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A cross-cultural perspective on academic resilience, academic vulnerability, and student attitudes towards mathematics: An analysis of TIMSS 2019 data

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Abstract

The study of academic resilience has received much attention in international large-scale studies of achievement in recent times and can provide insights into why some children coming from lower socioeconomic backgrounds do well academically, while others from similar backgrounds do not do as well. Applying definitions of academic resilience that meaningfully operationalise its two core constructs, adversity and successful outcomes, can be challenging. These difficulties become even more pronounced when attempting to apply such definitions across different countries. Considering that and the policy focus on science, technology, engineering, and mathematics (STEM) across many countries, this study uses Trends in International Mathematics and Science Study (TIMSS) data to examine academic resilience in the context of mathematics. Academic resilience is defined as better-than-expected achievement outcomes among students from lower socioeconomic backgrounds. The study focuses on four countries that are readily comparable on measures of adversity and successful outcomes: Australia, England, Ireland, and the United States. Academically resilient students are compared to academically vulnerable students, identified as those with similar levels of socioeconomic status but lower achievement. The aim of the study is to examine whether academic resilience in mathematics can be predicted by the extent to which students feel confident in, like learning, and value mathematics, and to examine the extent to which this may vary across countries. Based on the results of the binary logistic regression models, which accounted for student gender, how confident students felt in mathematics statistically significantly predicted academic resilience as opposed to academic vulnerability across all countries. Gender (favouring females) was only statistically significantly associated with academic resilience in Australia. Methodological implications and implications for educational policy are discussed.

Keywords: academic resilience, academic vulnerability, student attitudes, mathematics, TIMSS

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The study of academic resilience can offer researchers, policymakers, and educators a means to better understand why some children do well in school, while others from similar backgrounds do not do as well academically. Academic resilience can be applied to specific domains and may be considered particularly relevant in the areas of science, technology, engineering, and mathematics (STEM), given that the types of skills and concepts developed through STEM education are increasingly seen as necessary for young people to be able to engage as active citizens and several economies have committed to addressing shortages of such skills among their young people in recent years (Committee on STEM Education of the National Science & Technology Council, 2018; Department of Education and Skills, 2017; European Centre for the Development of Vocational Training, 2016; House of Commons Committee of Public Accounts, 2018; UK Commission for Employment and Skills, 2015). Indeed, longitudinal studies looking at the association between performance during schooling and later outcomes have demonstrated that strong performance in STEM-related subjects at school is likely to lead to higher numbers of STEM graduates and, thus, more people undertaking STEM job positions (e.g., Organisation for Economic Co-operation and Development [OECD], 2010).

In recent times, the study of academic resilience has received much focus in large-scale studies of achievement (Cheung, 2017; Erberber et al., 2015; OECD, 2011, 2019; Rudd et al., 2023). Such studies often examine the relationship between a defined set of factors, such as parental support, school climate, or students' attitudes and beliefs, and academic resilience, as well as reporting the prevalence of academic resilience, across a range of countries. While such studies can offer a cross-cultural perspective on academic resilience, what constitutes positive adjustment can differ depending

on societal expectations (Masten, 1994). Therefore, applying the same definition of academic resilience across a range of countries can present some challenges, as what is considered resilient behaviour or outcomes may differ based on cultural norms. For instance, in some high-performing societies, academic success may mean demonstrating advanced skills at the highest levels of achievement, while in others, with lower average levels of achievement, academic resilience may be defined by performance at more intermediate levels. Thus, sociocultural context is an important consideration in resilience research and there may be some merit in examining factors associated with academic resilience among a smaller set of countries that are more readily comparable on the key indicators that contribute to a definition of resilience, namely measures of risk and positive adjustment. These countries would likely share more similar societal expectations, potentially making cross-country comparisons more meaningful. However, it is important to note that this approach may limit the exploration of broader variations in how resilience is understood and manifested across more diverse cultural contexts.

Academic Resilience

Academic resilience, by definition, is a two-dimensional construct that includes both exposure to some type of adversity and the exhibition of successful outcomes in the presence of that adversity (Schoon, 2006). The positive and robust relationship of students' socioeconomic status, a multidimensional factor that can incorporate such factors as parental educational level, parental occupation, family wealth, and home resources, with student achievement has been well documented and students experiencing lower levels of socioeconomic status are often considered to be at-risk of poorer school outcomes (OECD, 2011; Schoon, 2006; Sirin, 2005). Consequently, academic resilience is often conceptualised as better-than-expected outcomes among students with lower socioeconomic status.

However, the measurement of socioeconomic status often varies across studies, with some drawing on one discrete indicator such as parental social class, and others using aggregated measures that include indicators such as home possessions, parental education, and parental occupation (Cheung, 2017; Erberber et al., 2015; OECD, 2011; Schoon, 2006). Regarding measures of successful outcomes, data from standardised assessments of reading, mathematics, or science are often used, as they provide a direct measure of students' academic achievement. However, as with measures of adversity, definitions of successful outcomes also vary across the literature. Many studies focus on one subject area (Cheung, 2017; Erberber et al., 2015; Schoon, 2006), while others jointly consider achievement across a number of domains (Agasisti et al., 2018). Variation in measures and operationalisation of socioeconomic status and achievement outcomes across studies creates difficulties in comparing the findings of different studies of academic resilience. Even when comparable or identical measures

are used, studies often vary in terms of the thresholds applied or how academic resilience is operationalised using these measures (Rudd et al., 2023). In some studies, absolute thresholds are used, such as students that fall into the *few resources* category of the *home educational resources* scale (a proxy measure for socioeconomic status) and who achieve at or above the intermediate benchmark of performance in TIMSS (Erberber et al., 2015; Sandoval-Hernández & Białowolski, 2016). In other studies, relative thresholds have been applied; however, where these have been used, they have not always been applied in the same way. For example, in PISA, students experiencing academic resilience have been identified as those among the lowest 25% of a country's socioeconomic distribution who are also in the top 25% of the achievement distribution (OECD, 2017, 2019), but also as those who are among the bottom third of the socioeconomic distribution and among the top third of students in terms of their achievement outcomes (OECD, 2011).

There are benefits and drawbacks to both approaches for defining academic resilience in studies that involve cross-cultural comparisons. As absolute thresholds are fixed, their characteristics are the same in different contexts, facilitating comparisons across countries. One difficulty with this approach, though, is that the proportions of students categorised as having low socioeconomic status, or few resources, can vary quite considerably across countries (e.g., between 2% and 55% of students were categorised as having *few resources* across countries in TIMSS 2019; Mullis et al., 2020). Similarly, the lower thresholds for performance outcomes may have different meanings in different countries, with a score of 475 (the lower threshold for the intermediate benchmark in TIMSS) being close to or above average performance in some countries, and substantially below average performance levels in other countries. On the other hand, applying relative measures in definitions of resilience can be useful in studies that include cross-country comparisons, as such approaches mean that the proportions of students considered disadvantaged and high-achieving are standardised across contexts. One drawback of this approach, however, is that it offers little insight into the experience of children placed in such categories, which may vary quite considerably, particularly in studies where numerous countries with wide variations in achievement outcomes and socioeconomic profiles are being compared.

Despite the variations in measures used to operationalise risk and successful outcomes, Masten (2001) notes that findings across numerous resilience studies point towards a relatively small set of global factors associated with resilience, and she suggests that the consistency of these resources in resilience research indicates that fundamental human adaptive systems are at work. These adaptive processes are generally also found to be related to better educational outcomes among the general population. Three broad sets of factors are commonly cited as being implicated in the development of resilience: attributes of the children themselves, aspects of their families, and characteristics of the wider social environment (Luthar, 2006). Students' attitudes towards the subjects they learn, which can be considered attributes of the

children themselves, are considered to be important factors in improving students' outcomes and research (e.g., Duckworth & Yeager, 2015; Lee & Shute, 2010) has shown that, unlike family characteristics and those of the wider community, such non-cognitive attributes are malleable and responsive to change through appropriate schooling and interventions and, thus, merit consideration.

Attitudes Related to Mathematics

Within a STEM context, mathematics can be considered a fundamental discipline as it underpins all other STEM disciplines. It is perceived by many as a difficult subject and promoting positive attitudes towards mathematics is considered important in not only developing mathematical skills but also in increasing uptake of STEM subjects and STEM careers (Kooken et al., 2013; National Numeracy, 2020; The STEM Education Review Group, 2016). Not only have students' subject-specific attitudes about mathematics been found to be positively associated with higher levels of mathematics achievement (Kavanagh et al., 2015; Mullis et al., 2016; OECD, 2013) but students' mathematics self-concept has been found to be a stronger predictor of choosing a STEM career than mathematics performance per se (Goldman & Penner, 2016).

Many studies have also found that students' attitudes towards mathematics vary by student characteristics, such as their gender and home background. For example, on average across all countries that participated in TIMSS in 2015, eighth-grade boys were found to be statistically significantly more likely than girls to report that they like learning mathematics, that they feel confident in learning mathematics, and that they value mathematics. In the case of liking and feeling confident in learning mathematics, these patterns were also evident among fourth-grade students (Perkins et al., 2020). Indeed, girls have been found to rate their own ability in mathematics as lower than that of boys as early as the first year of primary school (Herbert & Stipek, 2005; Jacobs et al., 2002).

Girls have also been found to hold much lower levels of mathematics self-efficacy and self-concept than boys do, even when they perform just as well as boys in mathematics, indicating that "gender disparities in drive, motivation and self-beliefs are more pervasive and more firmly entrenched than gender differences in mathematics performance" (OECD, 2015, p. 68). The OECD report on gender equality in education, which draws on data from PISA, notes that in the majority of PISA countries, the performance gap in favour of boys among the highest-achieving students is no longer significant when mathematics self-beliefs are taken into account. This report suggests that lower levels of self-efficacy and self-concept and greater levels of anxiety related to mathematics may inhibit girls from considering STEM professions as possible career options, especially amongst the strongest performers, and may, in part, account for the under-representation of women in STEM occupations.

Students' attitudes about mathematics have also been found to be associated with students' socioeconomic background in PISA. Students with lower levels of economic, social, and cultural status (ESCS), a proxy measure for socioeconomic status, were more likely to report lower levels of mathematics self-concept than their more socioeconomically advantaged peers and were less likely to report that they intend to take additional mathematics courses after they leave school (OECD, 2016). Furthermore, the relationships between mathematics performance and students' self-beliefs about and motivation to learn mathematics have been found to be stronger among socioeconomically advantaged students than disadvantaged students (OECD, 2013). Such findings highlight the importance of examining not only achievement levels but also other educational outcomes which, like achievement, may be shaped by schooling experiences, among students experiencing educational disadvantage, especially when the strong relationship between students' mathematics self-beliefs and choosing a STEM career is taken into consideration.

The Current Study

The current study aims to further explore the relationship between students' mathematics performance, their subject-specific attitudes, and their socioeconomic status by examining the extent to which academic resilience is predicted by students' reports of how much they feel confident in, like learning, and value mathematics. Considering the recent policy focus on increasing high-level STEM skills among students and promoting diversity and inclusion among STEM courses and careers, the relationship between students' mathematics attitudes and academic resilience in mathematics can be considered a highly relevant topic of study.

Furthermore, given the consistent finding that girls report less positive attitudes towards mathematics when compared to boys in the international literature, the current study also aims to explore the role that a student's gender plays in the relationships between mathematics attitudes and academic resilience, by examining relevant potential interactions.

Data from TIMSS 2019 at eighth grade are analysed to address the research questions of the current study. TIMSS data provide measures of mathematics achievement, students' subject-specific attitudes as well as students' access to home educational resources, which can be considered a proxy for socioeconomic status. Four countries, namely Australia, England, Ireland, and the United States, are involved in the analysis to facilitate cross-cultural comparisons among a small set of countries that share some similarities (i.e., all majority English speaking and economically developed countries), but also some differences (i.e., substantially different population sizes and considerable variation in the ethnic diversity of populations). Importantly, the four countries do not differ statistically significantly from each other in terms of the two dimensions used to define academic resilience, i.e., their mean mathematics scores at eighth grade in

TIMSS 2019 or their mean scores on the *home educational resources* scale (Mullis et al., 2020).

Three research questions underpin the current study:

(1) Are eighth-grade students' ratings of how confident they feel in mathematics, how much they like learning mathematics, and how much they value mathematics predictive of academic resilience in Australia, England, Ireland, and the United States?
(2) Does gender interact with the extent to which students feel confident in mathematics, their liking of learning mathematics, and how much they value mathematics in predicting academic resilience?
(3) Do the relationships between academic resilience and how confident students feel in mathematics, their liking of learning mathematics, and how much they value mathematics, and the interactions between gender and these attitudes vary across Australia, England, Ireland, and the United States?

Methods

TIMSS data were used to answer the research questions of this study. TIMSS is a cross-sectional, curriculum-based assessment of fourth- and eighth-grade students' mathematics and science achievement and has been conducted by the International Association for the Evaluation of Educational Achievement (IEA) every four years since 1995. In this study, TIMSS 2019 data from eighth-grade students in Australia, England, Ireland, and the United States were analysed.

Sampling and Participants

TIMSS selects its nationally representative samples based on a two-stage stratified sampling design. Individual schools constitute the sampling units at the first stage, and intact classes within the sampled schools are the second-stage sampling units (Martin et al., 2020). Table 1 presents the sample sizes for each of the countries that were employed in the analysis. In total, data from 25,241 eighth-grade students were analysed. These students had an average age of 14.2 years, and the samples were almost equally distributed between females and males.

TABLE 1

Student samples involved in the analysis

Country	*n*	*average age*	*% females/males*
Australia	9,060	14.1	49.5/50.5
England	3,365	14.0	53.0/47.0
Ireland	4,118	14.4	48.8/51.2
United States	8,698	14.2	49.4/50.6

Measures

TIMSS uses tests to assess fourth- and eighth-grade students' mathematics and science achievement. The scores for each student across subjects and grades are reported on scales with international centrepoints set at 500 (which are based on the average of all countries that took part in TIMSS 1995), and standard deviations at 100, meaning that most scores fall within the 300–700 band. Rather than a single score, each student in TIMSS is assigned five plausible value estimates of their performance (see the *Analysis* section below for more details on plausible values). Along with data on mathematics and science achievement, TIMSS collects data from students, parents, teachers, and school principals through questionnaires to study the home, community, classroom, and school contexts in which students learn mathematics and science (Martin et al., 2020). For the purposes of this study, student mathematics achievement data and data from the student questionnaire were used to identify the subgroups of academically resilient and vulnerable students in each education system, and to analyse factors that may be associated with academic resilience and academic vulnerability. The variables used are mathematics achievement, scores on the *home educational resources* scale (used as a proxy for students' socioeconomic status), student gender, and the extent to which students feel confident in, like learning, and value mathematics.

Outcome Variable

The main outcome in this study is academic resilience. Relative thresholds are used to define academic resilience and vulnerability in the current study for a number of reasons. First, given the overall similar mean scores in mathematics performance and on the *home educational resources* scale across the four selected countries, the meaning of lower socioeconomic status and positive adjustment can be considered comparable in these contexts. Second, while, conceptually, the categorisation of *few resources* on the *home educational resources* scale in TIMSS offers a valid and meaningful measure of adversity, the proportions of eighth-grade students included in this category in each of the four countries (between 4% and 8%) is considered too small for meaningful statistical analysis when combined with high levels of mathematics

performance. On the other hand, combining the *few resources* and *some resources* categories to measure adversity can be considered meaningless in this context, as between 75% and 83% of students in these countries meet these criteria. In terms of positive adjustment, many policies focused on addressing educational disadvantage aim to improve performance among students experiencing such disadvantage to bring it closer to the national average. For this reason, the median score in each country is considered a reasonable level to describe better-than-expected performance among students at the lower end of the socioeconomic distribution.

For the reasons outlined above, academically resilient students are defined here as those whose TIMSS mathematics scores are at or above the 50th percentile of performance and their socioeconomic status is at or below the 25th percentile of the TIMSS *home educational resources* scale within each selected country. Students in this category can be considered to be experiencing socioeconomic disadvantage relative to their peers, falling within the bottom quartile of socioeconomic status, while also performing at levels in mathematics that are close to the national average and considerably above the average for socioeconomically disadvantaged students in their countries. A comparison group of academically vulnerable students within each of the countries was also identified. Academically vulnerable students are defined here as those whose socioeconomic status is at or below the 25th percentile of the TIMSS *home educational resources* scale within each country (i.e., in the same socioeconomic category as academically resilient students) and whose TIMSS mathematics scores are at or below the 25th percentile of performance, meaning that they are performing at or below the typical level in mathematics for socioeconomically disadvantaged students in their countries, as can be seen in Table 2, which shows the scores at each of the national percentiles of mathematics achievement used for defining academic resilience and academic vulnerability, along with the mean scores for socioeconomically disadvantaged students in each country.

Table 3 presents the mean scores on the *home educational resources* scale and the scores at the 25th percentile on this scale for each country. Based on these scores presented in Tables 2 and 3, an academically resilient student in Australia would have a mathematics score of at least 518.0 points and up to a score of 10.2 on the *home educational resources* scale, while an academically vulnerable student would have a mathematics score of up to 455.8 points and up to a score of 10.2 on the *home educational resources* scale.

TABLE 2

Scores at national percentiles of mathematics achievement used for defining academic resilience and academic vulnerability, and mean mathematics scores of socioeconomically disadvantaged students

Country	*Score at the 25th percentile of mathematics achievement*	*Score at the 50th percentile of mathematics achievement*	*Mean mathematics score of students at or below the 25th percentile of the home educational resources scale*
Australia	455.8	518.0	471.9
England	456.9	516.5	476.0
Ireland	476.3	528.1	476.8
United States	447.6	518.5	459.7

TABLE 3

Mean scores on the home educational resources scale and scores at the national percentiles of this scale used for defining academic resilience and academic vulnerability

Country	*Home educational resources scale*		*Score at the 25th percentile of the home educational resources scale*	
	M	*SE*	*Score*	*SE*
Australia	11.1	0.04	10.2	0.00
England	10.7	0.05	9.6	0.00
Ireland	10.8	0.04	9.6	1.02
United States	10.7	0.04	9.6	0.00

Using the scores outlined in Tables 2 and 3 as cut-off points and in order to use all TIMSS plausible value estimates of student performance in the analysis, each student was assigned the value 0 or 1 based on whether each plausible value estimate was below or above the established cut-off point for academic resilience and academic vulnerability, respectively. As a result, two sets of plausible value estimates were generated: one for academic resilience and one for academic vulnerability. Next, a combined version of these two sets of plausible value estimates was generated whereby only academically resilient and academically vulnerable students were assigned values (1 and 0, respectively), and all other students were coded as missing. These binary variables constituted the outcome variables of the binary logistic regression models and were treated as standard binary outcome variables. The IEA IDB Analyzer (IEA, 2021), which was used for the analysis, appropriately accounted for all plausible values in generating the final estimates.

Predictor Variables

The contribution of student gender, how confident students feel in mathematics, how much they like learning mathematics, and how much they value mathematics in predicting academic resilience was examined. Information about student gender (female/male)[1] and their attitudes was collected through the TIMSS student questionnaire. Students reported their gender, and their level of agreement with a number of statements for each of the attitudes (e.g., *confident in mathematics*: "I learn things quickly in mathematics"; *liking learning mathematics*: "I enjoy learning mathematics"; *value of mathematics*: "I need to do well in mathematics to get the job I want"). Higher scores on the attitudes scales indicate that students feel more confident in mathematics and are more inclined to like learning and value mathematics, respectively. Table 4 presents the Cronbach's alpha (α) reliability coefficients for the attitudes scales and the *home educational resources* scale for each of the countries. All attitudes scales were highly reliable for all countries with Cronbach's alpha reliability coefficients ranging from 0.88 to 0.94. The *home educational resources* scale had lower Cronbach's alpha reliability coefficients for all countries, reflecting the more diverse nature of its components, compared to the ones used for the attitudes scales. However, these reliability coefficients were consistent across all four countries.

TABLE 4

Cronbach's alpha reliability coefficients for the attitudes and home educational resources scales

	Home educational resources	*Confident in mathematics*	*Liking learning mathematics*	*Value of mathematics*
Country	*α*	*α*	*α*	*α*
Australia	0.40	0.90	0.94	0.90
England	0.44	0.88	0.93	0.88
Ireland	0.42	0.90	0.94	0.88
United States	0.45	0.90	0.94	0.89

Analysis

A comprehensive picture of the prevalence of academic resilience and academic vulnerability within each of the countries as well as information about the variables of interest in this study was provided through descriptive statistics, while a series of bivariate analyses provided insights into the relationships among these variables. The contribution of the predictor variables in explaining variance in academic resilience was evaluated through a series of binary logistic regression models, which also

1 In TIMSS 2019, the gender question offered only two response options: *female* and *male*.

involved the examination of potential interactions between student gender and their attitudes (i.e., by including multiplicative interaction terms between gender and each attitudinal variable in the models). The IEA IDB Analyzer (IEA, 2021) was used to calculate all the estimates (means, percentages, standard errors) and perform all the analyses presented in this paper.

The use of the IEA IDB Analyzer ensured that all sampling weights, replicate weights, and plausible values were taken into account in the analysis following relevant guidelines such as those provided by von Davier et al. (2009). Specifically, given its sample-based design, each student in TIMSS does not have the same chance of being selected to participate in the assessment. To control for this, each student is assigned a weight, which needs to be taken into account in the analysis as ignoring weights can lead to biased results that may be influenced by responses coming from certain groups of students (e.g., students attending large schools). The TIMSS sampling design also leads to the clustered nature of its samples, whereby students are nested within classes and classes are nested within schools. This constitutes a threat to the assumption of independence as the observations within a cluster are expected to share common characteristics (Goldstein, 2011). One of the recommended approaches in taking this clustered nature into account, and the approach used in this study, is the use of replicate weights in the analysis of TIMSS data. Also, due to time restrictions, each student participating in TIMSS is administered a subset of test items from the total item pool for each subject, with different groups of students answering different, although overlapping, sets of items. Given this method of assessing students, and the fact that TIMSS is designed to make population-level estimations, rather than accurately describe individual students' proficiencies based on their test scores, the imputation methodology of plausible values is used. Plausible values constitute random draws from the distribution of scores that could be reasonably assigned to each individual (Wu, 2005) and should be used in any analysis of TIMSS data. In TIMSS 2019, five plausible values to estimate student performance in mathematics were generated, and these were taken into account in the analysis in this study.

Results

Overall Mathematics Performance and Attitudes

Table 5 presents students' overall mean mathematics performance and mean scores on the attitudes scales used in the analysis accompanied by their standard errors for each of the countries. As mentioned earlier, the four countries do not have statistically significantly different mean mathematics performance, but as can be seen in the table, Ireland had a slightly higher mean mathematics performance compared to the other three countries. The four countries were also similar in terms of students'

mean scores on the attitudes scales, with means on these scales ranging from 9.4 to 10.3.

TABLE 5

Mean mathematics performance and mean scores on the attitudes scales

	Mathematics achievement		*Confident in mathematics*		*Liking learning mathematics*		*Value of mathematics*	
Country	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Australia	517.3	3.77	9.9	0.05	9.4	0.05	9.7	0.04
England	514.9	5.26	10.1	0.05	9.4	0.04	9.8	0.05
Ireland	523.7	2.65	10.0	0.05	9.4	0.05	9.5	0.04
United States	515.4	4.78	10.3	0.05	9.6	0.05	9.8	0.04

Socioeconomically Disadvantaged Students

Table 6 presents the numbers and percentages of socioeconomically disadvantaged students (defined as those at or below the 25th percentile on the *home educational resources* scale) as well as the gender distribution for this group of students in each of the selected countries. The proportion of students falling below the 25th percentile on the *home educational resources* scale varies somewhat across countries, from 21.3% in the United States to 28.0% in Australia. As noted in Table 1, there was an almost equal percentage of females and males in the overall samples in each of the selected countries; however, there is a somewhat greater percentage of male students among the socioeconomically disadvantaged students in each country, particularly in Australia where 25.2% of female students fall within the socioeconomically disadvantaged subgroup of students compared to 30.7% of male students.

TABLE 6

Student samples at or below the 25th percentile of the home educational resources scale

Country	*n*	*% at or below the 25th percentile of the home educational resources scale*	*% females/males at or below the 25th percentile of the home educational resources scale*
Australia	2,261	28.0	25.2/30.7
England	877	27.2	25.3/29.4
Ireland	960	25.2	23.2/27.1
United States	1,851	21.3	19.6/22.9

Note. Although the percentages of students at or below the 25th percentile of the *home educational resources* scale are close to 25% across the four countries, they do not align exactly with 25%. This discrepancy arises because the *home educational resources* scale is based on ordinal variables, which leads to clusters of students at specific points within the scale distribution. As a result, when using the 25th percentile as a cut-off, some of these clusters may fall just above or just below the threshold, causing slight variations in the percentages.

Prevalence of Academic Resilience and Academic Vulnerability

Based on the criteria described earlier, a group of academically resilient and a group of academically vulnerable students were identified within each of the selected countries (Table 7). The proportions of academically resilient students in the selected countries ranged from 6.2% to 8.5%, with Ireland having the lowest proportion and England having the highest proportion. The proportions of academically vulnerable students in the selected countries ranged from 10.7% in England to 12.8% in the United States. It is noteworthy that although gender differences in the proportions of academically resilient and academically vulnerable students were not statistically significant for three out of the four countries (they were only statistically significant for Australia), consistently higher proportions of male students were identified as academically resilient and academically vulnerable compared to the corresponding proportions for female students.

TABLE 7

Proportions of academically resilient and academically vulnerable students, overall and by gender

Country	*Academically resilient*			*Academically vulnerable*		
	overall (%)	*females (%)*	*males (%)*	*overall (%)*	*females (%)*	*males (%)*
Australia	8.1	7.1	9.0	12.1	10.3	13.9
England	8.5	7.3	10.0	10.7	10.0	11.5
Ireland	6.2	5.4	6.9	12.2	11.2	13.3
United States	7.5	7.2	7.7	12.8	12.3	13.4

Note. Gender differences were statistically significant ($p < .05$) for academically resilient and academically vulnerable students in Australia only.

Attitudes of Academically Resilient and Academically Vulnerable Students

Table 8 presents the means of academically resilient and academically vulnerable students on the three attitudes scales used in the analysis accompanied by their standard errors for each country. Across all four countries, academically resilient students had statistically significantly higher mean scores on the confident in and liking learning mathematics scales compared to their academically vulnerable peers. Academically resilient students also had statistically significantly higher mean scores in the value of mathematics scale compared to academically vulnerable students in Australia, Ireland, and the United States but an exception was noted for England, where the difference was not statistically significant.

TABLE 8

Mean scores of academically resilient and academically vulnerable students on the attitudes scales

	Confident in mathematics				*Liking learning mathematics*				*Value of mathematics*			
	Academically resilient		*Academically vulnerable*		*Academically resilient*		*Academically vulnerable*		*Academically resilient*		*Academically vulnerable*	
Country	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Australia	10.8	0.09	8.8	0.07	9.9	0.11	8.6	0.09	9.8	0.11	9.0	0.12
England	10.8	0.13	9.4	0.11	9.8	0.14	9.1	0.10	9.9	0.14	9.7	0.15
Ireland	10.7	0.17	9.1	0.13	9.9	0.15	8.6	0.11	9.8	0.09	8.9	0.13
United States	11.1	0.12	9.0	0.09	10.1	0.10	8.9	0.09	9.8	0.09	9.4	0.09

Note. All differences between academically resilient and academically vulnerable students were statistically significant ($p < .05$), except for the difference in the value of mathematics scale in England.

Binary Logistic Regression Models

The results of the binary logistic regression models for each of the countries are presented in Table 9. Specifically, Table 9 presents the standardised coefficient (β) accompanied by its standard error, the Wald statistic (i.e., a measure of the precision of the estimated coefficient calculated by dividing the estimated coefficient by its standard error and then squaring the result), the odds ratio (*OR*) (i.e., exponent of the β), and the 95% confidence intervals (*CI*) of the *OR* for each predictor variable. The Nagelkerke R^2 (pseudo-R^2 measure used for logistic regression models expressing the proportion of variance in the outcome explained by the predictor variables) is also provided.

The only variable that was a statistically significant predictor of academic resilience across all four countries was the extent to which students felt confident in mathematics. Eighth-grade students were 2.39, 1.85, 1.68, and 1.87 times more likely to be academically resilient than academically vulnerable with every extra unit in the confident in mathematics scale in Australia, England, Ireland, and the United States, respectively.

Student gender retained its statistical significance within the Australian sample even after students' attitudes were taken into account. Notably, although gender differences in academic resilience were in favour of male students in the bivariate analysis (see Table 7), when these were examined in a multivariate context, they were in favour of female students. This suggests that among male and female students who were identical with regards to their attitudes, female students were more likely to be academically resilient in Australia.

While the latter finding could constitute evidence of a statistically significant interaction between student gender and their attitudes, at least in the case of Australia, when interactions between student gender and student attitudes in predicting academic resilience were examined in the final iteration of the modelling process, none of them were found to be statistically significant, and this finding was consistent across the four countries. This indicates that the relationships of the examined attitudes with academic resilience were not different for male or female students.

TABLE 9

Binary logistic regression models for academic resilience

	β (SE)	*Wald Statistic*	*OR*	*95% CI OR*	
Australia				*lower*	*upper*
Student gender (male)	.51 (.18)*	7.72	1.66	1.06	2.27
Confident in mathematics	.87 (.11)**	62.43	2.39	1.87	2.91
Liking learning mathematics	.03 (.08)	0.16	1.03	0.87	1.20
Value of mathematics	.03 (.06)	0.19	1.03	0.91	1.15
England					
Student gender (male)	.06 (.25)	0.05	1.06	0.53	1.60
Confident in mathematics	.61 (.12)**	26.07	1.85	1.41	2.29
Liking learning mathematics	-.06 (.08)	0.57	0.94	0.80	1.09
Value of mathematics	-.06 (.07)	0.84	0.94	0.81	1.07
Ireland					
Student gender (male)	.05 (.23)	0.05	1.05	0.57	1.54
Confident in mathematics	.52 (.11)**	22.54	1.68	1.31	2.06
Liking learning mathematics	.08 (.08)	1.04	1.09	0.91	1.26
Value of mathematics	.06 (.07)	0.75	1.06	0.92	1.21
United States					
Student gender (male)	.24 (.16)	2.10	1.27	0.86	1.69
Confident in mathematics	.63 (.06)**	121.58	1.87	1.66	2.08
Liking learning mathematics	-.05 (.05)	0.90	0.95	0.86	1.05
Value of mathematics	-.06 (.04)	2.70	0.94	0.87	1.01

Note. Reference category of dummy variables in parentheses. *Nagelkerke* R^2: Australia = 0.39, England = 0.21, Ireland = 0.24, US = 0.29. *OR*: odds ratio; *CI*: confidence intervals. * $p < .01$, ** $p < .001$.

Discussion

The current study aimed to examine the relationships between students' attitudes towards learning mathematics, which have been found to be important predictors of mathematics achievement and career expectations, and students' likelihood to experience academic resilience in the domain. Academic resilience has received much attention in recent years, particularly among international large-scale studies of achievement. While such studies offer rich datasets which draw on nationally representative samples of students, the variation in the socioeconomic profiles and the average achievement levels among the large number of countries involved in these studies can present difficulties in conceptualising comparable definitions of resilience. To address some of these difficulties, and to facilitate cross-cultural comparisons, the current study draws on nationally representative data of eighth-

grade students from TIMSS 2019 for four countries (i.e., Australia, England, Ireland, and the United States), which share some similarities (i.e., predominantly English speaking, economically developed countries) but also differ in a number of important aspects (i.e., population size and ethnic diversity). Importantly, these countries share similar mean scores in mathematics and on the *home educational resources* scale (a proxy measure for socioeconomic status) in TIMSS; two fundamental aspects of the definition of academic resilience used in the current study, and many other studies of this nature, thus facilitating more meaningful comparisons of this concept.

Within each country, two distinct groups of students are described and compared: academically resilient and academically vulnerable students. Both groups of students share a similar socioeconomic profile (i.e., in the bottom quartile of the *home educational resources* scale) but differ in terms of their mathematics performance. Academically resilient students are defined as those who are performing at considerably higher levels in mathematics than would be expected, given their socioeconomic profile (i.e., at or above the national median level in mathematics). Academically vulnerable students, on the other hand, are those whose mathematics performance is closer to the average performance of students with lower socioeconomic profiles (i.e., at the 25th percentile or below).

The percentages of academically resilient students ranged from 6.2% in Ireland to 8.5% in England, while the percentages of academically vulnerable students ranged from 10.7% in England to 12.8% in the United States. Across all four countries, males were more likely than females to be classified as academically resilient and academically vulnerable. Academically resilient students had higher scores on the three attitudinal scales examined (i.e., confident in mathematics, liking learning mathematics, and value of mathematics) when compared to academically vulnerable students, indicating that each of these constructs can play a role in improving students' engagement with and performance in mathematics among underrepresented groups. However, when all scales were examined together, along with student gender, in binary logistic regression models, how confident students felt in mathematics was the only variable that statistically significantly predicted students' odds of being academically resilient as opposed to academically vulnerable across all selected countries. The consistency of this finding across the four countries examined highlights the important association between how confident students feel and their performance in mathematics, particularly among students from lower socioeconomic backgrounds. This may have implications for policies aimed at improving mathematical skills and increasing uptake of STEM subjects and careers, which could be complemented by efforts to foster confidence, particularly for students facing socioeconomic or other barriers.

It should, however, be acknowledged that the current study did not examine the nature of the relationship between students' performance and how confident they feel in mathematics, and the extent to which students feel confident may have a reciprocal relationship with achievement. Among others, Williams and Williams (2010) noted

that there was evidence of a reciprocal determinism of mathematics self-efficacy and achievement in many countries that participated in PISA in 2003. Further research is needed to explore the influence of reciprocal determinism in findings associated with students' subject-specific attitudes and their academic resilience. With this in mind, it may be important for policies aimed at improving engagement in STEM to consider a possible reciprocal relationship between confidence in mathematics and performance in the domain. Indeed, it is likely that strategies that aim to improve confidence through engagement with mathematics problems and concepts, for example, by offering opportunities to engage with familiar mathematics concepts in novel contexts and to explore different solutions to problems, will also strengthen students' mathematical skills. Such approaches may be useful for improving mathematics confidence among academically vulnerable students, for whom skill development is also a key issue.

Lower levels of confidence in learning mathematics among girls have been highlighted as a particular concern across the relevant literature (Herbert & Stipek, 2005; Jacobs et al., 2002; OECD, 2015). However, in the current study, gender was only found to be statistically significantly associated with academic resilience in Australia, and the relationships between students' attitudes and academic resilience did not differ for males and females in any country. This suggests, particularly in Ireland, England, and the United States, that promoting confidence in mathematics among students from lower socioeconomic backgrounds is equally important for both males and females. Nonetheless, the findings in relation to gender differences need to be considered in light of the gender distribution patterns observed across the different subgroups described in this study. While there is an almost even split of male and female students in the overall samples in each country (with perhaps the exception of England where 53% of the sample were female), slightly greater proportions of males were found among the lower socioeconomic group of students (i.e., at or below the 25th percentile of the *home educational resources* scale) in each country. The reasons for this pattern are unclear and need further investigation. However, it should be noted that the *home educational resources* scale in TIMSS is based on students' self-reports and perception of these resources may differ for males and females, leading to different response patterns.

Furthermore, the statistically significant gender differences observed in Australia are noteworthy. While males were more likely than females to be classified as academically resilient in the bivariate analysis, they were about half as likely to be classified as academically resilient when students' attitudes towards mathematics were accounted for. This finding, that the gender difference in academic resilience is reversed when students' attitudes are accounted for, indicates that more negative attitudes towards mathematics may be holding female students from lower socioeconomic backgrounds in Australia back from reaching their potential in the domain. Additionally, males were also statistically significantly more likely to be classified as academically vulnerable in the bivariate analysis, suggesting a wider distribution of performance among males

than females from lower socioeconomic backgrounds in Australia. Thus, improving confidence in mathematics seems particularly important for females, while emphasising skill development may be more relevant for males. However, as noted previously, a reciprocal relationship between confidence and performance may exist, suggesting that skill development and building confidence may work in tandem.

There are some limitations underlying this study that should be acknowledged and taken into account in the interpretation of its findings. Firstly, the non-experimental nature of the data from large-scale studies of achievement that draw on nationally representative samples, such as the ones used in the current study, despite their scalability and transferability, do not allow for the establishment of causal relationships among the examined variables (L. Cohen et al., 2017). Hence, any inferences about the relationships between the examined variables should consider that the relationships may be reciprocal.

Secondly, contextual information used in this study was collected through self-report measures, to which respondents may, intentionally or unintentionally, have provided distorted responses, leading to self-report bias. This may, in turn, have reduced the validity of the inferences from these measures (R. J. Cohen & Swerdlik, 2009). Within this context, potential cultural differences in the way students report their attitudes and family socioeconomic status, which are the main constructs of interest in this study, also need to be considered in the case of cross-country comparisons. It should also be noted that while large-scale studies of achievement, such as TIMSS, measure a multitude of student- and school-level factors, these studies are not designed specifically to measure factors associated with academic resilience and some factors that have been found to be associated with resilience, including supportive relationships with teachers, may not be readily available in such datasets.

Moreover, the methodological challenges in examining academic resilience need to be considered in the interpretation of the findings of the current study. The lack of consensus on what constitutes a successful outcome and a high-risk group with regards to socioeconomic status, and the variability in the measures used to capture these, as well as the use of absolute and relative classification benchmarks, as discussed earlier, can alone be responsible for substantial differences in findings across studies and contexts, when, in reality, they do not exist.

Finally, the pseudo R^2 measure used in this study (as with other pseudo R^2 measures used for logistic regression models) needs to be interpreted with caution as it is likely estimated to be lower than would have been within a linear regression context. Bearing this in mind, it is worth noting that considerable proportions of the variance in academic resilience were explained by the binary logistic regression models, highlighting the important relationship between students' attitudes, gender, and their mathematics performance; however, this varied by country ranging from approximately 21% in England to approximately 39% in Australia. This finding indicates that, not only do

other factors play a role in predicting academic resilience in mathematics among students from lower socioeconomic backgrounds, but that the contribution of these factors differs across the selected countries. The current study is limited to student-level associations with academic resilience and there is scope to expand on this to examine how school- and classroom-level factors, such as school climate, may be related to students' attitudes and how these are associated with academic resilience.

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