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Measuring and validating students' attitudes towards mathematics in a Nordic context

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Abstract

Measuring students' attitudes towards mathematics is important because students' attitudes influence their mathematical progress. In this study, we administered the Motivation and Attitude (MAT) questionnaire to 4,742 fourth-grade students, aged 10–11 years, from 114 Danish primary schools. The questionnaire was based on the Attitudes Towards Mathematics Inventory (ATMI), but in this study, it was adapted to suit a younger age group than what the ATMI has previously been used. In this process, the questionnaire was reduced from 40 to 32 questions. The questionnaire was designed to measure students' attitudes towards mathematics in a Danish context. The structural validity and internal consistency reliability of the MAT questionnaire were satisfactory based on confirmatory factor analysis (CFA) and Cronbach's alpha analysis, and the scores indicate that the MAT questionnaire has adequate internal consistency reliability. The CFA supported the use of a four-factor model; each factor was directly associated with a specific subscale. Correlations between the motivation and enjoyment, and between motivation and self-confidence, were high (0.8), indicating a close connection between the subscales. This may be due to the theoretical background of the concepts, and a continued effort to define attitude may help develop the questionnaire further.

Keywords: Attitude towards mathematics inventory, Mathematics, Motivation, Nordic context, Nordic, Ordinal GSEM, Primary students, Questionnaire.

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Contents

Contribution of this paper to the literature
Hence, this study contributes to the existing literature by validating a modified ATMI-based questionnaire for younger students in a Nordic context. It documents the structural validity and reliability of the new MAT instrument using ordinal GSEM and CFA, and offers the first large-scale Danish assessment of fourth-graders' attitudes toward mathematics.

1. Introduction

In recent years, there has been a growing interest in increasing the number of students pursuing careers in mathematics. This interest led to a focus on middle school students' attitudes towards mathematics. Furthermore, research worldwide has focused on the relationship between emotion and cognition (Ma & Kishor, 1997), a relationship also considered in the current developments of the Danish school culture, with a strong emphasis on making mathematics meaningful to students.

Originally developed by Tapia and Marsh (2004), the Attitudes towards Mathematics Inventory (ATMI) questionnaire is used to measure high school and college students' attitudes towards mathematics (Lim & Chapman, 2013; Majeed, Darmawan, & Lynch, 2013). It consisted of 6 subscales (anxiety, enjoyment, value, motivation, confidence, and parent/teacher expectations) and 49 questions. It was, however, later condensed to 4 subscales (self-confidence, enjoyment, value, and motivation) and 40 questions (Majeed et al., 2013). Previous studies have demonstrated a correlation between the two subscales, enjoyment and motivation; therefore, researchers suggested that further studies could consider merging the two subscales into one (Guce & Talens, 2013).

The ATMI has been employed worldwide, with participants ranging from secondary school level to university level students (Lim & Chapman, 2013; Ma & Kishor, 1997; Majeed et al., 2013). While students' attitudes towards mathematics have been studied in a Finnish context (e.g., Metsämuuronen and Tuohilampi (2014)), the ATMI questionnaire has, to the best of our knowledge, not been employed in a Nordic context.

In this study of fourth-grade students aged 10–11 years, we assessed the performance of the Motivation and Attitude (MAT) questionnaire, a new questionnaire derived from ATMI. The questionnaire is designed to measure students' attitudes towards mathematics in a Danish context. In the subsequent sections, we discuss the background on the construction of the questionnaire; assess its structural validity and internal consistency reliability based on a large data set of student responses to the questionnaire; and discuss in detail the results of the statistical analysis to reveal possible caveats or shortcomings of the questionnaire. This means that the aim of this study is to examine the MAT questionnaire's validity, and the study addresses the following overarching question: How accurate is the MAT questionnaire in measuring fourth-grade students' attitudes towards mathematics in a Nordic context?

2. Theoretical Background

2.1. Students' Attitudes Towards Mathematics

In recent years, there has been a growing interest in defining attitude in the field of mathematics education, although the concept is still discussed (Hannula, 2002; Hannula et al., 2016; Martino, 2016). Understanding its definition is particularly important when developing an instrument to measure attitude. In research, attitude generally refers to a collection of emotional, cognitive, and behavioral elements (Martino, 2016).

Attitude can be defined as the learned tendency of a person to respond positively or negatively to an object or a situation (Joseph, 2013). Some scholars have criticised the existing research on attitude because historically the focus was more on developing ways to measure attitude than on theoretically defining it as a research concept (e.g. (Hannula, 2002; Martino, 2016)). For the purpose of this study, students' attitudes towards mathematics reflect their beliefs and feelings about the subject. Hence, attitude can be understood as a state of feeling, thinking, and acting that shows an individual's disposition in a way that is less intense than an emotional response (Joseph, 2013; Philipp, 2007), understood as a relatively stable psychological tendency, positive or negative, towards something (Clore & Schnall, 2005). In the current study of students' attitudes towards mathematics, attitudes may stem from automatised emotional responses to mathematics. Attitudes towards mathematics can be relatively stable and do not simply reflect a brief, momentary feeling about mathematics (Joseph, 2013; Philipp, 2007). This is why this study will focus on evaluating students' attitudes towards mathematics.

2.2. Relationship between Attitude towards Mathematics and Achievement in Mathematics

Mathematics is one of the major subjects in middle school. Research focusing on understanding students' attitudes towards mathematics has been ongoing for at least 30 years. Students form their attitudes towards mathematics based on their encounters and experiences with the subject (Davadas & Lay, 2018), and these in turn affect their expectations and future attitudes towards mathematics. For instance, students with negative attitudes towards mathematics tend to consider it an unnecessary subject for their future education (Mullis, Martin, Foy, Kelly, & Fishbein, 2020); consequently, they spend less time studying it Guo, Marsh, Parker, Morin, and Yeung (2015), and avoid mathematics-related activities.

While some studies, as discussed above, found that students' attitudes towards mathematics impact their achievement in the subject (Chen et al., 2018; Dowker, Cheriton, Horton, & Mark, 2019), others found no significant relationship between them (Mubeen, Saeed, & Arif, 2013; Papanastasiou, 2000). In addition, a recent meta-study by Vu, Scharmer, van Triest, van Atteveldt, and Meeter (2024) found that it might be more effective to improve academic skills than to bolster self-beliefs or motivation alone. These mixed results could be attributed to the different cultures, contexts, and age groups in the studies.

2.3. Background of the MAT Questionnaire

The MAT questionnaire is derived from the latest version of the ATMI questionnaire (Tapia & Marsh, 2004), which contains four subscales: self-confidence, enjoyment, value, and motivation. The self-confidence subscale consists of questions related to both positive and negative feelings towards mathematics, which affect learning (Majeed et al., 2013). The enjoyment subscale consists of questions related to liking mathematics and the challenge of problem-solving. The value subscale consists of questions related to considering mathematics as a necessary subject worth pursuing (Majeed et al., 2013). Finally, the motivation subscale consists of questions related to the student's will to pursue mathematics beyond what is expected by the school and the teachers (Majeed et al., 2013).

To obtain the MAT questionnaire, researchers initially translated the original ATMI questionnaire into Danish and made the wording of the questions more suitable for middle school students in a Danish school context. The questions were then translated back into English to ensure that the meaning of the questions was as close as possible to the original questions. For each question, there are five possible answers corresponding to a Likert scale with categories 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree.

Next, the MAT questionnaire was tested and evaluated in a pilot test for fourth-grade students (n = 681). The four subscales were evaluated using exploratory factor analysis (EFA). The EFA, based on the pilot test results, identified eight questions with low loadings, which indicated that the MAT questionnaire could be shortened. Consequently, the number of questions was reduced from 40 to 32 to enhance accessibility to middle school students (Lim & Chapman, 2013). According to the EFA, the motivation subscale appeared to strongly correlate with the self-confidence subscale in a Danish context. This correlation between the subscales has also been revealed in other studies (e.g. Guce and Talens (2013)).

2.4. Structural Validity and Internal Consistency Reliability

Structural validity is defined as the degree to which the subscales of a questionnaire adequately reflect the dimensionality of the construct being measured, in this case, attitude towards mathematics. We studied structural validity within the framework of generalised structural equation models (GSEM). For these models, the dimensionality of a construct translates to the number of latent factors that represent various possibly correlated aspects of the construct. If the MAT questionnaire is structurally valid, student responses should be consistent with a GSEM within four latent factors, each one associated with one of the questionnaire subscales. We investigated this by assessing the fit of the four-factor GSEM model and by comparing the model's fit with a competing one-factor GSEM model. Internal consistency reliability is concerned with the consistency of the items within each subscale, that is, to what extent the different items measure the same aspect of the construct. To investigate this, we used Cronbach's alpha (Cortina, 1993) to measure the degree of correlation between item responses within the same subscale.

3. Methods

3.1. Data Collection

The MAT questionnaire was administered to 4,742 fourth-grade students (average age: 10 years and 3 months) from 114 Danish schools. After excluding 165 students due to missing gender and/or age information, 4,577 students (2,296 boys and 2,281 girls) were included in the final analysis. We compared the distributions of item responses of the 165 omitted students with those of the remaining students and found no significant deviations. Hence, we considered the omitted students as a random subsample of the students.

All school principals approved the research project, and all parents were informed of the content of the project and their right to withdraw their child from the study. The procedure followed the Danish Code of Conduct and the General Data Protection Regulation. The ethnicity of the students aligned with that of the overall population (92.7% Danish origin, 6.8% non-Western immigrants, and 0.5% Western immigrants).

3.2. Confirmatory Factor Analysis (CFA)

To assess the structural validity of the questionnaire, we conducted a CFA using a GSEM. Initially, we considered a four-factor model, with one factor for each subscale. The fit of the model was assessed using empirical summary statistics as detailed below, and we further compared the four-factor model with a competing one-factor model. The comparison was done using the Akaike information criterion (AIC) and the Bayesian information criterion (BIC).

3.3. Ordinal Logistic Regression

The qualitative response for each item was ranked on a discrete, ordered scale ranging from 1 (strongly disagree) to 5 (strongly agree); hence, the observed data was ordinal. Thus, a standard structural equation model (SEM) was not appropriate since this model assumes normally distributed responses. Instead, we used a GSEM with ordinal responses and a logistic link function. Consider, for instance, a response Y_{ij} for the j'th item belonging to the i'th latent factor X_i. Furthermore, let Z be an indicator, which is 1 for a boy and 0 for a girl. Then, conditional on X_i and Z, the probability that the response Y_{ij} is less than or equal to response k (where k is 1, 2, 3, 4 or 5) is of a logistic form depending on the weighted sum $\alpha_{ij}Z + \beta_{ij}X_i$. The coefficient β_{ij} is called the loading. If it is zero, then the latent factor X_i has no influence on Y_{ij}. If β_{ij} is positive, then larger values of X_i make it more likely to observe high values of Y_{ij}, and the other way around if β_{ij} is negative. Thus, we can assess the β_{ij}s to determine if the questions depend on the latent factor (and vice versa), and if so, whether they depend on $X_i$in the same way. Similarly, if α_{ij} is positive, then it is more likely to observe higher values of Y_{ij} for boys than for girls, and vice versa if α_{ij} is negative. The GSEM approach also estimates variances and covariances for the latent factors. If the variance of a latent factor is small, it means that the factor does not vary much over the population of students and hence does not significantly influence the responses Y_{ij} across students. Furthermore, we can assess the extent to which the factors are correlated.

3.4. Assessment of the Structural Validity of the Four-Factor Model

In case of continuous response data modelled by a standard SEM, various indices such as comparative fit index, Tucker-Lewis's index and root mean square error of approximation are used for assessing the goodness-of-fit of a proposed model and hence the validity of the structure represented by the latent factors of the model (Kline, 2016). All these indices are based on the log likelihood ratio (also known as model χ^2) between the model considered and the so-called saturated model that imposes no restriction on the covariance matrix of the observed response data.

Along with the indices come rules of thumbs for judging whether the value of each index suggests a suitable fit of the model or not. In the case of GSEM, there does not appear to be an obvious viable candidate for a saturated model. Thus, the standard indices and rules of thumb for SEM are not available in the case of a GSEM with ordinal responses.

We borrowed ideas from SEM analyses and compared the model response covariance matrix with the empirical covariance matrix of the responses. The model response covariance matrix is the covariance matrix of the responses implied by the considered GSEM model. This covariance matrix is not available in closed form but can be approximated to any desired accuracy using Monte Carlo simulations of the fitted model. The empirical covariance matrix of the responses is saturated since it is not restricted by any model assumptions and thus only depends on the response data, supposing the model response covariance matrix agrees well with the empirical covariance matrix. The latent factor structure of the proposed model thus yields a covariance structure for the observed response data which is in good accordance with the covariance structure informed solely by the data. This then supports the structural validity of the proposed model.

3.5. Internal Consistency Reliability

To evaluate the internal consistency reliability of each subscale, we used Cronbach's alpha, which depends on the average intercorrelation among the questions within the subscale. For conceptual purposes, we provide the following formula for Cronbach's alpha.

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}}$$

Where N is the number of questions for the subscale, $\overline{c}$ is the average inter-item covariance among the questions, and $\overline{v}$ is the average variance. For a fixed number of questions and a fixed average variance, Cronbach's alpha increases if the average inter-item correlation increases, and vice versa.

4. Results

Almost all participants completed the shortened MAT questionnaire within 15 min. In the following sections, we focus on the 4,577 students with complete gender information and consider the pattern of missing responses from the students. The findings indicated that the missing responses were due to participants not fully completing the questionnaire. In fact, except for one student with a single missing response in the middle of the questionnaire, all the other students with missing responses stopped answering the questionnaire. However, we deemed the missing responses to be a negligible issue because for the last item, which had the most missing values, the proportion of missing values was a mere 1%. For more details, see Table 1, which contains item-level descriptive data.

Table 1. Descriptive statistics for the MAT questionnaire.

Label Full	Question Statement	M	SD
Value			
1	Mathematics is a very worthwhile and necessary subject.	4.17	0.85
2	I want to develop my mathematical skills.	4.31	0.85
4	Mathematics is important in everyday life.	3.86	0.95
5	What I learned in mathematics in school is important for my future.	4.31	0.87
6	I can think of many ways that I use mathematics outside of school.	3.51	1.03
7	Mathematics is one of my most dreaded subjects.	1.80	0.74
8	My mind goes blank, and I am unable to think clearly when working with mathematics.	1.94	0.72
27	I think I need to use mathematics when I grow up.	4.24	1.00
28	I believe studying mathematics helps me with problem-solving in other areas.	3.36	1.00
31	Being good at mathematics can be helpful later in my life.	4.33	0.84
Enjoyment			
3	I think it is fun to solve mathematics problems.	3.25	1.02
20	I usually enjoy having mathematics in school.	3.52	1.13
21	Mathematics is dull and boring.	1.83	0.75
23	I really like mathematics.	3.40	1.25
24	I am happier in a mathematics class than in any other class.	2.71	1.11
25	Mathematics is a very interesting subject.	3.38	1.14
Self-confidence			
9	Mathematics makes me feel nervous.	1.82	0.69
10	Mathematics makes me feel uncomfortable.	1.76	0.71
11	I am always under a terrible strain in a mathematics class.	1.94	0.71
12	When I hear the word "mathematics," I have a feeling of dislike.	1.52	0.66
13	It makes me nervous to even think about having to do a mathematics problem.	1.69	0.69
14	I am able to solve mathematics problems without too much difficulty.	3.33	1.11
15	I expect to do fairly well in any mathematics class I take.	3.79	1.02
16	I am always confused in my mathematics class.	2.06	0.71
17	I feel a sense of insecurity when attempting mathematics.	1.92	0.69
Motivation			
18	I learn mathematics easily.	3.32	1.11
19	I am sure that I could learn the mathematics meant for the next grade.	3.58	1.07
22	I would like to avoid using mathematics after school.	1.94	0.76
26	The challenges of mathematics appeal to me.	3.28	1.16
29	I am not afraid to come up with solutions to difficult problems in mathematics.	3.28	1.09
30	I am comfortable answering questions in mathematics class.	3.43	1.08
32	I believe I am good at solving mathematics problems.	3.54	1.05

Table 2 shows loadings for the four-factor model. The loading for the first item for each factor was fixed to the reference value 1.

Table 2. Loadings for the four-factor model.

Value questions	**1**	**2**	**4**	**5**	**6**	**7 (*)**	**8 (*)**	**27**	**28**	**31**
Value loading	1	0.8	0.9	1.0	0.7	-0.4	-0.3	0.9	0.7	1.1
Enjoyment questions	3	20	21 (*)	23	24	25				
Enjoyment loading	1	1.5	-0.5	2.6	1.1	1.6				
Self-confidence questions	9 (*)	10 (*)	11 (*)	12 (*)	13 (*)	14	15	16 (*)	17 (*)	
Self-confidence loading	1	1.3	0.8	1.4	1.5	-0.9	-1.2	0.8	1.1	
Motivation questions	18	19	22 (*)	26	29	30	32			
Motivation loading	1	0.6	-0.2	1.1	0.6	0.7	1.2			

Note: All loadings have p-values less than 0.0001. Questions for which only the smallest three categories are used are marked with an asterisk (*).

All remaining estimated loadings were significantly different from zero ($p < 0.0001$). For value, the loadings were close to 1, except for questions 6 and 7, which had negative loadings. For enjoyment, the third item deviated from the other questions as it had a negative loading. For self-confidence, all loadings were close to 1, except for the negative loadings for questions 14 and 15. For motivation, all loadings were close to 1, except for item 3, which had a negative loading of -0.2 (moderate absolute value). All questions inform on the latent factor, although a few to a lesser extent. For value, enjoyment, and motivation, negative loadings were obtained for questions with negative wordings, and positive loadings were obtained for positively phrased questions. This made sense because negatively and positively phrased questions should have loadings of opposite signs. The results for self-confidence were also consistent with the above findings. Since the first self-confidence item was negatively worded but forced to have a positive loading of 1, signs of loadings for self-confidence were interchanged compared to the other subscales.

Considering the number of Likert scale categories used, responses to questions with negative wordings always fell within the first three categories, while all five categories occurred for the responses to the remaining questions. This finding suggested that students were hesitant to agree with the negatively worded questions.

Regarding gender difference (Table 3), we observed that boys tended to use smaller categories than girls in their answers to value questions. They used smaller categories for the negatively worded self-confidence questions and higher categories for the positively worded self-confidence questions. This shows that boys tend to express a higher degree of self-confidence than girls.

Table 3. Gender regression coefficients α_{ij}.

Value item	**1**	**2**	**4**	**5**	**6**	**7**	**8**	**27**	**28**	**31**
Coef.	-0.1	-0.2 (0.00)	-0.2 (0.03)	-0.1	-0.1	-0.4 (0.00)	-0.4 (0.00)	-0.2 (0.02)	0.1	0.1
Enj. item	3	20	21	23	24	25				
Coef.	0.3 (0.00)	0.3 (0.00)	-0.4 (0.00)	1.0 (0.00)	0.6 (0.00)	0.6 (0.00)				
Self. item	9	10	11	12	13	14	15	16	17	
Coef.	-0.6 (0.00)	-0.5 (0.00)	-0.4 (0.00)	-0.3 (0.00)	-0.6 (0.00)	0.6 (0.00)	0.6 (0.00)	-0.3 (0.00)	-0.4 (0.00)	
Mot. item	18	19	22	26	29	30	32			
Coef.	1.1 (0.00)	0.7 (0.00)	-0.2 (0.00)	0.9 (0.00)	0.8 (0.00)	0.9 (0.00)	1.2 (0.00)			

Note: Positive values mean boys tend to use higher-answer categories than girls, and vice versa for negative values. P-values less than 5% are given in parentheses.

For enjoyment and motivation, the boys used higher scores on the questionnaire Likert scale for all the positively worded questions and vice versa for the negatively worded questions. These answers show that boys, in general, tend to express higher enjoyment and motivation than girls. Another Danish study found that boys generally showed a higher self-perception of their academic achievement than girls (Spaten, Christiansen, Rahbek, Rahbek, & Dahl-Jensen, 2014). This tendency perhaps partly explains our findings; however, further research is needed to gain a better understanding of this tendency.

4.1. Assessment of Structural Validity

The latent factor standard deviations in Table 4 show that all four latent factors have considerable variation over the population of students; for instance, the latent value factor ranges over a 95% probability interval from -3.6 to 3.6. This suggests that all factors should be considered. Furthermore, all four factors were correlated with absolute correlations ranging between 0.6 and 0.8. We, therefore, considered a one-factor model to determine if there was scope for reducing the four correlated factors to only one factor common to all questions.

Table 4. Standard deviations and correlations for the four-factor model.

	Value	**Enj.**	**Self.**	**Mot.**
Value	1.8	0.7	-0.6	0.7
Enjoyment		1.8	-0.7	0.8
Self-confidence			1.3	-0.8
Motivation				2.1

Table 5 shows AIC and BIC for the four- and one-factor models. The four-factor model is clearly favoured, having lower values of AIC and BIC. Hence, despite the correlations between the four factors, there is no scope for replacing them with a single common factor.

Table 5. Degrees of freedom, AIC, and BIC for Models with One and Four Factors.

Model	N	df	AIC	BIC
Four-factor	4,577	176	316856.1	317987.6
One-factor	4,577	170	323109.2	324202

The four-factor model performed better than the one-factor model. However, this does not imply that the four-factor model itself provides a good fit for the data. To assess this, we compared the model-based means, variances, and off-diagonal covariances of the responses with the empirical counterparts obtained directly from the observed responses (Figure 1). Overall, there was a good agreement between the model-based and the empirical quantities. In particular, the model captured well the differences between negative and positive empirical off-diagonal covariances as well as the tail of large positive off-diagonal covariances. For completeness, we also compared (lower right plot of Figure 1) empirical off-diagonal covariances with model-based off-diagonal covariances for the one-factor model. Especially in the middle part of the plot, the points show greater and more systematic deviations from the identity line than for the four-factor model. In particular, within-subscale covariances (black dots) are above the identity line, and between-subscale covariances (red dots) are below the identity line in the middle part of the one-factor plot. For the means and variances, the differences between the four-factor and one-factor model fits were minimal.

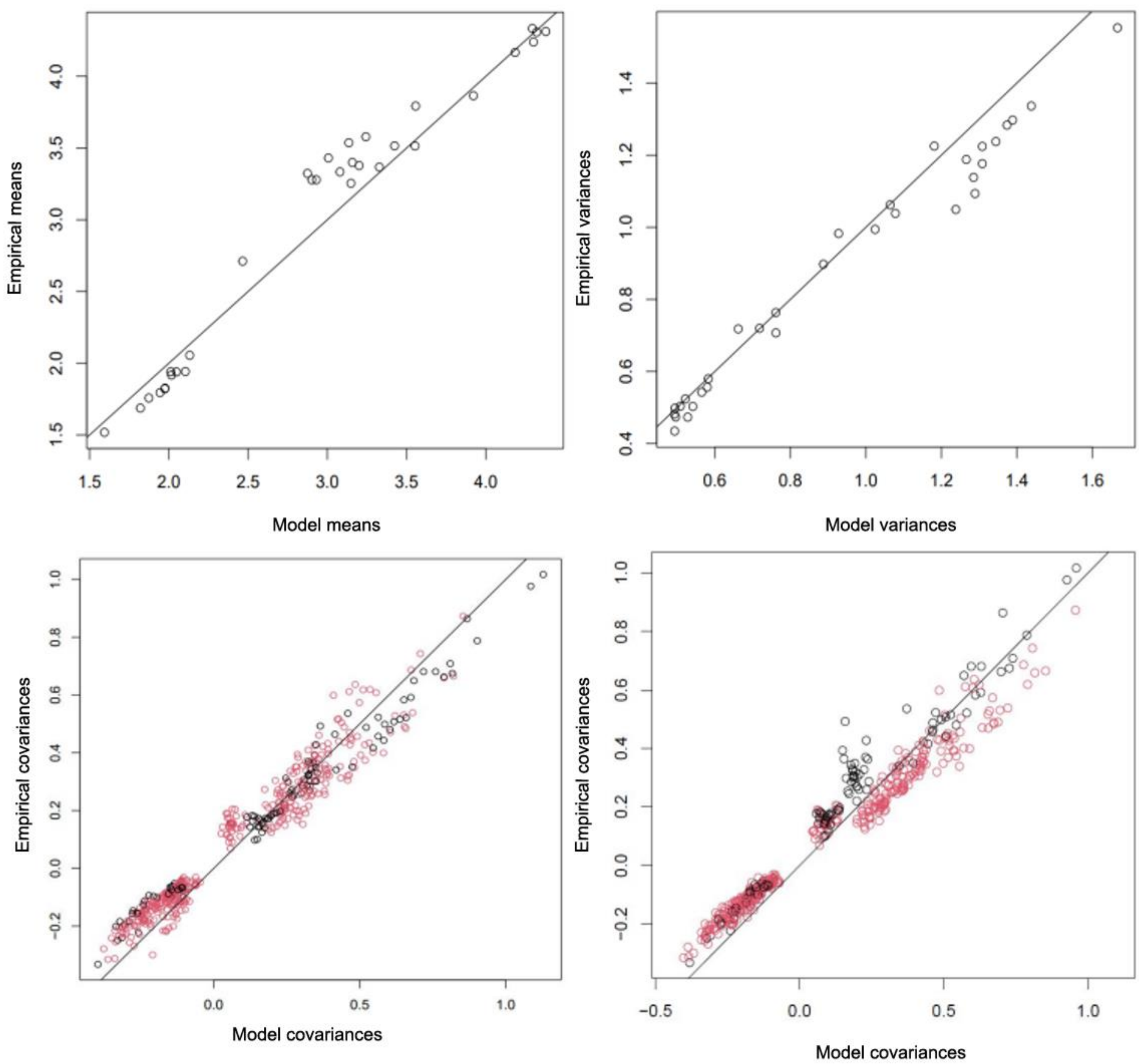

Figure 1. Comparison of empirical and four-factor model-based means (Upper left), variances (Upper right), and covariances (lower left). Lower right: comparison of empirical and model-based covariances for a one-factor model.

Note: Black dots in the lower plots show within-subscale covariances, and red dots show between-subscale covariances.

4.2. Internal Consistency Reliability

Evaluation of the internal consistency reliability showed that the Cronbach's alpha was above 0.7 for each subscale (see Table 6), with the enjoyment subscale (α = 0.85) having the highest score and the self-confidence subscale (α = 0.76) having the lowest score. Overall, the alpha coefficients suggested that the questions had relatively high internal consistency.

Table 6. Cronbach's alpha for each subscale.

Subscale	α	Number of items questions	Covariance
Value	0.80	10	0.22
Enjoyment	0.85	6	0.27
Self-confidence	0.76	9	0.16
Motivation	0.79	7	0.38

5. Discussion

5.1. Positively and Negatively Worded Questions

Positively and negatively worded questions in questionnaires have been validated in previous studies for middle school students, e.g., Harter (2012). Our aim was to phrase the questions in a way that retains the original meaning and intent as closely as possible, mainly because we intended to use the questionnaire in a longitudinal study. Moreover, to ensure that comparisons across cultures are accurate, it was important to stay close to the original setup. Previous studies (e.g., Bell (2007)) using the original questionnaire typically involved participants older than the ones in our study; therefore, negative questions were a normal part of the design. Based on the teachers' responses, the children here did not experience difficulty in answering the questions.

In the present study, we also considered difficulties pertaining to the suitability of the questions for the age group and the validity of the original ATMI questionnaire. Changing negatively phrased questions into positively phrased ones may help improve the middle school students' ability to understand the questions and, thereby, the validity of the questionnaire. This, however, would require a new validation of the questionnaire. Also, changing between the negatively and positively phrased questions may cause the students to reflect more deeply on the questions.

Research on children's self-perception suggested progression in their ability to differentiate the different aspects of their lives towards a more multidimensional self-perception (Harter, 2012). This, to some extent, explains the correlation between motivation and self-confidence observed in our study. Perhaps children's ability to differentiate different areas of their lives does not develop until later in life. In this regard, age appears to be an important factor that determines the children's ability to understand more linguistically complex negative questions (Meijer, Egberink, Emons, & Sijtsma, 2008).

5.2. Gender Differences

In line with the findings of previous studies in Western settings, we found that boys had a higher score on self-perception than girls (Harter, 2012; Spaten et al., 2014). It is noteworthy that the tendency for boys to have a higher self-perception may be connected to stereotypes in society that can significantly influence the children's perceptions of the link between gender and academic competence (Skårhøj & Østergaard, 2000). Similarly, Owen (2023) pointed out that males, especially academically low-performing ones, tend to be overconfident about their abilities. This tendency perhaps explained why the boys' answers in the questionnaire were more towards the upper end of the scale than the girls. Indeed, several studies have given various explanations for the gender differences in STEM fields; however, further studies are needed to gain a better understanding of the underlying factors (Ersoy & Rury, 2025).

5.3. Content of the Questions

Tapia and Marsh's (2000) study on second-grade students included four factors: self-confidence, enjoyment, motivation and value; they found a close correlation between enjoyment and motivation, in line with our findings. The questions about motivation in the MAT questionnaire may point towards what Ryan and Deci (2019) describe as 'intrinsic motivation', such as the statement, 'I believe I am good at solving mathematics problems'. In this phrasing, the child is being asked more about the intrinsic motivation and less about the extrinsic motivation (e.g., different types of rewards) they experience during mathematics lessons. Intrinsic motivation is closely related to a child's experience of enjoyment (Ryan & Deci, 2019), and this relation could further explain the correlation between the two subscales.

In the self-confidence subscale, we found questions similar to those in the motivation subscale, which asked students about problem solving in mathematics; the correlation here may be because of the similarity in the phrasing of some of the questions. For instance, we found some similarities between these two statements: 'I believe I am good at solving mathematics problems' (motivation, question 32) and 'I am able to solve mathematics problems without too much difficulty' (self-confidence, question 14). In fact, we found that the nuances between these two may be too subtle for the students to understand.

There are also similarities in the definitions of these two subscales (Majeed et al., 2013). Despite these correlations, our analysis continued to suggest four separate factors, and that the correlations do not indicate one collective factor. We believe that continued effort to define attitude could help develop the questionnaire and its subscales further.

6. Conclusion

The findings of our study indicate that the MAT questionnaire can provide teachers and researchers with meaningful and accurate data regarding students' attitudes towards mathematics. Therefore, the MAT questionnaire's subscales (self-confidence, enjoyment, value, and motivation) can be considered as four separate unidimensional subscales. However, the study also shows a close correlation between the subscales, which is not a surprise when considering the results theoretically. On that note, we consider the structural validity of the questionnaire acceptable. Furthermore, when evaluating the internal consistency of each subscale, the Cronbach's alpha coefficients show acceptable scores, indicating that the MAT questionnaire has adequate internal consistency reliability.

6.1. Future Studies

While some questions had strong correlations with other subscales, some in the motivation subscale lacked clear loading onto the subscale, a challenge identified in a previous study as well (Lim & Chapman, 2013). Rectifying this challenge warrants further research, with a focus on refining the definition of attitude. In addition, it requires a closer look at the four subscales to determine how they are intertwined and how they can be more clearly distinguished from one another.

The impact of age and gender differences on students' question-answering style also warrants further research. Age could play a role in their ability to see nuances in their lives (Harter, 2012) and to understand how to provide nuanced answers to the questions.

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