THE INTERPLAY OF FOURTH GRADERS' MATHEMATICS ATTITUDES AND PERFORMANCE: A MULTILEVEL STUDY

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The decline in global mathematics attitudes and performance raises significant concerns for educational outcomes and career choices. While evidence suggests that students' attitudes significantly influence their performance, some studies report no substantial relationship. This study examines the relationship between fourth graders' (n = 639) mathematics attitudes and performance at both the student and classroom levels. Utilizing multilevel modeling, we found that students' positive mathematics attitudes strongly predict better performance, a relationship that remains consistent across classrooms. These findings underscore the need for effective strategies to enhance student confidence and engagement in mathematics, ultimately supporting their long-term success in STEM fields.

INTRODUCTION

With the increasing demand for a STEM workforce (European Commission, 2021), mathematics plays a crucial role in fostering innovation and economic growth, serving as the foundation for fields such as engineering, technology, and science. Despite the growing need for STEM professionals, there has been a concerning decline in mathematics attitudes and performance in various countries, including Lithuania (Berger et al., 2020; OECD, 2023; Cibulskaitė & Augustinovič, 2020). Research indicates that students' attitudes toward mathematics significantly influence their performance and shape their academic and career choices (Wang et al., 2015). Therefore, understanding the relationship between mathematics attitudes and performance is essential for developing effective interventions that enhance student engagement with mathematics and ultimately support their success in STEM fields.

Much research highlights the positive impact of favorable mathematics attitudes on achievement, while negative attitudes correlate with lower performance (Johnson et al., 2024; Wen & Dubé, 2022). Expectancy-value theory explains this phenomenon, emphasizing that a student's attitudes (e.g., their expectations for success and the value they attach to the subject) significantly influence their motivation and engagement (e.g., Eccles & Wigfield, 2002). Students who believe they can succeed in mathematics tend to approach the subject with a positive attitude, which leads to improved performance (Wen & Dubé, 2022). Likewise, when students recognize the relevance of mathematics to their personal and professional lives, they invest more in their

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learning and are more likely to pursue advanced mathematics courses and careers (Levine & Pantoja, 2021).

The Fennema-Sherman Mathematics Attitudes Scales (FSMAS; Fennema & Sherman, 1976) have been widely utilized in studies, including international assessments such as PISA and TIMSS (Metsämuuronen, 2012). According to FSMAS, mathematics attitudes are multidimensional and encompass several constructs, including self-concept, intrinsic value, and utility value. A strong self-concept, or students' confidence in their mathematical abilities, fosters greater motivation and perseverance (e.g., Aladil, 2024; Niemivirta et al., 2023) while reducing anxiety (e.g., Wang, 2023), contributing to improved performance. Intrinsic value, defined as a liking for and enjoyment of mathematics, enhances student engagement and their willingness to invest time and effort in learning, ultimately boosting performance and encouraging further study (e.g., Aladil, 2024; Berger et al., 2020). Utility value refers to the perceived usefulness of mathematics; when students recognize its value, they are more motivated to engage, leading to better performance (e.g., Aladil, 2024; Wen & Dubé, 2022) and aspirations for mathematics-related careers (Berger et al., 2020).

The recent TIMSS 2023 results (von Davier et al., 2024) reveal a strong positive relationship between fourth graders' attitudes toward mathematics and their performance. Students who enjoyed learning mathematics (intrinsic value) scored an average of 32 points higher than their less enthusiastic peers, and those with higher confidence in their mathematical abilities (self-concept) scored an average of 87 points higher. However, while these results provide valuable insights, they focus solely on intrinsic value and self-concept, leaving the utility value of mathematics unexamined for fourth graders. Additionally, the relationship between these attitudes and performance in specific mathematical subdomains, such as multi-step word problems and early algebraic reasoning that require higher cognitive skills, remains inadequately studied.

Despite evidence suggesting that students' attitudes toward mathematics influence their performance, some studies report no significant relationship between the two (Hwang & Son, 2021). According to Hwang and Son, mixed findings may arise from limitations in previous research, including: (1) examinations of individual attitude dimensions without considering their interrelated nature, (2) failure to control for student background influences, and (3) reliance on small, non-representative samples. These discrepancies underscore the need for further investigation into the complex relationship between attitudes and performance in mathematics.

To address the identified research gaps, this study aims to answer the following questions: RQ1. What is the relationship between students' attitudes toward mathematics and their performance? RQ2. To what extent are students’ mathematics attitudes, gender, socioeconomic status, and town population size related to their performance? RQ3. Does the relationship between mathematics attitude and performance vary across classrooms?

THE PRESENT STUDY

Setting and participants

This study was conducted in 64 fourth-grade classrooms across 23 schools of varying sizes and types in 13 municipalities throughout Lithuania in Spring 2025. Initially, 1,107 students participated; after excluding those who did not complete the attitude questionnaire and all mathematics tests, or had missing covariate information, 639 students aged 10.97 (*SD* = 0.39; 51.5% boys) from 21 schools and 48 classrooms were included, representing a diverse group with varied backgrounds. Ethical considerations were addressed, including approval from the ethical review board, informed consent from guardians, and compliance with GDPR.

Instruments

A computer-based mathematics test comprising four sections was administered on the ViLLE platform (Laakso et al., 2018) within 45 minutes, followed by an attitude questionnaire.

Section 1: Arithmetic fluency. Arithmetic fluency is essential for early and advanced mathematics learning, as it supports higher-order thinking skills such as reasoning and problem solving, by freeing cognitive resources for grasping concepts (Psyridou et al., 2023). Students were asked to complete as many basic arithmetic calculations as possible in three minutes. The test consisted of 160 open-answer items based on the Woodcock-Johnson IV tests (r_{11} = .95; Schrank et al., 2014), including 50 addition and subtraction items and 110 multiplication and division items.

Section 2: Algebraic thinking. Algebraic thinking is crucial for developing problem-solving and reasoning skills essential in academic, professional, and daily contexts (Kieran, 2004). The algebraic thinking test consisted of 14 items (including 35 subitems; open-answer and multiple-choice; α = .91, deflation corrected) taken from the COMATH test (https://www.fsf.vu.lt/ct-math-able#assessment-instruments), assessing students' understanding of the equal sign, as well as their skills in equation solving, functional thinking, and the application of algebraic concepts.

Section 3: Word problem solving. Mastering word problems is vital for success in various contexts, as they require the integration of numerical skills, mathematical concepts, reading comprehension, and problem-solving (Fuchs et al., 2006). The word problem solving test consisted of 13 items (open-answer and multiple-choice; α = .83, deflation corrected) to measure students' multi-step arithmetic problem-solving skills.

Section 4: Curriculum-based mathematics. The final section comprised nine items (open-answer and multiple-choice) developed to assess curriculum-based mathematics, including seven items from previous Lithuanian national assessments and two items created for this study (α = .81, deflation corrected). The content areas include fractions, decimals, measurement, geometry, and data, ensuring no overlap with other test sections and aligning with the Lithuanian fourth-grade curriculum.

Mathematics attitude. The adapted version of the FSAS, used by the Finnish Education Evaluation Centre for over 20 years (Metsämuuronen, 2012), was employed in this study. This 4-point Likert-scale questionnaire included 15 items ($\alpha = .85$), with 5 items for each attitude dimension: self-concept ($\alpha = .70$), intrinsic value ($\alpha = .85$), and utility value ($\alpha = .64$), indicating opportunities to enhance the reliability of this dimension.

Data Analysis

To address RQ1 regarding the relationship between students' attitudes and performance, a correlation analysis was performed. Multilevel linear analysis further explored this relationship at the student ($n = 639$) and classroom levels ($n = 48$), since students from different classrooms may exhibit varying levels of mathematics attitudes and performance. The predicted variable was the total score of all mathematics tests, with fixed predictors including the attitude questionnaire score and covariates: student gender, socioeconomic status, and town population size. First, we ran an unconditional (null) model (Model 1), predicting mathematics performance solely from the classroom random effect and a fixed intercept. The intraclass correlation (ICC) assessed variance attributed to classroom differences; if ICC was at least 0.05, a multilevel model was used next. Next, we ran the first conditional model (Model 2), adding the fixed predictors to Model 1. To address RQ2, we examined the regression coefficients of the attitude variable and covariates for statistical significance. Finally, we ran the second conditional model (Model 3), allowing the effect of the attitude predictor to vary across classrooms (adding a random slope). To address RQ3, we performed a likelihood ratio test to evaluate whether allowing variations across classrooms improved model fit, along with comparing the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) between Models 2 and 3; lower AIC and BIC values indicate a better fit.

RESULTS

Regarding RQ1, correlations between attitude variables and performance were positive and statistically significant in all cases, except for the utility value and arithmetic fluency ($r = .053$, $p = .184$). The strength of the relationships varied across different mathematics attitude dimensions and performance, with the highest correlations observed between self-concept and performance in word problem solving ($r = .413$, $p < .001$) and the lowest between utility value and curriculum-based mathematics performance ($r = .093$, $p < .05$).

Table 1 displays the results of the fitted multilevel models. The unconditional model (Model 1) revealed that classrooms explain 16.7% of the variance in total mathematics test scores among students, with an overall mean performance of 79.84 ($p < .001$). The ICC of 0.167 (≥ 0.05) indicates a meaningful variance between classrooms, justifying the use of multilevel modeling in subsequent analyses.

Regarding RQ2, Model 2 indicates that attitudes are the only significant predictor of mathematics performance. Each 1-unit increase in attitude score corresponds to an

average increase of 0.73 points in total mathematics score, holding other predictors constant ($p < .001$). Other covariates did not significantly predict the total mathematics score. The ICC changed minimally compared to Model 1, with differences between classrooms explaining 16.9% of the total variance in mathematics performance.

Table 1: Multilevel Models Predicting Students' Mathematics Performance and Their ICC and Fit Measures

	Model 1 (Null)	**Model 2**	**Model 3**
Variable	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)
Fixed effects			
Intercept	79.84*** (1.48)	70.16*** (5.43)	70.06*** (5.44)
Attitudes		0.73*** (0.11)	0.73*** (0.13)
Gender (Boy)		2.80 (1.53)	2.74 (1.53)
Gender (Other)		5.73 (6.15)	6.53 (6.22)
Socioeconomic status		0.56 (0.65)	0.46 (0.66)
Town population[a]		4.72 (4.97)	5.27 (5.00)
Town population[b]		5.72 (3.81)	6.59 (3.82)
Random effects			
Student level variance (Residual)	358.35 (320.48, 402.43)[c]	330.62 (293.77, 369.00)[c]	324.85 (288.01, 365.09)[c]
Classroom level variance (Intercept)	72.08 (38.63, 124.68)[c]	67.09 (32.67, 110.00)[c]	67.53 (32.90, 111.01)[c]
Random slope variance			0.13
Intercept–slope correlation			-0.26
ICC and Fit Measures			
ICC Student	0.833	0.831	0.828
ICC Classroom	0.167	0.169	0.172
AIC		5572.81	5575.45
BIC		5612.95	5624.51

Note. *** $p < .001$; [a] 10,000–50,000; [b] >50,000; [c] (95% Profile likelihood CI).

Regarding RQ3, Model 3, which included a random slope, was fitted to the data. The fixed predictor estimates remained largely unchanged from Model 2. Attitudes continued to be the only fixed predictor positively and significantly associated with mathematics performance, with differences between classrooms explaining 17.2% of the variance. However, our analysis revealed that the inclusion of random slopes for classroom variations in Model 3 did not significantly enhance model fit compared to

Model 2. The AIC and BIC for Model 2 were lower than those for Model 3, and the likelihood ratio test yielded a p-value of .51. Therefore, these results suggest that the association between mathematics attitudes and performance remains consistent across classrooms. Additionally, the classroom ICC showed minimal change compared to Models 1 and 2.

DISCUSSION AND CONCLUSION

This study investigates the relationship between fourth graders' mathematics attitudes and their performance at both the individual and classroom levels. Our findings align with previous research (Johnson et al., 2024; von Davier et al., 2024; Wen & Dubé, 2022), demonstrating a strong positive correlation between students' attitudes and performance. Consistent with the TIMSS 2023 results (von Davier et al., 2024), we found that fourth graders with higher confidence in their mathematical abilities (self-concept) or a greater enjoyment of learning mathematics (intrinsic value) tend to perform better, especially in word problem solving—a result not reported in TIMSS. However, despite evidence linking the perceived usefulness of mathematics (utility value) to improved performance (Aladil, 2024; von Davier et al., 2024; Wen & Dubé, 2022), our study revealed a weak relationship between these factors across all mathematics tests, particularly in arithmetic fluency.

Multilevel modeling confirms that positive mathematics attitudes are strong predictors of better performance while accounting for differences across classrooms and other covariates. However, we found no significant relationship between other covariates (students' gender, socioeconomic status, and town population size) and their mathematics performance. This contrasts with previous research (e.g., Wang & Degol, 2017), which identified a statistically significant gender gap in mathematics performance, and the TIMSS 2023 results (von Davier et al., 2024), which reported a strong relationship between the socioeconomic status of fourth-grade students and their mathematics achievement. Additionally, while previous studies (e.g., Ajai & Ogungbile, 2023) suggest that classroom environments, such as teaching methodologies and teacher engagement, significantly impact students' mathematics attitudes and subsequent performance, our findings show that the positive association between attitudes and performance remains consistent across classrooms.

These findings underscore the importance of developing effective strategies to foster positive attitudes, particularly confidence and engagement in mathematics, thereby enhancing performance, narrowing the performance gap, and promoting long-term success in STEM fields. Since attitudes already develop during the early years, fostering positive mathematical dispositions is essential from the outset.

While this study addressed limitations in previous research by considering the interrelated nature of attitude dimensions, controlling for student background influences, and using larger, more representative samples, it still has limitations. Data were collected only from fourth-grade classrooms in Lithuania, limiting the

applicability of the results; future studies should include diverse populations. Additionally, the attitudes and socioeconomic status data relied on self-reports, which can introduce bias; future research should incorporate observational measures to complement these. Furthermore, our multilevel analysis focused on overall mathematics attitudes and performance, which may account for the lack of significant relationships with other covariates; future studies could explore how specific attitude dimensions relate to performance in various subdomains.

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