

## Research Article

# Trends in Malaysian Adolescents' Mathematics Performance Across Two Decades: What Factors Matter?

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Adolescents' mathematics performance and its explanatory factors have been a crucial issue. However, literature focusing on adolescents in Malaysia is missing. Thus, this study investigates what individual and school factors have been associated with adolescents' mathematics achievement over the last two decades. We examined six-wave data of Malaysia from the Trends in International Mathematics and Science Study (TIMSS). Multilevel modeling technique was employed for data composed of 5557, 5314, 4466, 5733, 9726, and 7065 eighth-grade students participating in 1999, 2003, 2007, 2011, 2015, and 2019, respectively. The results showed that 65.17%, 57.44%, 65.89%, 73.00%, 43.16%, and 61.69% of the total variance in mathematics achievement was due to school differences in these years. The findings also indicated that students with higher mathematics motivational beliefs scored higher. Students who more frequently spoke the language of the test at home achieved lower scores in the four waves of TIMSS; however, this trend changed in 2015 and 2019. Student educational aspiration emerged as a positive predictor of mathematics achievement in the last two assessments of TIMSS. Home educational resources and book ownership also significantly correlated with mathematics achievement. At the school level, teacher gender was negatively associated with achievement in all TIMSS waves except 2019. Students whom female teachers taught outperformed those whom male teachers taught. This longitudinal monitoring study of Malaysian students' mathematics performance provides empirical evidence for local practices and advances literature based internationally.

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# 1. Introduction

The Malaysian education system has focused on math and science, aiming to become a STEM-driven economy by 2025 (Blueprint, 2012). As a result, developing a high-quality science and mathematics workforce has become critical in fostering students' interest, attitudes, and knowledge of STEM-related careers (Ministry of Education Malaysia, 2013). However, students struggle with fundamental math skills and rely too heavily on calculators (Ibrahim & Othman, 2010). International assessments show a decline in math performance over time (Mullis et al., 2020).

In 1999, Malaysia joined TIMSS, an organization that assesses students' proficiency in math and science, identifies factors contributing to success in these subjects, monitors achievement over time, and promotes cross-country learning among policymakers (Martin et al., 2020). TIMSS conducts assessments every four years, allowing countries to monitor student performance and teaching factors (Mullis et al., 2020). This study aims to examine trends in math performance among Malaysian students from 1999 to 2019 and identify key factors influencing these patterns using TIMSS data.

According to Mullis et al. (2020), Malaysian students' average math scores have been declining steadily. In 1999, the average score was 519, which decreased to 508 in 2003, 474 in 2007, and 440 in 2011. The trend continued with scores of 465 in 2015 and 461 in 2019. The TIMSS assessment categorizes students' performance into four levels: advanced (625), high (550), intermediate (475), and low (400). In 1999, 10% of Malaysian students achieved the advanced level, but this percentage dropped to 6% in 2003, 2% in 2007, 2% in 2011, 3% in 2015, and 4% in 2019. Similarly, the proportion of students reaching the high level also decreased over the years. In 1999, 36% of Malaysian students reached the high level, but this figure declined to 30% in 2003, 18% in 2007, 12% in 2011, 18% in 2015, and 17% in 2019 (Mullis et al., 2020).

In Malaysia, the educational system is centralized and provides 11 years of free education, including primary and secondary school. Primary school is compulsory for children aged 6–11 and lasts for six years. After primary school, students take the primary school achievement test (UPSR). Secondary school is divided into lower secondary (Forms 1 and 2) and upper secondary (Forms 3 to 5), lasting for five years. At the end of secondary school, all students must take the Malaysian Certificate of Education or Sijil Pelajaran Malaysia (SPM). The results of the primary school achievement test are used as a criterion for admission into specific secondary schools, but there is no segregation based on abilities (Yusof, 2008).

Malaysia has a diverse population with three major ethnic groups: Malay, Chinese, and Indian. The official language is Bahasa Malaysia (BM), but many Malaysians are also proficient in English. In 2002,

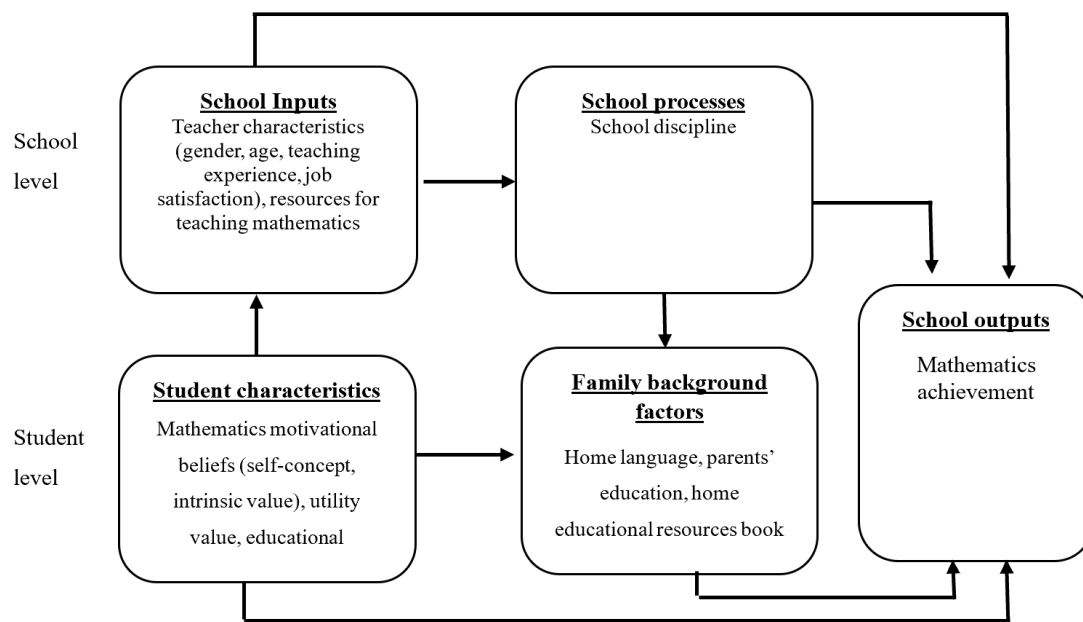
the government introduced teaching math and science in English to improve students' skills, but in 2009, they decided to switch back to BM as the language of instruction by 2012 (Yusof, 2008). This change also affected students' math achievement (Thien & Ong, 2015).

This research aims to understand the factors contributing to the decline in academic performance of Malaysian students in mathematics from TIMSS 1999 to 2011. It focuses on the correlations between different factors at the student and school levels and mathematics achievement, specifically among Malaysian adolescents. The study also investigates whether changes in these factors' relationships with mathematics achievement are linked to the overall decline in performance. By providing empirical evidence, this research offers valuable insights into the practicality of student and school-related factors in the context of TIMSS assessments. The findings can guide policymakers in developing effective interventions for mathematics teaching and learning.

### *1.1. School effectiveness model for student mathematics achievement*

The "Coleman Report" marked the start of school effectiveness research (Creemers & Kyriakides, 2015). It revealed that schools had minimal influence on students' academic performance once family background factors were considered. This sparked debate among scholars, leading to educational reforms and advancements in research methods. Numerous studies have since been conducted using large-scale assessments and sophisticated methodologies to investigate the impact of schools on student achievement (e.g., Downey & Condrón, 2016; Hanushek, 2016; Hill, 2017). Researchers have proposed solutions in educational inputs and processes (Huitt, 2003), resulting in the development of various models in school effectiveness research (e.g., Creemers & Kyriakides, 2010; Rumberger & Palardy, 2004).

Some of these models (e.g., Rumberger & Palardy, 2004, Figure 1) are based on the economic theory known as the education production function (EPF; Hanushek, 2006).



**Fig. 1.** A multilevel conceptual model of school effectiveness

In 2006, Hanushek identified three components of the educational school system: inputs, processes, and outputs. However, according to Kolawole in 2021, school outcomes are determined by inputs and processes. Nugba et al. (2022) further categorized factors that affect school outcomes into school inputs, practices, and processes. School inputs refer to characteristics that impact school outcomes, such as students' abilities, attitudes, home environment, and resources. Examples include teacher qualifications, student-teacher ratio, and expenditure per student. Processes encompass teaching quality, style, time spent on subjects, student composition, school organization, disciplinary climate, and achievement pressure.

Teacher quality is crucial for student achievement, as shown by a cross-national study (Akiba et al., 2007). Measurable indicators like age, experience, and job satisfaction determine teacher quality. Research indicates that older teachers are more effective, with those aged 31-40, 41-50, and 50+ scoring higher than those aged 21-30 (Rahida et al., 2018). However, another study suggests that age does not significantly affect academic performance (Francisco, 2020).

Many professions value employees' experience, including education where teacher experience is important (King Rice, 2010). Research shows a strong link between teacher experience and higher student achievement, as well as improved test scores and behavior (Ladd & Sorensen, 2017).

Studies show no correlation between teaching experience and academic performance in math and science (Zhang, 2008; Đerić et al., 2022). Contrary to expectations, experienced teachers do not necessarily have a greater impact on student achievement. The most significant growth in teacher effectiveness occurs in the first three years of their career (Akiba et al., 2007).

Teachers' gender can impact students' academic achievement through role modeling, stereotype threats, and biases (Paredes, 2014). Female teachers may have a greater impact due to their higher levels of math anxiety and different approaches to teaching (Antecol et al., 2015). Gender biases can also affect teacher-student interactions (Lavy, 2008). While some studies show a positive association between female teachers and student achievement (Ismail & Awang, 2009), others find no correlation (Holmlund & Sund, 2008).

### *1.2. Effects of student level factors on student mathematics achievement*

Scholars agree that schools impact students' academic performance (Anderson, 2004; Rumberger & Palardy, 2004). However, there is ongoing debate about the specific factors at the student and school level that contribute to these differences. Research shows that student characteristics, such as beliefs, family background, and language spoken at home, are linked to academic achievement (Rumberger & Palardy, 2004). Students' self-perception, intrinsic value, and perceived usefulness of mathematics also influence their learning (Steinmayr et al., 2019).

Two important factors that affect a student's achievement are expectancy and values. Expectancy refers to a student's confidence in their ability to succeed, while values relate to the reasons for doing a task. Values can be categorized into four types: attainment, intrinsic, utility, and cost (Wigfield et al., 2021). Math is a key subject in schools, valued in specific fields like commerce, technology, and science (Noyes, 2016). Research shows a positive link between valuing math and academic success (Österling & Andersson, 2013; Hill et al., 2019). In Malaysia, eighth-grade students show interest in learning math but don't see its practical benefits. They recognize its importance and real-world applications but view it as unnecessary in the school curriculum (Wong & Wong, 2019).

In the PISA 2012 evaluation, Malaysian students showed higher instrumental motivation and mathematical interest compared to the OECD average, but also had higher mathematics anxiety (OECD, 2014). Additionally, the intrinsic value of students was linked to the complexity and quantity of math problems, while math anxiety had a negative effect on problem complexity (Guo et al., 2020).

Self-concept is crucial for students' academic performance, including in mathematics (Ceci et al., 2014; Steinmayr et al., 2019; Master & Meltzoff, 2020; Zhu & Meyer, 2020). It refers to individuals' beliefs about their abilities and encompasses various dimensions (Bandura, 1997). Studies in Malaysia have shown the significant influence of self-concept on eighth-grade students' academic achievement (Authors, 2011, 2012; Noor et al., 2009). Factors such as self-confidence, aspirations, school safety perception, and time spent on math homework also correlate with math achievement (Noor et al., 2009). Boys tend to have higher math self-concepts than girls (Kyriacou & Goulding, 2006).

Girls have lower anxiety towards math, but this can lead to a negative perception of the subject (Hannula, 2002). Boys pursue math for practicality and career prospects, while girls enjoy it more (Williamson, 2004). Confidence in math abilities is linked to better performance in Malaysia (Ismail & Awang, 2009; Nga et al., 2012; Authors, 2011).

Intrinsic value, rooted in mathematics, significantly impacts students' academic achievement and self-perception. It evolves as students' progress through education and is a key objective in math education worldwide (Mullis et al., 2020). Early development of intrinsic value predicts future success in math and related fields (Ceci et al., 2014; Gunderson et al., 2012; Master & Meltzoff, 2020). Extensive research consistently shows its strong association with math success (e.g., Chiu & Klassen, 2010; Moyer et al., 2018; Dowker et al., 2019; Quaye & Pomeroy, 2021). Intrinsic value is also influenced by students' perception of their parents' attitudes, with middle-class students exhibiting more positive intrinsic value (Quaye & Pomeroy, 2021). Factors such as the home environment (Jacobbe et al., 2012; Lopez & Donovan, 2009; Evans & Field, 2020), teachers' attitudes (Marchis, 2011; Noyes, 2016), classroom instruction (Hodges & Kim, 2013), parental aspirations (Fan & Chen, 2001), and parents' self-efficacy in math can influence intrinsic value (Ingram et al., 2007).

Academic performance has been extensively studied in relation to students' educational expectations (Chepete, 2008; Pinquart & Ebeling, 2020). A significant finding was that having high educational expectations for future studies was identified as a predictor of academic performance (Park & Park, 2006).

Research consistently shows that students who have greater access to educational resources at home, such as books and higher socioeconomic status, tend to perform better academically, particularly in mathematics (e.g., Mullis et al., 2020; Mullis et al., 2008; Lam & Zhou, 2022; Thien & Ong, 2015). A study conducted in Malaysia found that home educational resources were the most influential predictor of mathematics achievement among eighth-grade students (Authors, 2012). Similarly, research in Malaysia

has shown that students from homes with more educational resources achieve higher scores in both mathematics and science (Azina et al., 2009). Additionally, students tend to perform better when their parents have higher levels of education and when they have access to additional resources like study desks, computers, and books at home (Ismail & Awang, 2009).

Numerous studies have found a correlation between home language and academic achievement, particularly in mathematics. Students who speak the test language more frequently at home tend to perform better (Van Laere et al., 2014; Strand & Schwippert, 2019; Mullis et al., 2020; Lopez-Agudo et al., 2021). However, a study on Malaysian students showed that speaking Bahasa Malaysia at home did not lead to higher science scores (Ng et al., 2012). This contradicts previous research (e.g., Henry, Nistor, & Baltes, 2014; Greisen et al., 2021). Interestingly, Malaysian students who didn't speak Bahasa Malaysia at home performed better in mathematics. Those who spoke it more frequently scored 13 points lower in TIMSS 2007 (Mullis et al., 2008).

## 2. Research Questions

Mathematics is one of the most critical subjects in the educational system of any society because it has a significant role in the development of the economy and technology. Malaysian eighth-grade students' performance in TIMSS assessment shows a downward trend. The relationships between students' performance in mathematics and background factors have been explored locally, nationally, and internationally. Teacher quality is one of these factors that has been examined using indicators such as the teacher's age, gender, and teaching experience, school discipline, mathematics teaching affected by resources shortage, and teacher job satisfaction. Among student-related factors, the relationships between self-concept, intrinsic value, utility value, home educational resources, language spoken at home, and books with mathematics achievement have been well investigated. Although the relationships between these factors and students' mathematics performance have been explored elsewhere, in Malaysia, the number of comprehensive studies that have examined the relationships between the influential factors and students' performance over time is limited. Therefore, the present study was designed to investigate the following questions:

1. How are student-level factors correlated to Malaysian eighth-graders' mathematics achievement?
2. How are the school-level factors correlated to Malaysian eighth-graders' mathematics achievement?
3. What is the trend of the relations of these factors with the mathematics achievement of Malaysian eighth-graders across the TIMSS assessments?

### 3. Methods

#### 3.1. Samples

The data for this study were obtained from the TIMSS assessments. A total of 5557, 5314, 4466, 5733, 9726, and 7065 nationally representative eighth-grade students from 150, 150, 150, 180, 207, and 177 secondary schools from Malaysia participated in TIMSS 1999, 2003, 2007, 2011, 2015, and 2019, respectively. TIMSS constantly used a two-stage stratified cluster sampling design. Schools were randomly sampled after considering their size, and then one intact classroom within each selected school was selected.

#### 3.2. Measures

Predicted factor (mathematics achievement): The five plausible values were averaged and used as the predicted factor. TIMSS used a test to measure students' mathematics achievement. Many items (e.g., 215 items in TIMSS 2007) were used to extend the coverage of the mathematics content and measure the trends across the TIMSS assessments, many items (e.g., 215 items in TIMSS 2007) were used (Olson et al., 2008). Indeed, implementing all the items for individual students was impossible. Thus, a matrix-sampling design was used to assemble the items into different booklets, and each student completed only one booklet consisting of a small sample of the items. The plausible values estimate how a student might have performed if it had been administered to the entire items. The plausible values for individual students were estimated based on their answers to a subtest of the mathematics items. The plausible values for any given scale are the best available measures of students' achievement, and they should be used as the outcome variable in any study of student achievement (Foy & Olson, 2009).

Predictors at the student level include eight factors. (1) *Self-concept*, based on students' responses to (a) I usually do well in math, (b) I learn things quickly in math, (c) math is not one of my strengths, and (d) math is more difficult for me on a 4-point Likert scale: 4= agree a lot; 3= agree a little; 2= disagree a little; 1= disagree a lot. The last statement is reversed coded. High: students who agreed a little or a lot on average with all four statements; Low: students who disagreed a little or a lot, on average; Medium: includes all other response combinations. (2) *Intrinsic utility*, based on students' responses to (a) I enjoy learning math, (b) I like math, and (c) math is boring. The scaling is similar to the self-concept. The last statement is reversed coded. High: students who agreed a little or a lot on average with all three statements; Low: students who disagreed a little or a lot, on average; Medium: includes all other response combinations. (3) *Utility value*, based on students' response to (a) learning math will help me in my daily



life, (b) I need math to learn other school subjects, (c) I need to do well in math to get into the university, (c) I need to do well in math to get the job I want, and (d) I would like a job to involve math. The scaling is similar to the self-concept and intrinsic utility. High: students who agreed a little or a lot on average with all four statements; Low: students who disagreed a little or a lot, on average; Medium: includes all other response combinations. (4) *Educational aspiration*, based on students' responses to "How far in school do you expect to go?", 1=Low, upper or post-secondary; 2= Medium, diploma or first degree; 3= High, beyond first degree. (5) *Home language*, based on students' responses to "How often do you speak the language of test at home?", 1= always; 2= almost always; 3= sometimes; 4= never. These codes are recoded to (0 sometimes and never; 1 always and almost always). (6) *Parents' education*, based on students' responses to "What is the highest level of education completed by your mother (or stepmother or female guardian) and father (or stepfather or male guardian)?", 1= Low, less than or complete lower secondary school; 2 = Medium, complete lower or upper secondary school; 3= High, university degree. (7) *Home educational resources*, based on students' responses to the four statements on a two-point scale: (a) having a calculator, (b) having a computer, (c) having a study desk, and (d) having a dictionary. TIMSS coding was: 1= Yes; 2= No. Responses were classified into three categories: 1= Low if responded "No" to all or three of the four statements; 2= Medium, all other response combinations; 3= High if responded "Yes" to at least three or all the four statements. (8) *Book ownership*, based on students' responses to "How many books are there in your home excluding magazines, newspapers, or your school books?", 1 Low, none or enough to fill one shelf (11-25 books); 2 Medium, enough books to fill one bookcase (26-100 books); 3 High, enough books to fill two bookcases (101-200 books); or more.

Predictors at the school level include six factors. (1) Teacher teaching experience as stated by teachers in number, (2) teacher gender (male=1, female=0). (3) Teacher age, as stated by teachers in number. (4) School discipline, based on the principal school response to (a) arriving late at school, (b) absenteeism, (c) skipping class, (d) cheating, (e) profanity, (f) vandalism, (g) theft, (h) physical injury to other students, and (i) physical injury to teacher or staff, on a 4-point Likert scale: 1=, not a problem; 2= minor problem; 3= moderate problem; and 4= serious problem. Cut scores divide the scale into three categories. Low: Students in schools with hardly any problems had a maximum 13 score, corresponding to their principals reporting that five of the nine discipline issues are "not a problem," and the other four are "minor problems." Minor: Students in schools with minor discipline issues scored between 14 to 23, corresponding to their principals reporting that five of the nine issues are a "moderate problem" and the other four are "minor problems." High: All other students attended schools with "moderate problems." (5)

Teaching affected by resources shortage for mathematics instruction, based on the principal school response to (a) computers for mathematics instruction, (b) computer software for mathematics instruction, (c) calculators for mathematics instruction, (d) library materials relevant to mathematics instruction, and (e) audio-visual resources for mathematics instruction, on a 4-points Likert scale: 1= not at all; 2= a little; 3= some; and 4= a lot. Cut scores divide the scale into three categories. Low: Students in schools where instruction was “not affected” by resource shortages had a maximum of 7 scores, corresponding to their principals reporting that shortages affected instruction “not at all” for three of the five resources and “a little” for the other two. Moderate: Students who attended schools where instruction was “somewhat affected” by resource shortages had scores between 8 and 13. High: All other students attended schools where instruction was “affected a lot” by resource shortages. (6) Teacher job satisfaction, based on the school principal response to (a) I am content with my profession as a teacher, (b) I find my work full of meaning and purpose, (c) I am enthusiastic about my job, (d) My work inspires me, and (e) I am proud of the work I do; on a 4-points Likert scale: 1= very often; 2= often; 3= sometimes; and 4= never or almost never. Low: Students with very satisfied teachers had a maximum of seven scores corresponding to their teachers responding “very often” to three of the five statements and “often” to the other two. Students with somewhat satisfied teachers scored between 8 to 13, responding “sometimes” to three of the five statements and “often” to the other two—all other students with Less than satisfied teachers.

### 3.3. Data analysis

Two-level hierarchical linear modeling (HLM) was applied in this study. The TIMSS data are nested or multilevel structured data. Students are nested within the classroom, and the classroom is nested within schools. Thus, it makes three-level structured data: students as level-1, classroom as level-2, and school as level-3. However, TIMSS data are three levels in nature, as with most other participating countries; in Malaysia, only one intact classroom was sampled per school. There was no possibility of disentangling the effect of classroom and school; thus, classroom and school combined to make the school level. The data were analyzed using HLM6.07 (Raudenbush et al., 2004).

The Full Maximum Likelihood (FML) was used to estimate the parameters (Hox, 2009; McCoach & Black, 2008). The grand mean centering was used as a centering approach at student and school levels (for detail, please refer to Enders & Tofighi, 2007; Hox, 2009; Tabachnik & Fidell, 2007; McCoach & Black, 2008). The TIMSS sampling design was multistage stratified cluster sampling. In these designs,

individuals are nested within clusters and clusters nested within strata. Thus, the probability of the selected sample units is not equal. We used sampling weight to avoid bias in parameter estimation, as experts suggested (Asparouhov, 2005; Rutkowski et al., 2010). The house weight (HOUWGT) at the student level and school weight (SCHWGT) at the school level (Rutkowski et al., 2010) was used as weighting sample in this study; however, as the weighting method at the school level has changed in TIMSS 2019, school weight factor (WGTFAC1) was used instead of SCHWGT.

### 3.4. *The Estimated Models*

A set of models was estimated: (a) the Null Model, in which no individual- or group-level predictors exist. This Model is also known as a one-way ANOVA (Raudenbush & Bryk, 2002). We used this Model to calculate the intraclass correlation coefficient (ICC), a measure of how much of the variance in mathematics achievement was accounted for by the “cluster effect.” (b) Model-1 In this Model, all the student-level factors were included as a fixed effect. The fixed effect refers to the effect of student-level factors that are assumed to have the same effect on achievement across all schools. (c) Model-2, in this Model, all the school-level factors entered into the Model together. (d) Model-3 in this Model aggregates all the student-level factors (averaged) and adds to the school-level model after controlling for all the school-level factors, the so-called compositional or contextual effect (Gamoran, 1992). (e) the Full Model, in this Model, all the students- and school-level factors are added into the Model simultaneously.

## 4. Results

### 4.1. *The Null Model*

The proportion of variance in mathematics achievement due to school-level difference was computed by  $\rho = \tau_{00} / (\tau_{00} + \sigma^2)$ , where  $\rho$  is Intra-class Correlation (ICC),  $\sigma^2$  is the student-level variance, and  $\tau_{00}$  is the school-level variance. In TIMSS 1999, for example,  $\sigma^2 = 2104.71$  and  $\tau_{00} = 3938.54$ . Therefore, the ICC ( $\rho$ ) =  $3938.54 / (3938.54 + 2104.71) = 0.6517$ . That is, 65.17% of the total variance in mathematics achievement of Malaysian eighth- grade students was due to school-level differences. The proportion was 57.44%, 65.89%, 73.00%, 43.16%, and 61.69% in 2003, 2007, 2011, 2011, and 2019, respectively.

## 4.2. Model 1

Model 1 was estimated using all the student-level factors. These factors were the same across all the TIMSS assessments, except for TIMSS 1999, where the data for mathematics self-concept were unavailable. The proportion reduction in the student-level variance was computed by  $(\sigma^2 \text{ the Null Model} - \sigma^2 \text{ Model-1}) / \sigma^2 \text{ the Null Model}$ . Model 1 accounted for 9.39%, 25.46%, 18.94%, 18.14%, 21.33%, and 17.15% of the student-level variance in mathematics achievement in 1999, 2003, 2007, 2011, 2015, and 2019, respectively. Theoretically, the student-level predictors also explain the school-level variance but not vice versa. The regression coefficients of the parameters in Model-1 are presented in Table 1.

$\beta$	TIMSS 1999	TIMSS 2003	TIMSS 2007	TIMSS 2011	TIMSS 2015	TIMSS 2019
1	No data available	16.11** (0.70)	13.07** (0.92)	8.76** (0.75)	18.07** (0.92)	11.69** (0.82)
2	12.70** (0.92)	16.71** (0.71)	6.56** (1.15)	14.67** (0.69)	16.65** (1.11)	10.76** (1.00)
3	0.33 (0.63)	1.18 (0.76)	0.44 (1.16)	2.96** (0.77)	4.41** (0.91)	2.05* (0.89)
4	4.47** (0.90)	0.82 (0.79)	0.10 (1.14)	0.62 (0.70)	17.46** (1.97)	13.26** (1.63)
5	-14.80** (3.00)	-20.87** (2.89)	-13.20** (2.58)	-24.62** (2.57)	18.93** (2.52)	10.21** (1.82)
6	3.03** (0.86)	2.42 (1.35)	1.07 (1.19)	0.48 (0.76)	4.88** (1.76)	2.64* (0.87)
7	2.02 (2.12)	2.50 (2.20)	15.42 ** (2.88)	6.68** (1.06)	0.52 (1.77)	4.62* (1.28)
8	7.83* (3.01)	2.20 (1.39)	5.97 ** (1.43)	2.19* (1.12)	5.87** (1.98)	9.94** (1.83)

**Table 1.** Student-level parameters regression coefficients in Model-1

(1) Self-concept, (2) Intrinsic value, (3) Utility value, (4) Educational aspiration, (5) Home language, (6) Parent's education, (7) Home educational resources, (8) Book ownership

The values within the brackets are standard errors. (\*)  $p < .05$  and (\*\*)  $p < .001$

Self-concept was one of the strongest predictors of mathematics achievement in all the TIMSS cycles. Intrinsic value also produced significant links with achievement in all the assessments. Utility value significantly related to mathematics achievement in the last three waves of TIMSS. Educational

aspiration produced a significant relation with mathematics achievement only in 1999, 2015, and 2019. The relationship between the language spoken at home and mathematics achievement was negative in TIMSS from 1999 to 2011. After controlling for the other student-level factors, students who spoke Bahasa Malaysia more at home achieved lower scores than those who did less frequently. However, the relation turned positive in the 2015 and 2019 assessments; that is, students who more frequently spoke Bahasa Malaysia at home achieved higher scores than those who did less frequently. Parents' level of education was significantly correlated with achievement in the years 1999, 2015, and 2019. Home educational resources were significantly correlated with mathematics achievement in 2007, 2011, and 2019, while book ownership produced significant links with mathematics achievement in all years except 2003.

#### 4.3. Model 2

All the school-level factors were added to Model 2. These factors are the same across all the TIMSS assessments. However, in TIMSS 2015 and 2019, mathematics teachers' job satisfaction was also included, but the data for these two factors were unavailable in the previous assessments. The variance explained by Model 2 was computed by  $(t_{00} \text{ the Null Model} - t_{00} \text{ Model- 2}) / t_{00} \text{ the Null Model}$ . Model-2 contributed 6.52%, 16.66%, 0%, 10.5%, 0.58%, and 6.26% of the school-level variance in 1999, 2003, 2007, 2011, 2015, and 2019, respectively. The regression coefficients of the parameters in Model 2 are presented in Table 2.

$\beta$	TIMSS 1999	TIMSS 2003	TIMSS 2007	TIMSS 2011	TIMSS 2015	TIMSS 2019
1	0.83 (2.85)	3.83 (4.91)	2.16 (6.55)	4.20 (6.55)	-3.76 (7.10)	-21.89* (8.74)
2	-34.99* (13.13)	-37.10 ** (9.39)	12.14 (13.22)	-39.35* (15.55)	-7.79 (11.73)	-40.02* (17.64)
3	4.58 (7.60)	-6.78 (9.29)	1.00 (9.37)	0.24 (8.16)	4.65 (9.56)	40.92* (18.00)
4	2.92 (8.68)	-12.31 (7.11)	-2.56 (12.83)	-36.34* (11.90)	52.21 (28.51)	14.700 (12.48)
5	-8.57 (9.04)	-23.92** (5.59)	-3.91 (8.76)	-16.38 (10.01)	-10.02 (8.51)	23.32 (13.71)
6	No data available	No data available	No data available	No data available	-0.65 (8.54)	(11.95)

**Table 2.** School-level parameters regression coefficients in Model- 2

(1) Teacher teaching experience, (2) Teacher gender, (3), Teacher age (4) School discipline, (5) Math teaching affected by resources shortage, (6) Teacher job satisfaction.

The values within the brackets are standard errors. (\*)  $p < .05$  and (\*\*)  $p < .001$

Teacher teaching experience significantly correlated with mathematics achievement in 2019, and the correlation was negative. Students taught by teachers with more years of teaching scored lower than others. Teachers' gender was significantly correlated with achievement in 1999, 2003, 2011, and 2019. The correlation was negative, indicating that after controlling for the other school-level factors in the model, students whom female teachers taught achieved higher scores than those whom male teachers taught. The relationship between school discipline and mathematics resource shortages, as reported by school principals, with mathematics achievement was negative. Students who attended schools having discipline problems and where resources for mathematics instruction were a problem achieved lower scores than those who attended other schools. However, the relation between school discipline and mathematics achievement was significant only in TIMSS 2011 and 2003, respectively.

#### 4.4. Model 3

In Model 3, after controlling for all the school-level factors, all the student-level factors were aggregated (averaged) and added to Model- 3. The variance explained by Model 3 was computed using  $(\tau_{00} \text{ Model 2} - \tau_{00} \text{ Model 3}) / \tau_{00} \text{ Model 2}$ . Model 3 accounted for 13.64%, 11.09%, 75.97%, 12.07%, 35.20%, and 29.72% of the school-level variance in mathematics achievement in TIMSS 1999, 2003, 2007, 2011, 2015, and 2019, respectively. The regression coefficients of the parameters in Model 3 are presented in Table 3.

$\beta$	TIMSS 1999	TIMSS 2003	TIMSS 2007	TIMSS 2011	TIMSS 2015	TIMSS 2019
1	No data available	48.25** (7.00)	45.85* (13.00)	0.25 (5.21)	3.05 (3.55)	67.54** (14.93)
2	6.92 (6.07)	20.82* (8.07)	27.64* (11.07)	2.35 (6.42)	0.93 (3.74)	1.77 (12.43)
3	6.13 (5.57)	36.87* (10.27)	22.65* (9.54)	4.32 (7.40)	2.52 (4.31)	0.90 (10.84)
4	24.82 (17.61)	3.79 (8.77)	4.44 (9.44)	5.89 (5.75)	9.10 (5.20)	117.50** (14.73)
5	54.69* (23.77)	-60.26** (9.50)	-24.31 (12.39)	-3.06 (12.70)	6.84 (10.02)	33.45 (17.55)
6	9.69 (27.18)	35.21* (12.26)	34.81* (10.87)	0.52 (6.43)	7.49 (4.02)	4.84 (7.63)
7	42.92 (42.66)	98.17** (25.78)	145.14** (23.50)	3.47 (8.10)	10.74 (7.27)	20.73 (24.66)
8	41.96* (20.44)	33.88 (21.41)	80.88** (19.10)	8.06 (9.33)	15.76 (8.94)	20.73 (24.66)

**Table 3.** The compositional factors parameters regression coefficients in Model-3

(1) Mean of Self-concept, (2) Mean of Intrinsic value, (3) Mean of Utility value, (4) Mean of educational aspiration, (5) Mean of home language, (6) Mean of parent's education, (7) Mean of home educational resources, (8) Mean of book ownership.

The values within the brackets are standard errors. (\*)  $p < .05$  and (\*\*)  $p < .001$

Mean of self-concept in 2003, 2007, and 2019, both the mean of intrinsic value and mathematics utility value in 2003 and 2007, the mean of educational aspiration in 2019, the mean of the home language in 1999 and 2003, both means of parent's education and mean of home educational resources in 2003 and 2007, mean of book ownership in 1999 and 2007 produced significant links with mathematics achievement.

#### 4.5. The Full Model

In the Full Model, all the student- and school-level factors were added into the model simultaneously to examine the relations of the student-level factors with mathematics achievement while the school-level factors were controlled and vice versa. The variance in mathematics achievement explained by the Full Model was computed using  $(\sigma^2 \text{ of the Null Model} - \sigma^2 \text{ of the Full Model}) / \sigma^2 \text{ of the Null Model}$  for the

student level and  $(\tau_{00}$  of the Null Model -  $\tau_{00}$  of the Full Model) /  $\tau_{00}$  of the Null Model for the school level. The Full Model explained 9.39%, 25.46%, 18.94%, 18.14%, 21.34%, and 17.15% of the student-level variance, and 15.11%, 35.88%, 17.31%, 21.30%, 35.57%, and 34.12% of the school-level variance in 1999, 2003, 2007, 2011, 2015, and 2019, respectively. The regression coefficients of the parameters in the Full Model are presented in Table 4.

$\beta$	TIMSS 1999	TIMSS 2003	TIMSS 2007	TIMSS 2011	TIMSS 2015	TIMSS 2019
1	No data available	16.08 ** (0.70)	13.08** (0.92)	8.75** (0.75)	18.05** (0.91)	11.68** (0.83)
2	12.70** (0.92)	16.72 ** (0.71)	6.56** (1.15)	14.68** (0.69)	16.64** (1.11)	10.76** (1.00)
3	0.34 (0.63)	1.20 (0.76)	0.42 (1.16)	2.95 (0.77)	4.43** (0.91)	2.06* (0.88)
4	4.46** (0.80)	0.85 (0.79)	0.10 (1.14)	0.62 (0.70)	17.45** (1.96)	13.23** (1.63)
5	-14.79** (3.00)	-20.90** (2.88)	-13.21** (2.57)	-24.64** (2.57)	18.91** (2.52)	10.20** (1.82)
6	3.01** (0.86)	2.40 (1.35)	1.07 (1.19)	0.47 (0.76)	4.88** (0.96)	2.64* (0.87)
7	1.96 (2.11)	2.47 (2.19)	15.41** (2.88)	6.67** (1.06)	-0.54 (1.77)	4.62* (1.28)
8	7.84* (3.01)	2.19 (1.40)	5.96** (1.40)	2.20 (1.13)	5.84* (1.99)	9.93** (1.84)
9	0.13 (3.27)	3.04 (4.39)	2.79 (5.96)	2.02 (6.25)	-3.04 (5.72)	-17.38* (7.22)
10	-33.56* (12.65)	-32.17** (8.24)	9.78 (12.14)	-38.49* (14.15)	-3.13 (9.65)	32.78* (14.56)
11	9.78 (7.91)	-6.75 (8.18)	0.23 (8.55)	2.77 (7.92)	4.76 (7.69)	33.24* (15.37)
12	3.17 (8.21)	-10.99 (6.50)	-4.32 (11.56)	-34.90* (11.27)	43.37* (18.37)	12.58 (10.68)
13	-8.23 (8.75)	-20.22 ** (4.83)	-2.88 (7.90)	-16.64 (9.45)	-8.70 (7.43)	16.89 (11.71)
14	No data available	No data available	No data available	No data available	0.88 (7.01)	16.66 (9.97)

**Table 4.** Parameters regression coefficients in the Full Model

Self-concept, (2) Intrinsic value, (3) Utility value, (4) Educational aspiration, (5) Home language, (6) Parent's education, (7) Home educational resources, (8) Book ownership, (9) Teacher teaching experience, (10) Teacher gender, (11), Teacher age (12) School discipline, (13) Math teaching affected by resources shortage, (14) Teacher job



satisfaction. The values within the brackets are standard errors. (\*)  $p < .05$  and (\*\*)  $p < .001$ .

After controlling for the school-level factors, mathematics self-concept and intrinsic value produced significant links with mathematics achievement in all years. Utility value was significantly correlated with mathematics achievement in the last two waves. The relationship between educational aspiration and mathematics achievement was significant in 1999, 2015, and 2019. The relationship between the language spoken at home and mathematics achievement in the Full Model was negative in TIMSS from 1999 to 2011. However, the relation turned positive in TIMSS 2015 and 2019. Parent's level of education was significantly associated with mathematics achievement in 1999, 2015, and 2019. Home educational resources were significantly correlated with mathematics achievement in 2007, 2011, and 2019. Book ownership produced significant links with mathematics achievement in all waves, except for 2003. At the school level, there was no clear pattern of relationships between the factors and mathematics achievement when student-level factors were considered.

## 5. Discussion

This study examined student- and school-level factors associated with Malaysian adolescents' mathematics achievement over the last two decades. To help the readers understand the results, first, the main results are summarised and followed by interpretation and discussion.

### 5.1. Sumurizing the findings

The results suggested that more than 50% of the variation in mathematics achievement of Malaysian students in all the six waves of the TIMSS assessment, except for TIMSS 2015 (43.16%), was due to between-school differences indicating, that students' mathematics achievement is highly affected by schools.

Self-concept and intrinsic value had a solid and positive relationship with mathematics achievement in all the TIMSS waves. However, the association for self-concept was stronger. Utility value was not significantly correlated with achievement in the first three assessments but yielded a significant correlation in the last three. Educational aspiration was significantly correlated with achievement in 1999, 2015, and 2019. The language spoken at home was significantly associated with achievement in all the TIMSS assessments. The correlation was negative in the first four assessments. However, it turned positive in the last two assessments. There was a significant correlation between parents' education in

1999; the significant correlation disappeared in 2003 and 2007; however, the correlation was significant again in the last three cycles. Home educational resources were significantly related to achievement in 2007, 2011, and 2019. Book ownership was significantly correlated with achievement in all years except 2003.

Among the school-level factors, teachers' gender was highly and negatively associated with achievement in 1999, 2011, and 2019. Students whom female teachers taught achieved higher scores than those whom male teachers taught. The teacher-teaching experience was negatively correlated to mathematics achievement only in 2019. Students whom more experienced teachers taught achieved lower scores; however, after controlling for the student-level factors, the relationship between teacher-teaching experience turned positive.

After controlling for the school-level factors, the mean of self-concept and intrinsic value were significantly and positively correlated to achievement in 2003, 2007, and 2019; however, the associations were stronger in 2003 and 2007 than in 2019. Similarly, the mean utility value was significantly correlated with achievement in 2003, 2007, and 2019; however, the correlation in 2019 was minimal. The mean of educational aspiration was significantly correlated to achievement only in 2019. The correlation between the mean of home language and mathematics achievement was significant in 1999 and 2003. The correlation was positive in 1999, but it turned negative in 2003. The mean of parents' education was significantly and positively correlated to mathematics achievement in 2003 and 2007. The mean home educational resources positively correlated with mathematics achievement in 2003 and 2007. The mean of book ownership positively correlated with mathematics achievement in 1999 and 2007.

## *5.2. School effectiveness theory*

School effectiveness and multilevel modeling theory were used as a guide to select the factors affecting students' mathematics achievement in this study. School effectiveness determines how various factors correlate with students' cognitive and affective performance (Creemers et al., 2010). From the view of the last five decades, schools make no difference, which was the conclusion of the Coleman et al. (1966) and Jencks et al. (1971) studies. There is a common agreement that schools make differences in students' academic achievement, and educational policies aim to improve all schools in general and the more ineffective schools in particular (Reynolds et al., 2000). This study provides evidence indicating that schools make students' academic achievement different.

### 5.3. Expectancy value theory

The findings showed that the relationship between self-concept and intrinsic value with achievement was powerful across the TIMSS assessments. The relationships between motivation and academic achievement have been extensively investigated using the expectancy-value theory (EVT) of motivation (Wigfield & Eccles, 2000; Eccles & Wigfield, 2002). EVT indicates that students' expectations of success and value in academic tasks influence achievement choices, performance, effort, and persistence (Metzger et al., 2019). Utility value is one of the EVT components (Eccles & Wigfield, 2002). Beliefs in learning mathematics are linked with more significant effort, higher self-efficacy, and engagement in mathematical learning (Pajares & Miller, 1994) and, finally, higher mathematics achievement. Having found a solid link between self-concept, intrinsic value, and utility value with students' mathematics achievement in this study provides support to the EVT and confirms prior findings (e.g., Ceci et al., 2014; Moyer et al., 2018; Dowker et al., 2019; Steinmayr et al., 2019; Master & Meltzoff, 2020; Quaye & Pomeroy, 2021). This indicates that the weight of motivational factors on students' achievement is higher than students' family background factors. This result supports Chepete's (2008) findings, who reported that the attitudinal factors are more effective on the variation in mathematics achievement than the family background factors. This finding has important policy implications because these factors, to some extent, are under the school's control. Through formal and informal instructional activities, schools can form, develop, and reinforce students' motivational beliefs to enhance their academic achievement.

The findings showed that the trend of the relationships between the utility value and students' performance was insignificant in the first three studies. However, this relationship is significant in the following three cycles. This finding can confirm the hypothesis that the role of mathematics and related fields, such as STEM, in technological knowledge and entrepreneurship of graduates of educational systems is changing rapidly in the world, and the utility value of mathematical knowledge is increasing.

Home language among the other family backgrounds was the most influential factor. Non-Bahasa speaking background students outperformed their Bahasa speaking background peers. This result is inconsistent with the recent findings nationally and internationally (Van Laere et al., 2014; Strand & Schwippert, 2019; Mullis et al., 2020; Lopez et al., 2021). A possible explanation for this inconsistency might be related to the school's location. Usually, wealthier students lived in urban areas. They were more advantageous concerning the quality of education (e.g., experienced teacher, more instructional resources, social combination) and family background (e.g., parents' education, home educational resources). Mathematics is the most challenging subject among the other school subjects (Howie, 2006).

Generally, students need support doing their assignments and homework, particularly in mathematics. Advantageous students in urban areas have parental support in doing assignments and homework. Research findings suggest that homework is an influential factor that improves the academic achievement of students who can work independently and those who have sufficient parental support to complete home learning assignments (Henderson & Mapp, 2002; Hoover-Dempsey et al., 2001; Stronge, 2007). Moreover, this outcome may also be partially attributed to cultural differences. As mentioned earlier, the Malaysian population consists of three distinct ethnic groups: Malay, Chinese, and Indian. Chinese students, whether they reside in mainland China, Singapore, Taiwan, or Hong Kong, strive to please their parents and bring honor to their families. Consequently, they exert more effort to meet their parents' expectations. The TIMSS results consistently reveal that the five East Asian countries, namely Singapore, Hong Kong, Taiwan, South Korea, and Japan, which share a common culture to a large extent, achieved the highest scores in mathematics and science at both the fourth and eighth-grade levels among all participating nations. However, it is important to note that the self-perception of learning these subjects, as well as the intrinsic and practical values associated with them, are not particularly high in these countries. In fact, they are even lower than in many countries where students performed poorly. The most likely explanation for the decline in the achievement of Malaysian eighth-graders over time could be attributed to the change in the language of instruction for mathematics from Bahasa Malaysia to English in 2003. That is, the Malaysian eighth-graders who participated in TIMSS 2007 studied mathematics (science as well) in Bahasa Malaysia during their 6-years of primary education suddenly had to switch to study both subjects in English (Yusof, 2008). Even though the TIMSS test was conducted in Bahasa Malaysia, there are reasons for the decline. Firstly, students' inability to master the content taught in the English language and secondly, due to the teachers' insufficient mastery of the English language to explain the mathematics contents to the students. Although English is the second language in Malaysia, as less educated parents, especially in rural areas, could not support their children in their assignments, finally, after much debate, the government decided in July 2009 to revert from English to Bahasa Malaysia.

## 6. Conclusion

The decline in mathematics performance among Malaysian eighth-grade students has been a consistent trend in successive TIMSS assessments. This research aimed to explore the factors at both the student and school levels that contribute to these differences in mathematics achievement. Multiple multilevel

models were utilized to analyze the relationship between mathematics achievement and various factors, using TIMSS data from 1999 to 2019. The analysis revealed several significant findings, ultimately leading to the conclusion that students' attitudinal factors (such as self-concept, intrinsic value, utility value, and educational aspiration) and their socioeconomic backgrounds, along with compositional and contextual factors at the school level, play a crucial role in explaining the variations in mathematics achievement.

## 7. Limitations

Several limitations of the study should be borne in mind in interpreting the results. First, the data analyzed were correlational. Thus, the findings cannot be interpreted causally. Second, all data were self-reported by the students, teachers, and principals, except for mathematics achievement scores, which is a potential source of inaccuracy. Third, TIMSS scores do not affect students' grades and are not considered for purposes such as promotion and graduation. Thus, some students may not have tried their best to answer the test questions. Fourth, our models were limited to the student and school levels, and we did not investigate the variation in achievement between classrooms within schools.

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