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# Home Environment Matters: Predicting TIMSS Math Success in Bosnia and Herzegovina

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**Abstract**

The Trends in International Mathematics and Science Study (TIMSS) is a large-scale international assessment that measures students' achievement in mathematics and science at the fourth and eighth-grade levels. Coordinated by the International Association for the Evaluation of Educational Achievement (IEA), TIMSS is conducted every four years. The 2023 assessment represented the eighth cycle of TIMSS, collecting data from 64 participating countries. This exploratory study examines the influence of several key factors—gender, home learning resources, experiences of bullying, disruptive classroom behavior, and students' sense of school belonging—on fourth-grade mathematics achievement in Bosnia and Herzegovina. The research sample included 2,712 students (mean age: 10.2 years; SD = 0.4; 1,388 girls and 1,324 boys). Results showed that home learning resources were the most important predictor of mathematics achievement, emphasizing the essential role that home educational conditions play in student academic outcomes. The observed difference between boys and girls in mathematics scores was minimal. Both bullying and disruptive behavior were found to have a statistically significant negative impact on mathematics performance, whereas the effect of students' sense of school belonging did not reach statistical significance. Home learning resources proved to be the most decisive variable in forecasting mathematics achievement among fourth-grade students in Bosnia and Herzegovina, reinforcing the value of home-based educational support in fostering academic progress. These results suggest the necessity for educational policies and interventions that ensure fair access to learning resources within the home environment. The paper concludes with a discussion of the implications of these findings and outlines potential avenues for future research and educational practice.

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## Introduction

The Trends in International Mathematics and Science Study (TIMSS) is an influential international assessment aimed at evaluating and comparing the mathematics and science achievements of students worldwide. Initiated in 1995 by the International Association for the Evaluation of Educational Achievement (IEA), TIMSS is conducted approximately every four years, providing a longitudinal perspective on educational outcomes across various countries (Mullis et al., 2015). TIMSS provides rich data that highlights trends in student achievement, the effectiveness of educational practices, and the factors that influence learning outcomes. The assessment covers a broad spectrum of topics in mathematics and science and encourages understanding of the educational contexts in which students learn, focusing on curriculum implementation and instructional methods used in different countries (Phang et al., 2021). The TIMSS results are typically reported in terms of average achievement scores, and countries are often ranked based on their performance, providing insights into educational effectiveness across different systems (Nixon & Barth, 2014).

The focus on mathematics within TIMSS is particularly significant, as mathematics is a cornerstone of modern education and an essential skill for navigating today's increasingly data-driven and technology-oriented world. Mathematics education in elementary school is of great importance — it lays the foundation for future academic success, fosters logical reasoning, and equips students with problem-solving skills that extend beyond the classroom. Early exposure to mathematical concepts enhances cognitive development and strengthens numeracy, which is indispensable not only for academic achievement but also for practical applications in daily life (Lee, 2014). Studies have shown that early exposure to mathematical ideas fosters children's mathematical sensitivity, which enhances their enjoyment and confidence in mathematics as they progress through their education (Liu, 2023).

The TIMSS not only assesses student performance but also gathers extensive background data from students, their teachers, and principals, which helps researchers analyze the factors contributing to educational achievement (Broer et al., 2019). Mathematical performance in elementary school is influenced by a variety of interconnected factors. Understanding these influences is critical for optimizing educational practices and enhancing student outcomes in mathematics. For example, studies have shown that socioeconomic status (SES) plays a critical role in mathematical achievement. Students from lower SES backgrounds often attend schools that lack resources necessary for high-quality mathematics instruction, negatively affecting their learning trajectory (Langenkamp & Carbonaro, 2018). Longitudinal studies suggest that early educational contexts significantly shape achievement outcomes; thus, continued exposure to lower SES environments can exacerbate achievement gaps over time (Bachman et al., 2015). Furthermore, the home learning environment, including parental education and engagement in math-related activities, contributes to how socioeconomic disadvantages manifest in children's math skills (Abdicevic & Kurtovic, 2022; Bonifacci et al., 2021). Another demographic variable that plays a role in the mathematical achievement of students is gender. A study analyzing the Program for International Student Assessment (PISA) mathematics achievement in Ireland found that males outperformed females across all mathematics subscales; however, while the difference was statistically significant, the effect size was relatively small, amounting to only one-sixth of a standard deviation (Close & Shiel,

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2009). These results were confirmed by the PISA mathematics achievement scores in Bosnia and Herzegovina (BIH), where boys again have achieved statistically better results, but the effect size was rather small amounting to less than one-tenth of a standard deviation, indicating no meaningful difference (Memisevic & Biscevic, 2022).

In addition to gender and SES, other variables have also been found to play a role in mathematics achievement. School climate variables such as school bullying and disorderly behavior can also affect mathematics performance. Research indicates that bullying can lead to school avoidance and reluctance to attend classes, which disproportionately affects learning outcomes in mathematics due to missed instructional time and a lack of practice (Wang et al., 2022). In the same line, disorderly behavior in classrooms characterized by high incidences of bullying can create a hostile learning environment. This dynamic often results in distractions and noise that hinder both teaching and learning processes, further impacting mathematics instruction as teachers may devote more time to addressing disruptive behavior than providing effective teaching (Hateriah & Sarkiah, 2023; Schoeler et al., 2018). Also, students' sense of belonging is linked to their motivation and academic performance. Studies indicate that students who feel they belong to their school or mathematics classroom are more likely to engage actively with the material and demonstrate higher levels of academic performance, particularly in mathematics (Good et al., 2012; Hughes, 2011). Thus, schools that actively work to improve their social climate tend to see a significant rise in academic performance among students (Le & Nguyen, 2019).

The goal of the present paper is to examine the effects of demographic variables (gender and SES) and some school climate indicators (bullying, disruptive behavior, and sense of belonging) on the mathematics performance of fourth-grade students in BiH.

## Methods

### *Participants*

Participants were 3310 4$^{th}$ grade-student from Bosnia and Herzegovina. Student selection was conducted through a two-stage stratified random sampling method to ensure a nationally representative sample. In the first stage, schools were randomly selected based on predefined stratification criteria, including geographic region and school type. In the second stage, intact classrooms within the selected schools were randomly chosen, ensuring that all students within the selected classrooms participated in the assessment. For the purposes of this study, we selected 2,712 students for whom there were no missing data on any of the measures employed. The mean age of students was 10.2 years (SD- 0.4 years). In relation to gender, there were 1,388 girls (51%) and 1,324 boys (49%).

### *Procedure*

The TIMSS assessment administration was conducted in a digital format in accordance with the group adaptive assessment design introduced in TIMSS 2023 (Yin & Foy, 2021). This design allows for the distribution of test items based on student ability levels, optimizing measurement precision. Students were presented with mathematics test booklets containing a combination of easy, medium, and difficult item blocks. The computerized adaptive format ensured that students received test booklets appropriate to their achievement levels, with higher-performing students

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receiving a greater proportion of more difficult items and lower-performing students receiving a greater proportion of easier items.

In addition to the mathematics test, students completed a student background questionnaire, from which I collected data on home resources for learning (as a proxy of socioeconomic status (SES)), school bullying, disruptive behavior, and students' sense of school belonging. The questionnaires were designed to capture key contextual factors that might influence student performance in mathematics. The assessment was conducted under standardized testing conditions, with trained test administrators ensuring compliance with TIMSS protocols. The total testing time for students included two 36-minute mathematics test sessions, separated by a short break, followed by a 30-minute student questionnaire session. Data collection occurred over a designated testing period to accommodate school schedules while maintaining consistency across all participating institutions.

*Instruments*

This study used data from the TIMSS 2023 assessment, which employs a set of standardized instruments designed to measure students' mathematics achievement and gather contextual information related to their learning environment. The mathematics assessment consisted of digitally-administered test items covering key content domains such as number, measurement and geometry, and data/chance. The test was designed using a group adaptive assessment format, ensuring that students received test items appropriate to their proficiency level. Student responses were scored and scaled according to the TIMSS international achievement scale, where the mean score is set at 500 with a standard deviation of 100 points. Data processing and cleaning followed IEA guidelines, ensuring data validity and reliability before analysis. This procedure ensured that data collected from students in Bosnia and Herzegovina adhered to TIMSS's rigorous methodological standards, allowing for meaningful comparisons of mathematics achievement within the country and in relation to international benchmarks.

The home resources for learning scale was used as a proxy of students' socioeconomic status (SES), including the number of books in the home, access to digital devices, and parental education levels. The questionnaire also included items related to school climate, capturing data on students' perceptions of bullying, classroom disorder, and sense of school belonging. The bullying scale measured students' exposure to different forms of peer victimization, while the disorderly behavior scale assessed classroom disruptions that may affect learning. Finally, the sense of school belonging scale included questions about students' feelings of inclusion and connectedness within their school environment.

*Statistical analysis*

To examine the relationships between student characteristics and mathematics achievement, hierarchical regression analysis was employed. This method allows for the sequential examination of predictors, enabling an assessment of the incremental variance explained by different sets of variables. In the first block, two demographic variables—gender and socioeconomic status (SES)—were entered into the model. In the second block, three additional predictors were introduced to the model: school bullying, disorderly behavior, and students' sense of school belonging. These variables, measured through self-reported scales within the TIMSS student questionnaire, captured aspects of students' psychosocial and behavioral experiences in school. In

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addition to hierarchical regression analysis, we also performed an independent t-test to examine the differences between boys and girls on TIMSS mathematics achievement. The data were analyzed with computer program SPSS v.27 for Windows (IBM, 2020).

**Results**

We first present the results of hierarchical regression analysis. In Table 1, gender and SES were included as predictors of mathematics achievement in the first block, while school bullying, disorderly behavior, and students' sense of school belonging were added in the second block.

Table 1.

| Predictors | B | SEB | β | t | $R^2$ | $R^2_{(adjusted)}$ | F |
|---|---|---|---|---|---|---|---|
| Block 1 | | | | | .16 | .16 | 151.1[a] |
| Gender | 10.0 | 3.2 | .07 | 3.1[a] | | | |
| SES | 22.6 | 1.3 | .39 | 17.1[a] | | | |
| Block 2 | | | | | .21 | .20 | 83.3[a] |
| Gender | 11.7 | 3.2 | .08 | 3.7[a] | | | |
| SES | 21.2 | 1.3 | .37 | 16.3[a] | | | |
| Student bullying | 5.5 | 0.8 | .17 | 6.8[a] | | | |
| Disorderly behavior | 3.3 | 0.9 | .09 | 3.7[a] | | | |
| Sense of school belonging | -1.4 | 0.8 | -.04 | -1.7[b] | | | |

Note. [a] $p < .01$; [b] $p = .08$.

Next goal was to examine the differences in mathematics achievement between boys and girls. The results are shown in Table 2.

Table 2. Mean mathematics scores of boys and girls

| Gender | M | SD | t-test | p | Cohen's d |
|---|---|---|---|---|---|
| Boys[a] | 463.7 | 73.9 | 3.3 | <.001 | 0.02 |
| Girls[b] | 454.8 | 66.0 | | | |

Note. [a] N = 1324; [b] N = 1388.

As can be seen from the table, boys have achieved higher mean scores, but the effect size of the difference is negligible.

**Discussion**

The goal of the present paper was to analyze the effects of several predictors on mathematics TIMSS achievement. The model including gender and SES explained 16% of the variance in the mathematics scores. The addition of student bullying, disorderly behavior and sense of school belonging improved the model further, by explaining additional 4% of the variance in the scores. Although addition of these variables still produced statistically significant model it only had a modest effect. Furthermore, somewhat surprising, sense of school belonging did not have a statistically significant effect on mathematics performance, while school bullying and disorderly behavior had a statistically significant effect.

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By a significant margin, the most important variable in explaining the mathematics scores was SES. It was clearly shown that the higher the SES (home learning resources), the higher the mathematics scores. These findings provide strong evidence that the social environment plays a crucial role in shaping academic success. These results support previous findings that students from varying socioeconomic backgrounds experience significant disparities in academic achievement, particularly in mathematics. Research consistently demonstrates a strong association between SES and mathematics achievement, suggesting that disparities in financial resources contribute to differences in academic outcomes. For example, studies have shown that socioeconomic disparities in mathematics achievement are substantial, with factors such as income status and maternal education playing influential roles in children's academic success (Bachman et al., 2015). Even more, both the individual and school SES correlate strongly with academic outcomes in reading and mathematics (Perry & McConney, 2010b). Parental economic status likely influences children's access to educational resources, such as tutoring, learning materials, and a conducive study environment, which in turn may contribute to variations in their mathematics performance. (Nugraheni & Hidayana, 2019). It seems that children from lower SES backgrounds might have less exposure to math-related activities and discussions at home, adversely affecting their early math skills (Lu et al., 2025). Some of the potential strategies that might be helpful in mitigating the negative effects of SES are through increasing parental involvement and strengthening parent-school partnerships. For instance, creating programs that facilitate parental engagement in academic activities and providing resources that educate parents on how to support their children's learning can enhance school readiness in children from disadvantaged backgrounds (Berry et al., 2022). Parental involvement is associated with positive outcomes in children, both academically and socially (Đorđević et al., 2022). It is also important that educational policies emphasize inclusivity and promote mixed-SES environments to foster better learning conditions for disadvantaged students (Perry & McConney, 2010a).

In relation to the effects of gender on mathematics achievement, in this study boys achieved somewhat higher mean results than the girls, but the size of difference, although statistically significant due to large sample size, was negligible. This is in line with existing literature. Studies consistently indicate that when it comes to basic numerical skills, gender differences are minimal. Gender differences in children's basic numerical skills are often an exception rather than a rule, with no significant male advantage in math performance in certain countries like the Netherlands (Hutchison et al., 2018). It also seems that gender differences are dependent on the type of the task: boys solve mathematical tasks better and verbal tasks worse; girls solve verbal tasks better and mathematical tasks worse, thus it would seem appropriate to first discover the basic types of achievement and only then look for gender-specific differences (Merkys et al., 2025). Moreover, research suggests that gender differences in mathematics achievement may become more pronounced at higher levels of education, particularly in complex problem-solving tasks that require spatial reasoning, such as mental rotation, where boys tend to outperform girls (Lauer et al., 2019). According to Lauer, environmental factors, including the types of activities boys and girls are exposed to during childhood, contribute to the development of spatial skills differently between genders, suggesting that increased experience with spatial activities enhances these skills

In addition to this, it seems that the attitudes towards mathematics are gender-specific, with females often exhibiting more negative attitudes and higher test anxiety. Studies reveal that emotional and psychological aspects associated with mathematics, such as anxiety, disproportionately affect

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female students due to societal stereotypes (Dowker & Sheridan, 2022). When young girls are exposed to stereotypes suggesting that boys are inherently better at math, they are likely to internalize these beliefs, leading to decreased confidence and motivation in their mathematical abilities (Dersch et al., 2022; Gonzalez et al., 2021). Therefore, initiatives that actively work to dismantle these gender stereotypes are vital. For instance, educators and parents can foster positive math images by showcasing female role models in mathematics and STEM careers, which can help counteract negative stereotypes and encourage a sense of belonging in these fields (McKellar et al., 2018). By promoting an inclusive and supportive learning environment, such initiatives can enhance girls' self-efficacy and interest in mathematics, ultimately leading to improved performance and greater representation in STEM fields. This highlights the role of educational policies and societal attitudes in shaping students' confidence and achievement in mathematics.

As for the effects of school-related psychosocial factors, school bullying and disruptive behavior had a statistically significant, although small effect on math achievement, while the sense of school belonging did not have a significant effect on mathematics achievement. Results of TIMSS have shown that children who were bullied tended to have lower mathematics scores. Bullying has been increasingly recognized as a significant factor negatively impacting academic achievement among students. Bullying can be defined as repeated aggressive actions that can have harmful consequences for victims, and it involves not only direct aggression but also forms of social manipulation (Thornberg et al, 2012). A growing body of literature demonstrates that the experiences of being bullied—whether as victims or witnesses—are intricately linked with various academic outcomes, including lower grades, decreased school attendance, and declining engagement in school activities. One of the primary mechanisms through which bullying affects academic performance is via the emotional and psychological distress it creates in victims. Studies have shown that victims of bullying experience heightened anxiety, depression, and reduced self-esteem, which can lead to disengagement from the educational environment (Feldman et al., 2014; Samara et al., 2021). In addition, the experience of being bullied can lead to negative academic attitudes, which in turn affect students' performance (Jiang et al., 2024). In terms of interventions, schools play a critical role in addressing bullying and its effects. Establishing comprehensive anti-bullying programs and promoting a positive school climate can contribute significantly to improving academic outcomes among victims. Proactive measures, such as social-emotional learning programs and workshops focusing on building resilience and coping strategies in affected students, may help mitigate the psychological toll of bullying, thereby improving academic engagement and performance (Agrawal & Gautam, 2023; Muluk et al., 2021).

Disruptive behavior is a term that encompasses a range of actions exhibited by individuals, particularly students, that interfere with the learning environment and hinder both their own and their peers' educational experiences. This type of behavior can manifest in various forms, including verbal interruptions, physical restlessness, and acts that violate established classroom rules (Indrayani et al., 2023). Disruptive behavior had a significant negative effect on mathematics performance. Again, this is in line with existing studies. Disruptive behavior in classrooms presents a significant obstacle to effective teaching and learning, negatively impacting academic achievement across various educational settings. This issue is multifaceted, with research indicating that classroom disruptions can lead to decreased learning efficiency, hinder teachers' instructional abilities, and diminish overall student engagement. Disruptive behavior in schools universally challenges both teachers and students, ultimately impairing academic achievement

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(Duesund & Oedegaard, 2018). Such behavior requires teachers to divert their attention away from instruction, which can have lasting effects on students' academic success (Bektiningsih et al., 2023). To mitigate the negative consequences of disruptive behavior on academic achievement, effective classroom management strategies must be a priority. Research indicates that teachers who constructively address disruptive behaviors through interventions and supportive classroom environments can help restore focus and learning effectiveness (Khotimah et al., 2023; Umar & Khair, 2022).

The final variable we considered in this analysis was the sense of school belonging. The sense of school belonging refers to the extent to which students feel accepted, respected, and supported within their educational environment (Roffey et al., 2019). It encompasses both emotional and social dimensions, highlighting students' perceptions of their interactions with peers and teachers, as well as their overall sense of inclusion in the school community. A positive sense of belonging is linked to various beneficial outcomes, including academic performance, psychological well-being, and social engagement. Interestingly, contrary to expectations, this variable did not have a significant effect on mathematics achievement. The sense of school belonging is increasingly recognized as a critical factor influencing academic achievement among students at various educational levels. The construct pertains to how students perceive their acceptance, connection, and involvement within their school community. A growing body of research links a positive sense of belonging to various favorable academic outcomes, illustrating the necessity of fostering such environments in educational settings (Abdollahi et al., 2020; Lam et al., 2015). There are several potential explanations why the sense of school belonging did not have a significant effect on mathematics achievement. Given the large sample size, it is unlikely that the lack of effect stemmed from insufficient statistical power to detect a true relationship. It might be the case that academic success might be more strongly driven by factors such as parental involvement, teacher expectations, or school resources rather than by a student’s emotional connection to school. In highly structured or performance-driven environments, achievement may depend more on external expectations than on personal feelings of belonging. Another potential explanation might be that sense of school belonging may have a greater impact on subjects that require more verbal interaction and collaborative learning (e.g., language or humanities), while mathematics achievement might be more dependent on individual cognitive abilities, instructional methods, and prior knowledge.

*Limitations and Future Directions*

While the present study provides valuable insights into the factors influencing mathematics achievement, several limitations should be acknowledged. First, the study relies on a cross-sectional design, which limits the ability to establish causal relationships between predictors and mathematics achievement. Future research should consider longitudinal designs to better capture the dynamic interplay between socioeconomic status, school-related psychosocial factors, and academic outcomes over time. Second, although the TIMSS dataset offers a robust and internationally comparable measure of mathematics achievement, the study is constrained by the available variables in the dataset. For example, while school belonging was included as a predictor, the measure may not fully capture all dimensions of belonging that could be relevant to academic success. Future research could incorporate other measures, such as student-teacher relationships or peer support, to further explore the role of school connectedness in learning outcomes.

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Additionally, the study primarily focused on broad psychosocial and demographic predictors, but did not include characteristics of teachers and cognitive variables such as executive functions, working memory, or problem-solving skills, which are well-documented contributors to mathematics achievement (Bukva & Memisevic; Sadak, 2023). A more comprehensive model incorporating all these factors could provide a clearer understanding of the mechanisms driving differences in mathematics performance.

## Conclusion

This analysis has shown the critical role of socioeconomic status in shaping mathematics achievement and provide further evidence of the negative impact of bullying and disruptive behavior on academic outcomes. While the lack of an effect for school belonging was unexpected, it highlights the complexity of academic achievement and suggests that belonging may play a more indirect role in student performance. Future research should continue to explore these relationships, particularly in longitudinal and intervention-based studies, to develop more targeted strategies for supporting student success.

## Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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