JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE | SPRING 2025 | VOLUME 16, ISSUE 1

The Relationship Between Student Attitude Towards Mathematics and Student Mathematics Achievement

Michael Osborne
Eastern Kentucky University

Brandon Hibbard
University of the Cumberlands

ABSTRACT Using the United States data from the 2019 Trends in International Mathematics and Science Study, which included a total of 9924 randomly selected students in grade eight from 325 randomly selected schools, the present study examined the relationship between the students' attitudes towards mathematics and the mathematics achievement of the students. Due to the hierarchical structure of the educational data, multilevel statistical modeling was used to analyze the data. While including sex and parent education level as student-level control variables and school location and school socioeconomic status as school-level control variables, the students' attitudes towards mathematics demonstrated significant positive effects on the students' mathematics achievement. Furthermore, this relationship was shown to vary significantly across schools; however, school disciplinary climate was not found to be a significant contributor to this variation.

KEYWORDS *Attitude towards mathematics, mathematics achievement, Trends in International Mathematics and Science Study (TIMSS), Hierarchical linear modeling (HLM)*

Introduction

Mathematical literacy is a key that unlocks many doors of opportunity for K-12 students in terms of both educational success and future careers (Wang et al., 2017). Unfortunately, mathematics is also an area in which many students struggle to reach a level of proficiency, and so the doors of opportunity remain locked. Among the various factors that contribute to students' mathematics achievement, research has demonstrated that students' attitudes towards the subject play a key role (Arnold et al., 2019; Yerdelen-Damar et al., 2021).

Review of Literature

Student attitude towards mathematics encompasses such things as the feelings and opinions that a student holds about the subject (Mata et al., 2012). Attitude towards mathematics varies significantly among students and impacts their motivation, engagement, and willingness to learn the subject (Kariadinata et al., 2019). Students with positive attitudes towards mathematics are more likely to persevere when faced with challenges and setbacks in mathematics by seeking out additional resources and support (Clinkenbeard, 2015).

Various factors can influence students' attitudes towards mathematics (Moussa & Saali, 2022). For example, students' previous experiences with, personal beliefs about, and self-efficacy in mathematics can significantly impact their attitudes towards the subject (Chirove et al., 2022). In addition, parents who demonstrate a positive attitude towards mathematics and express belief in their child's ability to succeed in the subject can foster a similar positive attitude in their child. Furthermore, even societal beliefs and stereotypes around mathematics can affect students' attitudes towards the subject (Chirove et al., 2022).

The association between students' attitudes towards mathematics and their performance in the subject is significant. Many studies, such as those by Dowker et al. (2019) and Kiwanuka et al. (2022), have found that students with positive attitudes towards mathematics generally perform better on mathematics assessments than students with negative attitudes. Additional studies have demonstrated that student attitude towards mathematics accounts for a significant portion of the variance in mathematics achievement (Hwang & Son, 2021).

The relationship between student attitude towards mathematics and student mathematics achievement has been demonstrated to hold across grade levels. A study involving the mathematics achievement and attitude towards mathematics of a sample of 240 elementary students between the ages of seven and 11 found that students whose attitudes towards mathematics are positive tend to have higher achievement in mathematics than students whose attitudes towards mathematics are negative (Chen et al., 2018). While controlling for other cognitive and affective factors, the study also revealed that student memory affects the relationship between achievement and attitude.

In another study, Smith et al. (2014) examined data on 7,377 randomly selected middle school students in grade eight who participated in the 2007 Trends in International Mathematics and Science Study (TIMSS). Beyond measuring students' achievement in mathematics, TIMSS also collects information on the background characteristics of students. Some of these characteristics, such as the students' attitudes towards mathematics, can potentially play a role in the students' mathematics achievement. In addition to finding a positiveassociation between achievement and attitude, the study by Smith et al. (2014) also found a positive association between achievement and frequency of group work in the mathematics classroom.

A study by Hemmings and Kay (2010) examined the relationships among prior mathematics achievement, current mathematics achievement, and current attitude towards mathematics, among other variables. For a sample of 78 high school students in grade 10, the data included students' scores from a standardized mathematics test they took in grade seven, scores from a standardized mathematics test they took in grade 10, and scores from a questionnaire they completed in grade 10 that measured their attitudes towards mathematics. The study revealed that a significant positive correlation exists between students' attitudes towards mathematics and their mathematics achievement in both grade seven and grade 10.

A study by Hemmings et al. (2011) extended the study by Hemmings and Kay (2010) by considering the effect of sex on the relationships among prior mathematics achievement, current mathematics achievement, and attitude towards mathematics. The sample included 53 female and 47 male high school students in grade 10. Overall, the data revealed that females are more likely than males to have a positive attitude towards mathematics. Further, the researchers found that prior mathematics achievement and attitude towards mathematics, when taken together, are good predictors for current mathematics achievement.

While the relationship between student attitude towards mathematics and student mathematics achievement is well-established (Arthur, 2019; Ma & Kishor, 1997), it is also complex and multifaceted. Therefore, the present study sought to join the ongoing body of research seeking to explain this relationship by addressing the following three research questions:

1. What is the nature of the relationship between student attitude towards mathematics and student mathematics achievement, with control over sex and parent education level at the student level and city population size and school socioeconomic status (SES) at the school level?
2. How does the relationship between student attitude towards mathematics and student mathematics achievement vary across schools?
3. How does school disciplinary climate contribute to the school-level variation?

Method

Data

TIMSS is an international assessment of fourth- and eighth-grade students conducted every four years by the International Association for the Evaluation of Educational Achievement (IEA). The aim of TIMMS is to measure students' mathematics and science achievement, with the goal being to enable "countries around the world to make evidence-based decisions to improve educational policies related to mathematics and science teaching and learning" (IEA, n.d.).

TIMSS 2019 made use of a multi-stage, random sampling procedure involving both stratified and cluster methods for obtaining its sample. First, for each participating country, a number of schools with students in grades four or eight was randomly selected based on the number of students enrolled. Next, for each selected school, a number of classes was randomly selected from the subpopulation of all classes meeting TIMSS eligibility criteria. Finally, every student in the selected classes was invited to participate in the study (Martin et al., 2020). In addition to the standardized achievement tests, students, as well as teachers and principals, filled out questionnaires that included information about beliefs and background characteristics of the students and schools. In our study, we considered only the U.S. sample of eighth-grade students, utilizing the nationally representative sample of 9924 students from 325 schools (Egan et al., 2022).

Table 1

Items Used to Construct Composite Variable of Student Attitude Towards Mathematics

Items	Possible Responses
How much do you agree with these statements about learning mathematics? • I enjoy learning mathematics. • I wish I did not have to study mathematics.* • Mathematics is boring.[1] • I learn many interesting things in mathematics. • I like mathematics. • I like any schoolwork that involves numbers. • I like to solve mathematics problems. • I look forward to mathematics lessons. • Mathematics is one of my favorite subjects.	0 = disagree a lot 1 = disagree a little 2 = agree a little 3 = agree a lot

Note. Students chose one of the possible responses for each statement.
[1] Responses for this item were reverse coded.

Outcome Variable

TIMSS 2019 included over 200 items in its assessment of mathematics (Martin et al., 2020). These items measured student achievement across four mathematical content domains: number, algebra, geometry, and data and probability. The number domain included topics such as integers, fractions, decimals, ratios, and proportions; the algebra domain included topics such as expressions, operations, equations, relationships, and functions; the geometry domain included topics such as geometric shapes, transformations, area, volume, and the Pythagorean theorem; the data and probability domain included topics such as data collection, graphs, numerical summaries, interpretation of data, and basic probability (Mullis & Martin, 2017).

To measure student mathematics achievement for our study, we used as our outcome variable a student's overall score (combining the four content domain scores) on the TIMSS mathematics assessment. For reference, scores on the TIMSS assessment are distributed according to a bell-shape with a mean (referred to as the scale centerpoint) of 500 points and a standard deviation (SD) of 100 points (Mullis et al., 2020).

Predictor Variables

For the present study, our predictor variables were derived using information gathered from the student, teacher, and principal questionnaires (see Martin et al., 2020). The primary predictor variable for our study was student attitude towards mathematics, measured at the student level.

Student Attitude Towards Mathematics.

TIMSS 2019 measured the type of attitude students have towards mathematics by using information gathered from some student questionnaire items (see Table 1). Based on student responses, TIMSS created (and standardized) a composite variable of student attitude towards mathematics, where each student was assigned one score (Cronbach's $\alpha = .94$; Martin et al., 2020).

School Disciplinary Climate.

Based on information gathered from the school questionnaire, TIMSS 2019 determined whether each school's disciplinary climate is considered to be problematic. The variable of school disciplinary climate (1 = problematic, 0 = not problematic) was included as a school-level variable.

Student-Level Control Variables.

There are some variables that often differ from student to student that are related to the students' personal and family backgrounds. These variables, sometimes called student background characteristics, often help explain variation in students' performance in academic subject areas in general, and in mathematics in particular (Ma et al., 2008). Two such variables include a student's sex and the education level of the student's parent(s), measured by whether the student has at least one parent with a bachelor's degree or higher. The present study included sex (1 = male, 0 = female) and parent education level (1 = at least bachelor's degree, 0 = less than bachelor's degree) as student-level control variables.

School-Level Control Variables.

As with background characteristics of students, there are variables that often differ from school to school that may also help explain the variation in students' mathematics achievement (Ma et al., 2008). Two such variables include the population size of the city where a school is located and the school's SES. As a result, the present study included city population size (1 = at least 50,000 people; 0 = less than 50,000 people) and school SES (0 = high SES, 1 = middle SES, 2 = low SES) as school-level control variables.

Statistical Analysis

Due to the hierarchical structure of the educational data, multilevel statistical modeling was used to analyze the data. Specifically, we employed a hierarchical linear model (HLM) with two levels (student and school). The analysis included three steps. Step one incorporated the null model, meaning that neither the student nor school level included any predictor variables. The purpose of the null model was to estimate the mean student mathematics achievement and to determine how the variance in student mathematics achievement is split between the student and school levels. Here is the null model:

$$MATHij = \beta_{0j} + r_{ij}$$
$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where $MATH_{ij}$ is the mathematics achievement for student i in school j, β_{0j} is the mean mathematics achievement for school j, r_{ij} is the error term representing the unique effect associated with student i in school j, γ_{00} is the grand (overall) mean mathematics achievement, and u_{0j} is the error term representing the unique effect associated with school j.

For step two of the analysis, student attitude towards mathematics, as well as all other control variables at both the student and school levels, were included in the model. The purpose of this model was to determine whether student attitude towards mathematics has a statistically significant relationship with student mathematics achievement. Further, in this model, student attitude towards mathematics was allowed to vary randomly at the school level to determine any school-to-school variance in its relationship with student mathematics achievement. The first two research questions were addressed using the results from this second step. Here is the model at this step:

$$MATH_{ij} = \beta_{0j} + \beta_{1j}\,(ATT)_{ij} + \beta_{2j}\,(SEX)_{ij} + \beta_{3j}\,(PED)_{ij} + r_{ij}$$
$$\beta_{0j} = \gamma_{00} + \gamma_{01}\,(SES)_j + \gamma_{02}\,(POP)_j + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$

where $MATH_{ij}$ is the mathematics achievement for student i in school j, β_{0j} is the mean mathematics achievement for school j, $(ATT)_{ij}$ is the attitude towards mathematics score for student i in school j, β_{1j} is the slope associated with $(ATT)_{ij}$, $(SEX)_{ij}$ is the sex for student i in school j, β_{2j} is the slope associated with $(SEX)_{ij}$, $(PED)_{ij}$ is the parent education level for student i in school j, β_{3j} is the slope associated with $(PED)_{ij}$, r_{ij} is the error term unique to student i in school j, γ_{00} is the grand (overall) mean mathematics achievement, $(SES)_j$ is the SES for school j, γ_{01} is the slope associated with (SES)j, (POP) j is the city population size for school j, γ_{02} is the slope associated with (POP)j, u_{0j} is the error term of school j unique to the intercept, γ_{10} is the effect of $(ATT)_{ij}$, u_{1j} is the error term of school j unique to the slope of $(ATT)_{ij}$, γ_{20} is the effect of $(SEX)_{ij}$, and γ_{30} is the effect of $(PED)_{ij}$.

Finally, in step three of the analysis, school disciplinary climate was added to the model at the school level to examine whether it contributes to the between-school variance in the relationship between student attitude towards mathematics and student mathematics achievement. The third research question was addressed using the results from this third step. Here is the model at this step:

$$MATH_{ij} = \beta_{0j} + \beta_{1j}\,(ATT)_{ij} + \beta_{2j}\,(SEX)_{ij} + \beta_{3j}\,(PED)_{ij} + r_{ij}$$
$$\beta_{0j} = \gamma_{00} + \gamma_{01}\,(SES)_j + \gamma_{02}\,(POP)_j + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}\,(DIS)_j + u_{1j}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$

where MATHij is the mathematics achievement for student i in school j, β_{0j} is the mean mathematics achievement for school j, $(ATT)_{ij}$ is the attitude towards mathematics score for student i in school j, β_{1j} is the slope associated with $(ATT)_{ij}$, (SEX)ij is the sex for student i in school j, β_{2j} is the slope associated with $(SEX)_{ij}$, $(PED)_{ij}$ is the parent education level for student i in school j, β_{3j} is the slope associated with $(PED)_{ij}$, r_{ij} is the error term unique to student i in school j, γ_{00} is the grand (overall) mean mathematics achievement, $(SES)_j$ is the SES for school j, γ_{01} is the slope associated with $(SES)_j$, $(POP)_j$ is the city population size for school j, γ_{02} is the slope associated with $(POP)_j$, u_{0j} is the error term of school j unique to the intercept, γ_{10} is the effect of $(ATT)_{ij}$, (DIS)j is the disciplinary climate for school j, γ_{11} is the slope associated with $(DIS)_j$, u_{1j} is the error term of school j unique to the slope of $(ATT)_{ij}$, γ_{20} is the effect of $(SEX)_{ij}$, and γ_{30} is the effect of $(PED)_{ij}$.

Results

Descriptive Statistics

We calculated descriptive statistics for each of the predictor variables in order to explore their primary features (see Table 2).

Table 2

Descriptive Statistics for Predictor Variables

	M	SD
Student-level variables		
Student attitude towards mathematics[1]	0.00	1.00
Sex (1 = male, 0 = female)	0.50	0.50
Parent education level (1 = at least bachelor's degree, 0 = less than bachelor's degree)	0.41	0.49
School-level variables		
School disciplinary climate (1 = problematic, 0 = not problematic)	0.61	0.49
City population size (1 = at least 50,000 people; 0 = less than 50,000 people)	0.48	0.50
School SES (0 = high SES, 1 = middle SES, 2 = low SES)	1.33	0.81

[1] This variable was standardized.

Student-Level Variables.

The TIMSS 2019 index used to measure student attitude towards mathematics was standardized to have a mean of 0 with an SD of 1. Regarding the sex of the students, 50.3% were male, and 49.7% were female. In terms of parent education level, about 41% of the students had at least one parent with a bachelor's degree (or higher).

School-Level Variables. About 48% of the schools were in cities whose population size was 50,000 or greater. In terms of SES, 22% of the schools were high SES, 23% of the schools were middle SES, and 55% of the schools were low SES. The disciplinary climate was considered to be problematic in 61% of the schools.

Estimating the Mean and Partition of Variance for Mathematics Achievement

The outcome variable for the present study was student mathematics achievement. However, since TIMSS uses a plausible-value approach to assign scores to students, descriptive statistics could not be calculated. Rather, we used the null model from an HLM to produce estimates for both the mean and the variance for student mathematics achievement. The estimated mean mathematics achievement for the students was 519.49 (t = 117.84, p < .001), which is about one-fifth of an SD higher than the overall TIMMS mean of 500.

After using the HLM to partition the variance in student mathematics achievement, we found that about 54% can be attributed to student-level differences, while about 46% can be attributed to school-level differences (variance at student level: $\sigma^2 = 5241.79$, variance at school level: $\tau = 4458.44$; $\sigma^2/(\sigma^2+\tau)=0.54$, $\tau/(\sigma^2+\tau)=0.46$). As the school-level variance was statistically significant ($\chi^2 = 6576.05$, $p < .001$), we affirmed that the mathematics achievement of students does indeed differ from school to school.

Relationship With Student Attitude Towards Mathematics

Student attitude towards mathematics was shown to have a statistically significant relationship with student mathematics achievement ($t = 18.82$, $p < .001$), even when controlling for the student-level variables of sex and parent education level and the school-level variables of city population size and school SES. In particular, each 1-point increase in student attitude towards mathematics was associated with an increase of 22.42 points in student mathematics achievement. As such, we found that student mathematics achievement is positively related to student attitude towards mathematics.

With the TIMSS mathematics achievement having a mean of 500 points and an *SD* of 100 points (Mullis et al., 2020), the effect size calculation was straightforward, yielding an effect size of 22.42% of an *SD* (Cohen's d=22.42/100=0.2242) for student attitude towards mathematics.

Between-School Variance in Relationship With Student Attitude Towards Mathematics

In addition to examining the relationship between student attitude towards mathematics and student mathematics achievement, we also examined whether this relationship varies from school to school. Indeed, the between-school variance in the relationship between student attitude towards mathematics and student mathematics achievement was shown to be statistically significant ($\chi_2 = 282.53$, $p = .023$). In other words, the extent to which a student's mathematics achievement is related to the student's attitude towards mathematics depends on the school in which the student is enrolled.

Contribution of School Disciplinary Climate to Relationship With Student Attitude Towards Mathematics

Because a statistically significant between-school variance exists in the extent to which student mathematics achievement is related to student attitude towards mathematics, disciplinary climate was included in the model as a school-level variable to determine if it helps explain the between-school variance; however, it was not found to do so ($t = -0.23$, $p = .817$). In other words, there is insufficient evidence to conclude that differences in schools' disciplinary climates help explain why the relationship between student attitude towards mathematics and student mathematics achievement is greater at some schools than at others.

HLM Model Performance

To determine how well the HLM model performed, we calculated the proportion of variance explained. Specifically, the full model explained roughly 14% of the student-level variance in student mathematics achievement and roughly 41% of the total school-level variance in student mathematics achievement. As a whole, the full model explained roughly 27% of the total variance in student mathematics achievement. Based on the standard benchmarks used in educational research (see Gaur & Gaur, 2006), these results are considered acceptable, demonstrating that the HLM model performed well.

Discussion

Revisit of Research Literature

Although there is a substantial amount of literature on the positive relationship between student attitude towards mathematics and student mathematics achievement, most studies have involved relatively small, nonrandom samples from relatively small geographical regions (e.g., one school district). In addition, most existing studies have not taken into account the hierarchical structure of educational data. The use of large-scale, randomly selected data for the present study lends further evidence of a positive relationship between student attitude towards mathematics and student mathematics achievement. Further, the present study made use of multilevel modeling techniques to account for students being nested within schools. Taken together, these constitute a marked improvement in research methodology. As a result, our study contributes to the research literature by yielding findings that are more generalizable.

Educational Implications

While we recognize that variables being correlated does not necessarily mean there is a causal relationship between them, there is a clear connection between attitude and achievement; thus, it follows that using strategies that foster a positive attitude towards mathematics is crucial in promoting student academic achievement in the subject. One such strategy is to address any negative beliefs or stereotypes that students may hold about mathematics (Awoniyi & Butakor, 2021). This can be done by challenging misconceptions and providing examples of successful individuals who have excelled in mathematics. By debunking the idea that math is only for "geniuses" or "mathematical prodigies," students can develop a more positive view of their own potential in mathematics and become more motivated to succeed in the subject (Hwang & Son, 2021).

Since the classroom environment plays a crucial role in shaping students' attitudes towards mathematics (Awoniyi & Butakor, 2021), another strategy for fostering positive attitudes is for teachers to create a supportive and inclusive learning environment. This can be achieved by valuing and respecting every student's contribution, providing opportunities for collaborative learning, and promoting a growth mindset. Furthermore, integrating real-world applications and problem-solving activities into the mathematics curriculum can also help students develop a positive attitude towards the subject. By demonstrating the relevance and practicality of mathematics in everyday life, students can see the value in learning the subject and become more engaged (Elçi, 2017).

Teachers can also influence students' attitudes towards mathematics through their own attitudes towards the subject. This relationship between teacher attitudes and student attitudes towards mathematics is well-established and supported by research (Elçi, 2017; Hwang & Son, 2021). Teachers who demonstrate enthusiasm for the subject, provide clear explanations, and create a supportive learning environment can help students develop a positive attitude towards mathematics, which, in turn, can also increase the students' academic achievement in the subject (Awoniyi & Butakor, 2021). Because of this connection, it is imperative that educational administrators aim to help teachers improve (when needed) their own attitudes towards mathematics in order to establish a supportive and engaging classroom learning environment that fosters students' interest in and enthusiasm for mathematics (Ayob & Yasin, 2017).

Moreover, it has been observed that a decline in student enrollment in advanced mathematics classes may be attributable to poor attitudes towards mathematics (Arnold et al., 2019). This decrease in enrollment limits the number of students who can pursue careers in science, technology, engineering, and mathematics (STEM) fields, demonstrating that fostering positive attitudes towards mathematics among students is not only important for their academic success but also for their future career prospects in fields that rely on mathematical proficiency. This connection raises concerns among mathematics educators and educational policymakers, as well as society as a whole, about the continued STEM workforce shortage (U.S. Chamber of Commerce Foundation, 2022).

Limitations and Suggestions

While this study found that student mathematics achievement is positively related to student attitude towards mathematics, only certain student and school background characteristics were included in the study. Future studies could examine the ways in which student attitude towards mathematics interacts with other such variables, including student race/ethnicity (Parks & Schmeichel, 2012). Including other key background variables could provide further insight into the relationship between attitude and achievement. In addition, student attitude towards mathematics could be considered alongside other outcome variables in mathematics. For example, one could analyze whether improving students' attitude towards mathematics helps decrease students' mathematics anxiety.

Another key finding from the study is that the relationship between student attitude towards mathematics and student mathematics achievement varies across schools, meaning there are school-level variables that affect the relationship. Since school disciplinary climate was not found to contribute to the relationship, future studies could consider other school-level variables that might help explain the variation. An obvious limitation of this study is that it only included the U.S. data from TIMSS 2019. It is possible that the relationship between student attitude towards mathematics and student mathematics achievement might also vary across countries. With that in mind, future research could examine the larger set of TIMSS data that includes other countries and country-level variables.

Finally, this study measured student attitude towards mathematics in a particular way, specifically by making use of TIMSS' composite variable of student attitude towards mathematics developed using information obtained through the TIMSS 2019 student questionnaire. While the TIMSS attitude variable had a high level of internal consistency, for future studies, researchers could seek to measure student attitude towards mathematics in different ways by using other well-established attitude surveys or even designing their own.

References

Arnold, D. M., Mortensen, C. J., Thoron, A. C., Miller-Cushon, E. K., & Miot, J. K. (2019). Contrasting science learning gains and attitudes of students in an early research-based experience. *NACTA Journal*, *63*(2), 180-187. https://www.jstor.org/stable/26769635

Arthur, Y. D. (2019). The effect of background on students' interest in mathematics: The mediation of students' motivation and perception in Ghana. *Asian Journal of Probability and Statistics*, *5*(3), 1-13. https://doi.org/10.9734/ajpas/2019/v5i330135

Awoniyi, F. C., & Butakor, P. K. (2021). The role of teacher-student relationship on performance in mathematics of the eleventh graders in the Cape Coast metropolis: Critical friendship perspective. *Cogent Education*, *8*(1), 1-17. https://doi.org/10.1080/2331186x.2021.1908690

Ayob, A., & Yasin, R. M. (2017). Factors affecting attitudes towards mathematics. International *Journal of Academic Research in Business and Social Sciences*, *7*(11), 1100-1109. https://doi.org/10.6007/ijarbss/v7-i11/3548

Chen, L., Bae, S. R., Battista, C., Qin, S., Chen, T., Evans, T. M., & Menon, V. (2018). Positive attitude towards math supports early academic success: Behavioral evidence and neurocognitive mechanisms. *Psychological Science*, *29*(3), 390-402. https://doi.org/10.1177/0956797617735528

Chirove, M., Mogari, D., & Ogbonnaya, U.I. (2022). Students' mathematics-related belief systems and their strategies for solving non-routine mathematical problems. *Waikato Journal of Education*, *27*(3), 101-121. https://doi.org/10.15663/wje.v27i3.822

Clinkenbeard, J. (2015). Attitudes and experiences in liberal arts mathematics. *Journal of Humanistic Mathematics*, *5*(2), 26-50. https://doi.org/10.5642/jhummath.201502.04

Dowker, A., Cheriton, O. M., Horton, R., & Mark, W. (2019). Relationships between attitudes and performance in young children's mathematics. *Educational Studies in Mathematics*, *100*, 211-230. https://doi.org/10.1007/s10649-019-9880-5

Egan, L., Tang, J. H., Ferraro, D., Erberber, E., Tsokodayi, Y., & Stearns, P. (2022). U.S. technical report and user guide for the 2019 Trends in International Mathematics and Science Study (TIMSS). *U.S. Department of Education*. Washington, DC: National Center for Education Statistics. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2022049

Elçi, A. N. (2017). Students' attitudes towards mathematics and the impacts of mathematics teachers' approaches on it. *Acta Didactica Napocensia*, *10*(2), 99-108. https://scite.ai/reports/10.24193/adn.10.2.8

Gaur, A. S., & Gaur, S. S. (2006). *Statistical methods for practice and research: A guide to data analysis using SPSS*. Thousand Oaks, CA: Sage. https://doi.org/10.4135/9788132108306

Hemmings, B., & Kay, R. (2010). Prior achievement, effort, and mathematics attitude as predictors of current achievement. *Australian Educational Researcher (Australian Association for Research in Education)*, *37*(2), 41-58. https://doi.org/10.1007/BF03216921

Hemmings, B., Grootenboer, P., & Kay, R. (2011). Predicting mathematics achievement: The influence of prior achievement and attitudes. *International Journal of Science and Mathematics Education*, *9*(3), 691-705. https://doi.org/10.1007/s10763-010-9224-5

Hwang, S., & Son, T. (2021). Students' attitude towards mathematics and its relationship with mathematics achievement. *Journal of Education and e-Learning Research, 8*(3), 272-280. https://doi.org/10.20448/journal.509.2021.83.272.280

International Association for the Evaluation of Educational Achievement (IEA). (n.d.). TIMSS. https://www.iea.nl/studies/iea/timss

Kariadinata, R., Yaniawati, R. P., Sugilar, H., & Riyandani, D. (2019). Learning motivation and mathematical understanding of students of Islamic junior high school through active knowledge sharing strategy. *Infinity Journal, 8*(1), 31. https://doi.org/10.22460/infinity.v8i1.p31-42

Kiwanuka, H. N., Van Damme, J., Van den Noortgate, W., & Reynolds, C. (2022). Temporal relationship between attitude towards mathematics and mathematics achievement. International Journal of Mathematical *Education in Science and Technology, 53*(6), 1546-1570. https://doi.org/10.1080/0020739x.2020.1832268

Ma, X., & Kishor, N. (1997, January 1). Assessing the relationship between attitude towards mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, *28*(1), 26-47. https://doi.org/10.2307/749662

Ma, X., Ma, L., & Bradley, K. D. (2008). Using multilevel modeling to investigate school effects. In A. A. O'Connell & D. B. McCoach (Eds.), *Multilevel modeling of educational data* (pp. 59-110). Charlotte, NC: IAP. https://www.worldcat.org/title/multilevel-modeling-of-educational-data/oclc/666928890

Martin, M. O., von Davier, M., & Mullis, I. V. S. (2020). Methods and procedures: TIMSS 2019 technical report. International Association for the Evaluation of Educational Achievement. https://timssandpirls.bc.edu/timss2019/methods

Mata, M. L., Monteiro, V., & Peixoto, F. (2012). Attitudes towards mathematics: Effects of individual, motivational, and social support factors. *Child Development Research*, 2012, 1-10. https://doi.org/10.1155/2012/876028

Moussa, N., & Saali, T. (2022). Factors affecting attitude towards learning mathematics: A case of higher education institutions in the Gulf region. *SAGE Open*, *12*(3). https://doi.org/10.1177/21582440221123023

Mullis, I. V. S., & Martin, M. O. (2017). TIMSS 2019 assessment frameworks. International Association for the Evaluation of Educational Achievement. https://timssandpirls.bc.edu/timss2019/frameworks

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). TIMSS 2019 international results athematics and science. International Association for the Evaluation of Educational Achievement. https://timss.bc.edu/timss2019/

Smith, T. J., McKenna, C. M., & Hines, E. (2014). Association of group learning with mathematics achievement and mathematics attitude among eighth-grade students in the US. *Learning Environments Research, 17*(2), 229-241. https://doi.org/10.1007/s10984-013-9150-x

U.S. Chamber of Commerce Foundation (2022, October 17). *Addressing the STEM workforce shortage*. https://www.uschamberfoundation.org/blog/post/addressing-stem-workforce-shortage

Wang, M., Ye, F., & Degol, J. (2017). Who chooses STEM careers? Using a relative cognitive strength and interest model to predict careers in science, technology, engineering, and mathematics. *Journal of Youth and Adolescence*, *46*(8), 1805-1820. https://doi.org/10.1007/s10964-016-0618-8

Yerdelen-Damar, S., Aksoz, B., Sezer, S., Arabaci, N., & Arikan, F. (2021). Investigating the interrelationships among science and mathematics achievement, attitudes towards STEM, and gender. *Bartin University Journal of Faculty of Education, 10*(2), 342-357. https://doi.org/10.14686/buefad.778281