6	9.59 (0.42)	8.35 (0.42)	1.25 (0.19)	0.93	1.57	**24983.5**	**25027.9**	**0.56**	0.13	0.15
3	NT6	9.59 (0.41)	8.46 (0.42)	1.13 (0.19)	0.82	1.44	38895.1	38962.6	0.51	0.12	0.13

Direct = Direct effect, Indirect = Indirect effect, Total = Total effect, P_M = IE/TE, R_M = IE/DE, LI / UI – lower / upper limit of 95% confidence interval for indirect effect. books = Number of books at home (TIMSS), HER index = Home educational resources index, PEdR = Highest parental education from official registers, G6 = Mathematics grade from school year 6, NT6 = National test in mathematics from school year 6.

Table 3. SEM Mediating Models with 'Students' Positive Attitude Towards Mathematics' as a Mediator and TIMSS Plausible Values for Mathematics as Y and Different X Variables

Model	X	Total	Direct	Indirect	LI	UI	AIC	BIC	R^2	P_M	R_M
1a	books	20.62 (1.81)	17.74 (1.71)	2.88 (0.77)	1.62	4.14	42128.2	42240.4	0.27	0.14	0.16
2a	books	17.99 (1.85)	14.80 (1.79)	3.19 (0.83)	1.82	4.56	**41839.4**	**41957.2**	**0.30**	0.18	0.22
3a	books	16.66 (1.83)	13.32 (1.76)	3.34 (0.91)	1.84	4.84	48934.8	49075.4	0.27	0.20	0.25
1b	HER	41.83 (4.38)	36.98 (4.16)	4.85 (1.21)	2.86	6.85	59367.7	59530.8	**0.38**	0.12	0.13
2b	HER	35.03 (4.05)	29.52 (3.66)	5.52 (1.40)	3.22	7.82	58993.9	59162.6	**0.38**	0.16	0.19
3b	HER	33.84 (4.62)	27.75 (4.19)	6.10 (1.63)	3.42	8.77	**58653.1**	**58878.0**	0.33	0.18	0.22
1a	PEdR	20.21 (1.98)	18.39 (1.97)	1.83 (0.60)	0.84	2.82	41853.0	41965.2	0.30	0.09	0.10
2a	PEdR	16.07 (1.75)	13.96 (3.27)	2.12 (0.70)	0.96	3.27	**41654.9**	**41772.6**	**0.31**	0.13	0.15
3a	PEdR	13.25 (1.81)	11.62 (2.68)	1.63 (0.71)	0.46	2.80	49084.8	49225.4	0.26	0.12	0.14

Table 3. Continued

Model	X	Total	Direct	Indirect	LI	UI	AIC	BIC	R^2	P_M	R_M
1a	G6	10.29 (0.44)	9.03 (0.42)	1.26 (0.19)	0.96	1.57	39293.3	39404.7	0.51	0.12	0.14
2a	G6	9.77 (0.42)	8.49 (0.40)	1.28 (0.21)	0.93	1.63	**38968.7**	**39085.7**	**0.57**	0.13	0.15
3a	G6	9.63 (0.43)	8.46 (0.41)	1.16 (0.21)	0.82	1.50	53355.8	53496.4	0.51	0.12	0.14
1a	NT6	10.09 (0.46)	8.78 (0.44)	1.31 (0.18)	1.01	1.61	38325.6	38436.6	0.53	0.13	0.15
2a	NT6	9.61 (0.42)	8.24 (0.43)	1.37 (0.22)	1.00	1.74	**38039.9**	**38156.5**	**0.57**	0.14	0.17
3a	NT6	9.58 (0.42)	8.41 (0.44)	1.17 (0.21)	0.83	1.51	53257.7	53398.3	0.51	0.12	0.14

Direct = Direct effect, Indirect = Indirect effect, Total = Total effect, P_M = IE/TE, R_M = IE/DE, LI / UI – lower / upper limit of 95% confidence interval for indirect effect. books = Number of books at home (TIMSS), HER = Home educational resources, PEdR = Highest parental education from official registers, G6 = Mathematics grade from school year 6, NT6 = National test in mathematics from school year 6.

Table 3 resembles Table 2 but provides a summary of the results obtained from the conducted mediation analyses using three distinct SEM models. The findings from the SEM analyses exhibit a strong concordance with those derived from the multilevel analyses, which is consistent with similar comparisons of multilevel analyses and multilevel SEM analyses in other studies (see, e.g., Curran, 2003; Hox, 2013). The largest disparities arise in the context of the *HER index* (*HER* in SEM), where SEM reveals higher direct, indirect, and total effects, as well as a greater R^2 compared to the multilevel approach. Additionally, there is a noteworthy discordance observed in the goodness-of-fit indices and R^2 values pertaining to model fitness.

Discussion

The overall aim of this study was to examine the association between Swedish students' attitudes towards mathematics, mathematics achievement measured by TIMSS, SES, and educational background variables. A further aim was to investigate if students' attitudes towards mathematics have a mediating role between their mathematics achievement and their background.

The first research question concerned whether there is a difference in attitude towards mathematics for students of different SES and different educational backgrounds. As expected, the descriptive statistics analyses indicated that students with a more positive attitude towards mathematics were also students with higher SES (regardless of how SES was measured). The statistical analysis confirmed that the students' backgrounds and attitudes towards mathematics were not independent. This result is in line with previous findings showing that the students' attitudes are influenced by factors in their surroundings (see, e.g., Mullis, Martin & Loveless, 2016).

The second research question concerned whether students' SES and educational background measures are directly associated with students' TIMSS mathematics achievement and students' attitude towards mathematics. The correlations between TIMSS mathematics achievement and the different SES measures were reasonably high, as expected and in line with Wiberg (2019), especially for the two measures based on students' grades (*G6*) and national test results (*NT6*). These results are also in line with Albayrakoğlu and Yıldırım (2022), who concluded that there is a statistically significant positive relationship between SES and TIMSS achievement in Sweden, although they only examined school SES. In the mediating models, there were significant direct effects between TIMSS mathematics achievement and SES. The strongest effects were when either *books* or *HER index* (*HER* in SEM) were used, which is in line with Wiberg (2019) and Østbø and Zachrisson (2021). The stronger effect with *books* is also in line with Evans et al. (2014), who concluded that growing up in a home with a large exposure to books has a major impact on academic performance. The students' SES association with students' attitude towards mathematics in terms of correlation was found to be highest with the two variables based on previous mathematics performance (*G6* and *NT6*). This is not surprising, as these are performance measures rather than SES measures. This result is in line with Mullis et al. (2020), who showed that the percentage of students who do not like mathematics or do not feel confident in mathematics is higher among students in school year 8 compared to students in school year 4.

The third research question concerned how students' attitudes towards mathematics directly associate with students' TIMSS mathematics achievement. The result that students who like mathematics more tend to have higher results on TIMSS mathematics is in line with Berger et al.'s (2020) study of TIMSS 2015 in an Australia sample. The results are also in line with S. Hwang and Son (2021) and Ajisuksmo and Saputri (2017), who concluded that there is a positive relationship between attitudes towards mathematics and mathematics achievement. However, our results are in contradiction to what has been known as the enjoyment–achievement paradox (Mullis, Martin & Loveless, 2016). A possible reason for this could be that the Swedish students were motivated to take TIMSS even though it is a low-stakes

test for them, a result seen in Eklöf (2007) for a previous TIMSS administration. Another reason could be that high-performing Swedish students have high self-esteem and thus the enjoyment–achievement paradox is not applicable here. This is, however, a hypothesis that should be examined in future research.

The fourth research question examined whether students' attitudes towards mathematics mediate the relationship between the students' SES and students' TIMSS mathematics achievement, where we separated the effect of students' background on TIMSS mathematics achievement into a direct effect and an indirect effect operating through the students' attitude towards mathematics. The main findings from the single-level, multilevel and SEM mediation models indicate that students' positive attitudes towards mathematics can be used as a mediator between SES (defined as HER index or HER, and books), and TIMSS mathematics achievement. The direct effect was, however, not large (varied from 8.78 with NT6 to 36.98 with HER; or for standardized coefficients varied from 0.292 with books to 0.595 with NT6), and it was similar to those found in Østbø and Zachrisson (2021) (0.26 with mediator Self-Concept Motivation Factor and 0.33 with an Intrinsic Motivation Factor in standardized coefficients), which examined SES and different motivational and attitude mediators in TIMSS 2015 mathematics achievement in Norway. Nevertheless, the indirect effect in our models (which varied from 1.26 with G6 to 4.85 with HER; or for standardized coefficients, varied from 0.034 with PEdR to 0.082 with books or 0.088 with NT6) was smaller than the indirect effect of 0.39 (standardized) in the model with mediator Self-Concept Motivation Factor in their study, but was similar in size than the indirect effect of 0.11 (standardized) in the model with an Intrinsic Motivation Factor. The overall findings are similar, i.e., that students' attitude (or in their case self-concept) accounted for a small but statistically significant portion of SES effects on the students' achievement. The indirect effect observed here was also similar to that in Mittal's (2019) study of TIMSS science. She found that Self-confidence in science, a mediator between SES and TIMSS science achievement, has a significant positive indirect effect of 0.101 for Sweden and 0.138 for Ukraine. In practice, the results imply that by influencing students' attitudes towards mathematics, students' TIMSS mathematics achievement may be improved. This result is in line with the result by Berger et al. (2020), who found that students with a positive attitude towards a subject (mathematics/science) tended to perform better on TIMSS than students with a less positive attitude. Note that both multilevel and multilevel SEM analyses converge in their findings. The use of mediation models appears to be useful in the TIMSS context, as also noted previously by Nilsen et al. (2022).

Finally, the fifth research question concerned whether it was useful to use other information about the students' background, rather than using only information provided from the TIMSS international database when performing the mediation analyses. Although extra information was valuable in the first three research questions, the same conclusion was not seen with the mediation models. Even though the mediation models with other information had the highest proportion of explained variance, the indirect effects were lower than when books and HER were used. This was somewhat surprising, as in Wiberg (2019) and Wiberg and Rolfsman (2023), using other information about the students' background, rather than only TIMSS measures, made the analyses better. However, these studies did not use mediation analyses. One possible reason for our finding could be that as test scores and grades capture the performance of the students better than SES, they thus explain the students' TIMSS results better (more of the variance is explained in the models). Adding attitudes as a mediator is thus not as necessary in these cases.

Conclusion

In conclusion, we found that there were differences in attitude towards mathematics among the students in relation to the different SES and educational measures, which has not been examined in previous studies. There is an association between students' SES and both TIMSS mathematics achievement and their attitudes towards mathematics. Students' attitude towards mathematics as a mediator, which has not been studied previously in a Swedish context focusing on TIMSS mathematics achievement and SES measures within a multilevel framework, only had a small mediation role between the students' background and TIMSS mathematics achievement. Finally, although the mediation models had better fit when including other information, the mediation effect was lower.

Recommendations

We recommend digging deeper into the relationship between achievement and students' attitudes in the future. It would be interesting to replicate this study with TIMSS 2019 data, or in other countries, or with TIMSS science data. Fully replicating this study in other countries or with TIMSS 2019 data requires access to additional information. As students' attitudes towards mathematics tend to decrease from school year 4 to school year 8 (Mullis, Martin & Loveless, 2016), it is urgent that further studies include school year 4. However, a prerequisite is that researchers should have access to similar student official registers for those younger students. Our study suggested that students' attitudes towards mathematics have a small mediating role. It would therefore also be of interest to examine the mediating role of students' attitudes in other countries, although one must be aware that the academic gains may differ among countries for different groups of students (Aydın & Erdem, 2023). Further studies should also include other variables linked to students' attitudes and how they are shaped, e.g. teacher attitude, as there is evidence that teacher attitude is associated with student attitude (Mensah et al., 2013).

Limitations

One limitation of the current study is that we only used a small number of students' SES indicators. In the non-SEM models, we also only used one indicator of students' attitudes toward mathematics. The results did not change, however, when more items related to attitudes toward mathematics were included using SEM. Another limitation is that we only assumed that we examined all possible confounding variables in the mediation analyses. Future studies could consider conducting a sensitivity analysis.

Ethics Statements

This study has an ethical review approval 2017/42-31, so we were allowed to use the students' social security numbers to connect official register data with the students' TIMSS 2015 data.

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