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Exploring the Relationship between Students' Attitudes toward Mathematics and Mathematics Achievement in the UAE

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Exploring the Relationship between Students' Attitudes toward Mathematics and Mathematics Achievement in the UAE

استكشاف العلاقة بين اتجاهات الطلاب نحو الرياضيات وتحصيلهم الدراسي في دولة الإمارات العربية المتحدة

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Abstract

This study presents the relationship between students' attitudes toward mathematics and mathematics achievement in the United Arab Emirates (UAE) using the Trends in International Mathematics and Science Study (TIMSS) 2019 data. The target population is grade 8 UAE students, and the sample consisted of 22,334 eighth-grade students. The researcher used the variables "like learning mathematics," "confident in mathematics," and "value mathematics" to represent the independent variable, students' attitudes toward mathematics. The dependent variable, achievement in mathematics, contains four content domains (algebra, geometry, data probability, and numbers) and three cognitive domains (knowing, applying, and reasoning). After conducting regression analysis, the researcher found a positive relationship between students' attitudes toward mathematics and mathematics achievement. Both confidence in mathematics and valuing mathematics significantly predict mathematics achievement, while there is no significant relationship between liking to learn mathematics and mathematics achievement. The study recommends using instructional strategies to improve students’ attitudes toward mathematics, such as constructive feedback and solving real-world problems.

Keywords: attitudes toward mathematics, mathematics achievement, grade 8, TIMSS.

مستخلص البحث

عرضت هذه الدراسة العلاقة بين مواقف الطلاب تجاه الرياضيات وتحصيلهم الدراسي في دولة الإمارات العربية المتحدة، باستخدام بيانات دراسة الاتجاهات الدولية في الرياضيات والعلوم (TIMSS) لعام 2019. استهدفت الدراسة طلاب الصف الثامن في دولة الإمارات، وبلغ عدد طلاب الصف الثامن 22334 طالبًا. تم استخدام ثلاثة متغيرات وهي "حب تعلم الرياضيات" و"الثقة في الرياضيات" و"تقدير الرياضيات" لتمثيل المتغير المستقل، وهو مواقف الطلاب تجاه الرياضيات. أما المتغير التابع، وهو التحصيل الدراسي، فيتضمن أربع مجالات محتوى (الجبر، والهندسة، واحتمالات البيانات، والأعداد) وثلاثة مجالات معرفية (المعرفة، والتطبيق، والاستدلال). بعد إجراء تحليل الانحدار، وجد الباحث علاقة إيجابية بين مواقف الطلاب تجاه الرياضيات وتحصيلهم الدراسي. تشير كل من الثقة في الرياضيات وتقدير الرياضيات إلى تأثير كبير على التحصيل الدراسي، بينما لا توجد علاقة دالة إحصائيًا بين الرغبة في تعلم الرياضيات وتحصيلهم الدراسي. توصي الدراسة باستخدام استراتيجيات تعليمية لتحسين مواقف الطلاب تجاه الرياضيات، مثل التغذية الراجعة البناءة وحل المشكلات الواقعية.

الكلمات المفتاحية: الاتجاهات نحو الرياضيات، التحصيل في الرياضيات، الصف الثامن، TIMSS.

Introduction

Mathematics is an essential subject, and the world cannot be developed without it. Mathematics is an influential subject since it contributes to the cognitive development of students, which may assist them later in their careers (Inkeeree et al., 2017). Mathematics is essential for our daily life and is used in many industries and professions, such as banking, engineering, and natural sciences (Hodaňová & Nocar, 2016). By developing mathematical knowledge and skills, students will be able to handle analytical and statistical tasks in the workplace (Olango, 2015). Mathematics today is a diverse discipline, involving far more than arithmetic and geometry. Scientists use data, measurements, and observations from science to make inferences, deductions, and proofs; and they design mathematical models to understand natural phenomena, human behavior, and social systems (Yadav, 2019). The role of mathematics education is essential because what students learn in mathematics is applied in other fields such as engineering, physics, chemistry, computer science, economy, and other disciplines (Vázquez, 2001; Yadav, 2019).

The UAE's Ministry of Education (MOE) included in its Education 2020 Strategy that its goal is to develop the quality of education in the UAE, including mathematics education. In 2008, the UAE started to participate in international tests such as the Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS), and Progress in International Reading Literacy Study (PIRLS) (UAE Government, 2022). Also, one of the essential targets in 2021 was to be among the top 15 countries in TIMSS (United Arab Emirates Ministry of Education, 2021). UAE eighth-grade students ranked 23rd in mathematics in TIMSS 2011 and 2015 with average scores of 456 and 465, respectively, and 26th in TIMSS 2019 with an average score of 473 (Mullis et al., 2020).

Nor et al. (2020) suggested that mathematics achievement could be affected by three essential factors: liking to learn mathematics, confidence in own mathematics ability, and valuing mathematics. Mata et al. (2012) mentioned that positive attitudes toward mathematics lead to high mathematics achievement in Portuguese students. The Australian Council for Educational Research (ACER, 1999) announced at a conference that liking mathematics learning positively correlates with mathematics achievement. Also, Mullis et al. (2020) reported that there is a strong relationship between liking mathematics and mathematics achievement. They added that understanding the value of learning mathematics could decrease the negative attitudes toward mathematics learning, and that the relationship between valuing mathematics and mathematics achievement is positive and strong. Students' valuing of mathematics is related to their beliefs about how they feel that learning mathematics is important in their lives, and how it could affect their future careers (Mazana et al., 2019). Thomson et al. (2003) found that students with higher confidence in mathematics show higher mathematics achievement, and attitudes toward learning mathematics positively affect mathematics achievement. According to Kadijevich's (2006) study of mathematics attitudes in thirty-three countries, self-confidence is a critical component of the mathematics attitude in countries with higher mathematics achievement.

Many factors could affect students' achievement in mathematics related to the students. One such factor could be students' attitudes toward mathematics, which may influence their mathematics learning and achievement. According to Hwang and Son (2021), attitudes toward mathematics can affect students' engagement, persistence, and achievement in mathematics. Kibrislioglu's (2015), study suggested that students with high mathematics achievement have a high attitude towards learning mathematics. Positive attitudes towards mathematics are associated with enjoying mathematics, understanding its value, and having confidence in it; therefore, they are expected to prioritize studying mathematics and have a high performance in mathematics (Hwang & Son, 2021).

Problem Statement

Mathematics achievement is a critical factor in students' academic success and their preparation for future careers in science, technology, engineering, and mathematics (STEM) fields. Despite its importance, many students struggle with mathematics, and their performance is often linked to their attitudes toward the subject (Organisation for Economic Co-operation and Development [OECD], 2019). Research suggests that students with positive attitudes toward mathematics tend to achieve higher academic outcomes, as their attitudes influence motivation, effort, and engagement in learning activities (Ma & Kishor, 1997). However, the relationship between attitudes and achievement is complex and may vary across cultural and educational contexts.

In the UAE, mathematics education is a national priority due to its alignment with the country's vision of fostering innovation and economic development. Nevertheless, many students in the UAE underperform in mathematics compared to their international peers, as evidenced by results in assessments such as the PISA and TIMSS (Mullis et al., 2020; OECD, 2019). While several factors may contribute to this issue, understanding the role of students' attitudes toward mathematics in shaping their achievement is critical for developing effective interventions.

Existing studies have explored the relationship between attitudes and achievement in various contexts, but limited research focuses on the UAE's unique educational system and cultural environment. Additionally, students' attitudes toward mathematics learning may influence the strength and direction of this relationship. Addressing this research gap is essential for providing evidence-based recommendations to policymakers, educators, and curriculum developers aiming to improve mathematics performance in UAE schools.

Purpose of the Study and Research Questions

This study was conducted to determine the relationship between students' attitudes toward learning mathematics and their achievement in mathematics. Understanding any such relationship could help provide teachers with recommendations and strategies to improve students' attitudes toward mathematics, which could improve students' achievement in mathematics.

The study has three research questions:

1. Do students' attitudes toward learning mathematics predict mathematics content domain achievement for eighth-grade UAE students?
2. Do students' attitudes toward learning mathematics predict mathematics cognitive domain achievement for eighth-grade UAE students?
3. Is there a relationship between students' achievement in mathematics cognitive domains and content domains?

Literature Review

Attitudes towards mathematics

According to Sarmah and Puri (2014, p. 6), "attitude refers to the learned tendency of a person to respond positively or negatively to objects, situations, concepts, or other people." Cohen and Swerdlik (2009) mentioned that an attitude could be described as a disposition to respond to a specific object, group, or institution in a particular manner. Fishbein and Ajzen (1972) state that a person's attitude towards an object is generally determined by their beliefs about that object and its effect. They added that this combination of affective values and others usually forms a person's overall attitude. According to Bakanauskas et al. (2020), there are three elements of attitudes: cognitive (thinking and remembering), affective (feelings and emotions), and conative (behavior and actions). Consequently, as per Çetingöz and Özkal (2009), students' attitudes will have an impact on their interactions with their friends, families, school, and lessons. Also, the attitude of students can change over time (Syyeda, 2016), and a positive attitude improves their learning (Akinsola & Olowojaiye, 2008; Mutai, 2011). Alternatively, a negative attitude hinders effective learning, thus affecting learning outcomes and performance (Joseph, 2013).

An individual's attitude toward mathematics reflects his or her personal views and opinions about the subject. A positive attitude toward mathematics reflects a positive emotional disposition, while a negative attitude toward mathematics reflects a negative one (Zan & Di Martino, 2008). According to Neale (1969), attitudes toward learning mathematics measure whether the student likes or dislikes mathematics, their predisposition to be involved in or avoid mathematics activities, their view of their own abilities at mathematics, and whether mathematics is beneficial or ineffective. Researchers have found that attitude plays a crucial role in determining students' performance in mathematics (Mohamed & Waheed, 2011; Mata et al., 2012; Ngussa & Mbuti, 2017). McLeod (1992) stated that the affective domain in mathematics education is influenced by students' attitudes, beliefs, and feelings. Also, Nicolaidou and Philippou (2003) found that attitudes toward mathematics have a significant positive relationship with mathematics achievement. Mazana et al. (2019) studied the attitude toward mathematics of high school and university students, and they found that it significantly affects mathematics performance. Based on the study by Zakaria and Yusoff (2009), students who achieve their goals have a positive attitude toward mathematics and other problem-solving activities. Also, a positive attitude toward mathematics is generally associated with higher levels of success in mathematics, according to Papanastasiou (2000). Deveci and Aldan-Karademir (2019) found that students' mathematical achievement is significantly related to their attitudes.

Similar to this study, researchers have used three components to measure attitudes toward mathematics: liking mathematics, valuing mathematics, and confidence in mathematics (Hwang & Son, 2021). TIMSS 2019 measures students' attitudes toward learning mathematics in terms of the following factors: their liking to learn mathematics, their confidence in their own mathematics ability, and their perceptions of the value of learning mathematics (Mullis et al., 2020). Self-confidence in mathematics refers to a student's perceptions of self as a mathematics student, including beliefs and expectations about one's ability to learn and perform in mathematics (Adelson & McCoach, 2011). A strong sense of self-confidence empowers students to overcome the fear of failure in mathematics, according to Van der Bergh (2013). When students are self-confident, they can take on mathematical challenges, ultimately improving their academic performance. On the other hand, low self-confidence may prevent students from taking on mathematical challenges (Adelson & McCoach, 2011). Hart & Walker (1993) indicated that students' confidence in mathematics is essential and related to their achievement in mathematics. Liking and disliking learning mathematics are related to mathematics achievement and students' progress in mathematics. Hwang and Son (2021) found that liking learning mathematics had a positive relationship with mathematics achievement. This means that when students like learning mathematics, they are more likely to achieve high mathematics scores. In contrast, Balfaqeeh et al. (2022) found a negative relationship between liking learning mathematics and mathematics performance, which may indicate a gap between what students learn in mathematics and what they are assessed on. A student's valuing of mathematics shows to what extent the student believes in mathematics' usefulness and importance or its applications in other fields (Berger et al, 2020). Values play an important role in mathematical development and in students' personal and social identity. According to Lim and Chapman (2013), mathematics achievement was correlated with self-confidence in mathematics and perceived value of mathematics, and Jurdak (1999) mentioned that values must be embedded in mathematics content. Nor et al (2020) found that 92% of grade 8 Malaysian students value mathematics, and they achieved higher scores than the students who do not value mathematics in TIMSS 2015, and with similar results in Singapore and Thailand. Ethington (1992) found that valuing mathematics learning is positively associated with students' achievement in mathematics.

Mathematics achievement and its importance

Public and private sectors in education have been concerned about students' achievement in mathematics (Appiah et al., 2022). Sa'ad et al. (2014) asserted that it is of great concern to educators that low performance levels in mathematics will negatively affect a country's scientific and technological industries in the near future. According to Zakariya (2022), there has been an increased focus on affect in mathematics education, which has led to researchers proposing a unified theoretical framework for motivation. Wilkins and Ma (2002) reported that educators and politicians have repeatedly emphasized the importance of mathematical learning.

Tella et al. (2008) mentioned that knowledge of mathematics is essential in various fields of study, such as design, software engineering, engineering, development, woodwork, and many others. Shone et al. (2021) mentioned that science and technology are based on arithmetic and logical reasoning, so mathematics is considered a fundamental subject. Quaye and Pomeroy (2021) consider mathematics a core subject at the secondary level. For example, Science and engineering, as well as economics and finance, rely heavily on mathematics to generate critical thinking, problem-solving, and innovation (Casing & Casing, 2024). Also, Guinocor et al. (2020) indicate that mathematics is an established discipline, and it is included in every curriculum worldwide. Various business, technological, and scientific roles require high-level mathematical skills, making mathematics a core subject than others (Quaye & Pomeroy, 2021). Increasing attention has been paid to mathematics as a core academic skill where students need to achieve better results (Vostanis et al., 2021). For success in both academic and professional settings in the fast-paced and technology-fueled 21st century, mathematics proficiency has become increasingly essential (Casing & Casing, 2024).

The National Council of Teachers of Mathematics (NCTM) developed standards to improve mathematics education quality and establish teaching, learning, and assessment goals. These standards are outlined in several publications, including the Principles and Standards for School Mathematics (NCTM, 2000) and the Mathematics Teaching Practices from the NCTM's Principles to Actions (2014). The NCTM (2014) identifies five content areas that are fundamental for students from pre-kindergarten to grade 12: 1) Number and Operations (an understanding of numbers, ways of representing numbers, relationships among numbers, and number systems); 2) Algebra (understanding patterns, relations, functions, and the use of algebraic symbols and models); 3) Geometry (exploring geometric shapes, spatial relationships, and properties); 4) Measurement (understanding and applying techniques, tools, and formulas for measurement); and 5) Data Analysis and Probability (developing skills in data collection, organization, representation, and statistical reasoning). Also, there are five process standards developed by the NCTM that focus on how mathematics is taught and learned: 1) Problem-Solving (engaging students in meaningful and challenging problems); 2) Reasoning and Proof (encouraging logical thinking and justification of solutions); 3) Communication (promoting the expression of mathematical ideas verbally, in writing, and through visual representations); 4) Connections (demonstrating how mathematical concepts connect to other disciplines and real-world applications); and 5) Representation (encouraging students to use multiple forms of representation to deepen understanding).

In TIMSS 2019, the grade 8 mathematics assessment includes Numbers, Algebra, Geometry, and Data and Probability, while the cognitive domains in both grade 4 and 8 assessments contain Knowing, Applying, and Reasoning (Mullis & Martin, 2017). By comparing TIMSS content domains and the NCTM standards, it is evident that they have common areas, namely Numbers, Algebra, Geometry, and Data and Probability. In contrast, Measurement, included in the NCTM standards, is not mentioned in the TIMSS mathematics framework.

Assessment

According to the NCTM (1995), assessment in mathematics is a process by which we obtain evidence about how students know, use, and feel about mathematics and make inferences about those attributes from this evidence for various purposes. There are three types of assessment: diagnostic, formative, and summative. Thompson et al. (2018) mentioned that assessment could be formative or summative according to the purpose of gathering information. If the purpose is the accountability for the performance of individual students or to judge a school or country's quality of education, then the assessment is summative. Summative assessment could be external or internal, such as the end-of-unit test. If the collected information is used to know about students' thinking and understanding, and the teacher plans to use this information for instruction, then the assessment is formative. Students are the center of the assessment process in formative assessment, and they can assess their learning.

Black and Wiliam (2010) defined assessment for learning as the activities that are done by teachers or their students to assess their learning, then the data provided by those assessments can serve as feedback so the teachers can improve future activities for students. Broadfoot et al. (1999) mentioned that assessment for learning is the assessment that promotes learning, and it has the following characteristics: 1) It is integral to a view of teaching and learning; 2) learning goals are shared with the students; 3) it ensures that students know and understand the standards they are striving for; 4) it encourages students self-assessment; 5) it enables pupils to determine their next steps and the way to take them through feedback; 6) it underpins a belief that students can improve; 7) it includes teacher and students reviewing and reflecting on assessment data.

In mathematics classrooms, teachers implement different assessment methods to monitor their students' learning and plan for their instruction. However, policymakers in many countries used large-scale assessments to measure the students' mathematical knowledge level and compare their results with those of other countries (Suurtamm et al., 2016). Large-scale assessments are designed to monitor and regulate mathematics teaching and learning in the school, providing information about what mathematical concepts students must learn in school and what feedback should be given to the students to move their performance forward (Andrade-Molina & Díaz Moreno, 2018). A large-scale assessment is considered a summative assessment since its results are used to judge the country's education and are used at the end of a study period (Thompson et al., 2018). TIMSS and PIRLS are examples of large-scale assessments; they were designed and conducted to provide data about the students’ learning outcomes for all participating countries and compare them with other countries (Stanat & Lüdtke, 2008). In addition to their role in measuring students' assessment in the country, teachers can take items from the large-scale assessments to create cognitive models for their cognitive diagnostic assessment, reducing the teacher's workload and saving time (Sia & Lim, 2018). Also, producing large data sets became a productive avenue for research, and an extensive amount of secondary analysis was performed on the data (Baird et al., 2014). Sometimes, a large-scale assessment can be a challenge for teachers. For example, it is not easy to connect between large-scale assessments such as PISA and classroom assessments made by the teacher. Moreover, assessment practices in the classroom are affected by large-scale assessment (Suurtamm et al., 2016).

Method

This study applied a quantitative research method to explore the relationship between eighth-grade students' attitudes toward mathematics and their mathematics achievement in the UAE. The research method and data collection procedures were based on the TIMSS 2019 framework and data, employing secondary data analysis and regression techniques.

Procedures of data collection

To collect the data, the researcher first used the International Association for the Evaluation of Educational Achievement (IEA) website to download the needed Statistical Package for the Social Sciences (SPSS) data files. After downloading the files, the items included in the study were kept, and others were excluded, i.e, the outcome, predictors, mathematics achievement, and gender variables were kept while the unneeded variables were removed from the SPSS file. The descriptive statistics were generated using IBM SPSS Statistics version 25 to find each variable's number of respondents, mean, and standard deviation. The numbers of respondents in each item were compared, and it was found that some variables had missing data. However, these missing data (approximately 3% of the sample) are unlikely to affect the results.

Measures

Outcome measures

There are seven outcome measures in this study, and each of them is a domain of mathematics assessment in TIMSS. The first four measures are the content domains:

Number: The target percentage of the number domain is 30% of the assessment. This domain consists of integers (10%), fractions and decimals (10%), and ratios, proportions, and percents (10%) (Mullis & Martin, 2017).

Algebra: The target percentage of the algebra domain is 30% of the assessment. Expressions, operations, and equations contribute 20%, and relationships and functions contribute 10% (Mullis & Martin, 2017).

Geometry: The target percentage of the geometry domain is 20% of the assessment (Mullis & Martin, 2017).

Data and Probability: The target percentage of the data and probability domain is twenty percent of the assessment. This domain consists of data (15%) and probability (5%) (Mullis & Martin, 2017).

The other three measures are the cognitive domains:

Knowing: The target percentage of the knowing domain is 35% of the assessment. This domain contains facts, concepts, and procedures needed to solve mathematical problems (Mullis & Martin, 2017).

Applying: The target percentage of the applying domain is 40% of the assessment. This domain assesses students' ability to apply facts and concepts in solving mathematical problems (Mullis & Martin, 2017).

Reasoning: The target percentage of the reasoning domain is 25% of the assessment. This domain involves solving non-routine problems in unfamiliar circumstances, complex situations, and multistep problems (Mullis & Martin, 2017).

Predictors

As reported in TIMSS reports, attitudes toward learning mathematics are measured using three variables: liking learning mathematics, students' confidence in mathematics, and valuing learning mathematics (Mullis et al., 2020). Each scale is measured using a number of positive and negative statements. For any positive statement, “agree a lot” is coded by 1, “agree little” is coded by 2, “disagree little” is coded by 3, and “disagree a lot is coded by 4. In contrast, the negative sub-scales are coded reversely.

Liking Learning Mathematics

This is a four-point Likert scale. This scale measures students' attitudes toward mathematics and mathematics learning, and it is measured by nine items such as: "I enjoy learning mathematics," "I learn many interesting things in mathematics," and "I like to solve mathematics problems." Students can respond to the statements by choosing "agree a lot" to indicate very much like learning mathematics, "agree a little" and "disagree a little" to indicate somewhat like learning mathematics, or "disagree a lot" to indicate they do not like learning mathematics (Mullis et al. 2020). All sub-scales for liking learning mathematics statements are positive, except “I wish I did not have to study mathematics” and “Mathematics is boring” are negative. The mean value for each variable is above 1.90 and below 2.90 for all variables. The two highest mean values are for the negative sub-scales (see Table 1). This might mean that most respondents choose to agree a little and disagree a little. The reliability coefficient of Cronbach's alpha for the UAE is 0.92 (Yin & Fishbein, 2020). Cronbach's alpha for the "like learning mathematics" scale with nine items is 0.73.

Students Confident in Mathematics

This scale shows students' perceptions of their mathematics ability; it is measured by nine statements, such as: "I usually do well in mathematics," "Mathematics is not one of my strengths," and "Mathematics makes me confused." The scale is a four-point Likert scale, "agree a lot" indicates very confident in mathematics, "agree a little" and "disagree a little" indicate somewhat confident in mathematics, and "disagree a lot" indicates not confident in mathematics (Mullis et al. 2020). In this scale, five sub-scales are negative, while the other four are positive. The mean values for all sub-scales are above 2.00, except for the first sub-scale, which is 1.80. This means that for all sub-scales, the majority of students agree little or disagree little with the statements (see Table 1). The reliability coefficient of Cronbach's alpha for the UAE is 0.84 (Yin & Fishbein, 2020). Cronbach's alpha for the "confidence in mathematics" scale with six items is 0.73.

Valuing Mathematics

Students’ value of mathematics shows to what extent the student believes in mathematics’s usefulness and importance, or its applications in other fields (Berger et al., 2020). Valuing mathematics is measured by nine statements, such as: "I need mathematics to learn other school subjects," I would like a job that involves using mathematics," and "It is important to do well in mathematics." This scale is a for-points Likert scale, "agree on a lot" indicates student strongly value mathematics, "agree on a little" and "disagree a little" indicate somewhat valuing mathematics, and "disagree a lot" means do not value mathematics (Mullis et al. 2020). In value learning mathematics, all nine sub-scales are positive. All sub-scales have a mean value less than 2.00, except for the sub-scale “I would like a job that involves using mathematics,” the mean is 2.30 (see Table 1). This means that the majority of students value mathematics a lot or value mathematics little. The reliability coefficient of Cronbach's alpha for the UAE is 0.90 (Yin & Fishbein, 2020). Cronbach's alpha for the "value mathematics" scale with nine items is 0.90.

Table 1
Means values for each sub-scale

Sub-scales	Mean
Like learning mathematics	
I enjoy learning mathematics	1.97
I wish I did not have to study mathematics [R]	2.81
Mathematics is boring [R]	2.64
I learn many interesting things in mathematics	1.94

Sub-scales	Mean
I like mathematics	2.07
I like any schoolwork that involves numbers	2.23
I like to solve mathematics problems	2.18
I look forward to mathematics lessons	2.26
Mathematics is one of my favorite subjects	2.32
Confident in mathematics	
I usually do well in mathematics	1.80
Mathematics is more difficult for me than for many of my classmates [R]	2.67
Mathematics is not one of my strengths [R]	2.57
I learn things quickly in mathematics	2.01
Mathematics makes me nervous [R]	2.57
I am good at working out difficult mathematics problems	2.22
My teacher tells me I am good at mathematics	2.03
Mathematics is harder for me than any other subject [R]	2.64
Mathematics makes me confused [R]	2.57
Value mathematics	
I think learning mathematics will help me in my daily life	1.71
I need mathematics to learn other school subjects	1.89
I need to do well in mathematics to get into the university of my choice	1.58
I need to do well in mathematics to get the job I want	1.71
I would like a job that involves using mathematics	2.30
It is important to learn about mathematics to get ahead in the world	1.73
Learning mathematics will give me more job opportunities when I am an adult	1.66
My parents think that it is important that I do well in mathematics	1.47
It is important to do well in mathematics	1.50

Population and sampling

The population is all eighth-grade UAE students who enrolled in private or public schools. However, the population size was not mentioned in the TIMSS database. Sampling in TIMSS is implemented in two stages, using a random sampling design to ensure the validity and reliability of the data. In the first stage, schools were sampled within the country, and in the second stage, students were sampled within each school (LaRoche et al., 2020). The sample size of this study is 22,334 eighth-grade students from 623 schools across the UAE. The average age of the respondents is 13.7 years. The girls comprise 49.1% of the sample, and the boys comprise 50.9%.

To analyze the data, the researcher used IBM SPSS Statistics version 25 to run a linear regression analysis to investigate the relationship between the predictors and the outcomes. In addition, the Pearson correlation coefficients between the content and cognitive domains were calculated using SPSS.

Data analysis procedures

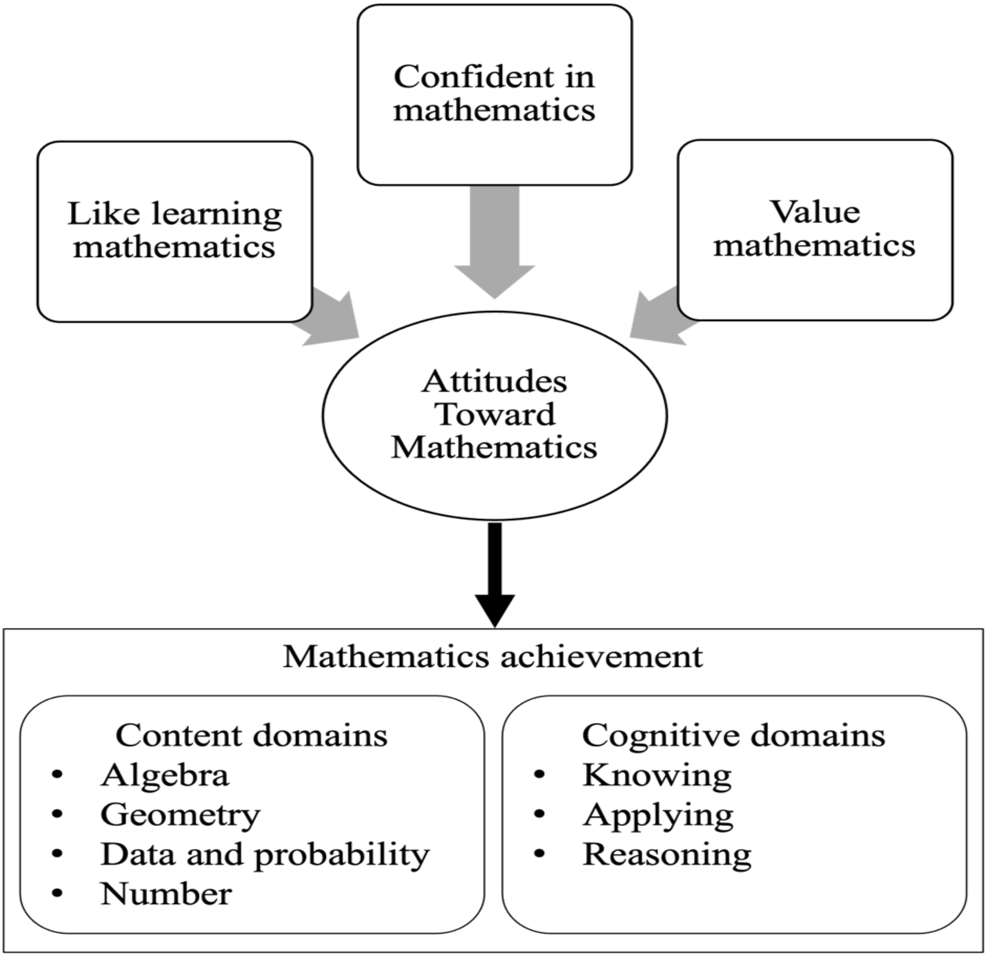
To answer the first and second research questions, this study employed a quantitative method using regression analysis with three models. The first model only has one independent variable, "like learning mathematics," to examine its effect on each content and cognitive domain. The researcher added the variable "confident in mathematics" in the second model to analyze the combined effect of attitudes on student achievement in each content and cognitive domain. In the third model, the variable "confident in mathematics" was added to the independent variables to assess the effect of the three predictors on achievement in the content and cognitive domains. The questionnaires included mathematics assessments in the content and cognitive domains and students' attitudes toward learning mathematics.

To answer the third research question, the study used the correlation between mathematics content and cognitive domains in TIMSS 2019 to find out if there is a significant relationship between mathematics cognitive and content domains. In addition, the adjusted R-squared values were calculated in each model to determine if the independent variables explained the variation in each dependent variable for each model.

Figure 1 represents the model of the study and the relationship between the predictors and the outcome measures.

Figure 1

Relationship between predictors and outcome measures



Results

Descriptive statistics

The descriptive statistics show that the highest average for the content domains was in algebra (*M* = 480.11, *SD* = 102.09), and the lowest average was in data and probability (*M* = 445.30, *SD* = 114.80), followed by geometry (*M* = 456.25, *SD* = 108.78) and numbers (*M* = 468.63, *SD* = 99.24).

The highest average was for reasoning (M = 474.62, SD = 96.29) for the cognitive domains, followed by knowing (M = 473.31, SD = 103.11); and the lowest was for the applying domain (M = 460.58, SD = 103.29).

The mean values for the predictors are close to each other; valuing mathematics is the lowest (M = 10.05, SD = 2.16), followed by liking to learn mathematics (M = 10.18, SD = 1.94), and confidence in mathematics is the highest (M = 10.38, SD = 2.02).

Correlation

The correlation between cognitive and content domains of mathematics is significant, positive, and strong (above 0.85). The highest correlation is between applying and reasoning (r = 0.97, $p < 0.001$), and the lowest is between knowing and both data and probability and geometry (r = 0.86, $p < 0.001$). Mathematics domains are all highly related, and students can master most of the mathematics domains. The correlation between liking learning mathematics and mathematics achievement in all domains is significant and positive but weak; the highest correlation was with both algebra and knowing (r = 0.22, $p < 0.001$). The correlation between confidence in mathematics and achievement in all mathematics domains is positive and moderate. The highest correlation was with knowing (r = 0.31, $p < 0.001$), and the lowest was with data and probability (r = 0.25, $p < 0.001$). The correlation between valuing mathematics and mathematics achievement for all domains is a weak positive correlation since it is less than 0.2 (see Table 2).

The correlation between the independent variables is significant and positive; for confidence in mathematics and value mathematics, the correlation is moderate, but the correlation between liking to learn mathematics and confidence in mathematics (r = 0.65, $p < 0.001$) and valuing mathematics (r = 0.58, $p < 0.001$) is strong, which may cause problems of multicollinearity in the model (see Table 2).

Table 2

Correlation between variables in the model

Variables	Algebra	D & P	Geometry	Number	Knowing	Applying	Reasoning	Like	Confident	Value
Algebra	-									
D & P	0.90**	-								
Geometry	0.92**	0.91**	-							
Number	0.94**	0.92**	0.93**	-						
Knowing	0.87**	0.86**	0.86**	0.88**	-					
Applying	0.88**	0.88**	0.87**	0.89**	0.96**	-				
Reasoning	0.87**	0.86**	0.87**	0.88**	0.95**	0.97**	-			
LIKE	0.22**	0.15**	0.21**	0.19**	0.22**	0.18**	0.19**	-		
CONF	0.29**	0.25**	0.29**	0.29**	0.31**	0.28**	0.27**	0.65**	-	
VALUE	0.17**	0.13**	0.18**	0.15**	0.18**	0.15**	0.16**	0.58**	0.41**	-

Note. D & P: data and probability. LIKE: liking to learn mathematics. CONF: confidence in mathematics. VALUE: valuing mathematics. ***p* < .001.

Regression analysis

Content Domain

Model 1

The first model regression analysis shows that liking learning mathematics has a positive relationship with student's achievement in algebra (B = 11.31, p < 0.001), data and probability (B=8.66, p < .001) is the lowest, geometry (B=11.82, p < .001) is the highest, and numbers (B = 9.73, p < .001). The positive values of regression coefficients mean that when liking mathematics learning increases, student achievement increases.

The values of R^2 show that the predictor liking to learn mathematics explains 5% of students' achievement in algebra, 2% of students' achievement in data and probability, and 4% of students’ achievement in both geometry and numbers domains (see Table 3).

Model 2

After adding confidence in the mathematics variable in the second model, the regression coefficients for liking learning mathematics changed.

Table 3 shows that there is a significant positive relationship between liking to learn mathematics and students' achievement in algebra (*B*=2.61, $p < .001$) and geometry (*B*=2.34, $p < .001$), suggesting that as liking to learn mathematics increases, students' achievements in algebra and geometry domains increase. For data and probability, the regression coefficient is negative (*B*=-1.39, $p < .01$), which means that when "like learning mathematics" increases, achievement in data and probability decreases. There is no significant relationship between "like learning mathematics" and achievement in the number domain.

Confidence in mathematics has significant positive relationships with all content domains. The regression coefficient for students' achievement in algebra is the lowest (*B*=12.93, $p < .001$), data and probability are the highest (*B*=14.93, $p < .001$), geometry (*B*=14.08, $p < .001$), and numbers (*B*=13.90, $p < .001$).

The values of R^2 show that the independent variables explain 8% of the variance in students' achievement in each of the algebra, geometry, and number domains and 6% of students' achievement in the data and probability domains.

Model 3

In the third model, after adding "value mathematics", the regression analysis shows a positive relationship between attitudes toward mathematics learning and students' achievement in mathematics. Like the learning mathematics scale, there is no significant relationship with students' achievement in algebra, geometry, and numbers, while it has a weak negative relationship with the data and probability domain (*B*=-3.20, $p < .001$).

Confidence in mathematics has a significant positive relationship with all outcomes. The regression coefficients for algebra are the lowest (*B*=12.75, $p < .001$), data and probability is the highest (*B*=14.73, $p < .001$), geometry (*B*=13.85, $p < .001$), and numbers (*B*=13.75, $p < .001$) are almost similar, which suggests that when confidence in mathematics increases, achievement in mathematics will increase.

Valuing mathematics also has a positive relationship with all outcomes ($p < .001$). The regression coefficients for algebra (B=2.69, $p < .001$), data and probability (B=2.99, $p < .001$), geometry is the highest (B=3.38, $p < .001$), and numbers is the lowest (B=1.80, $p < .001$) suggest that an increase in value mathematics increases achievement in mathematics. (see Table 3).

The value of R^2 for algebra suggests that the independent variables explain 9% of the variation in students' achievement in the algebra domain in the model. 6% of the variation in students' achievement in the data and probability domain is explained by the independent variables in the model. The independent variables explain 9% of the variation in students' achievement in the geometry domain in the model. For numbers, 8% of the variation in students' achievement in the numbers domain is explained by the independent variables in the model (see Table 3).

Table 3

Attitudes Toward Learning Mathematics Predicting Mathematics Achievement (content domains)

Variables	Algebra		Data & prob		Geometry		Numbers	
	B	SE	*B*	SE	*B*	SE	*B*	SE
Model 1								
LIKE	11.31**	0.35	8.66**	0.40	11.82**	0.37	9.73**	0.34
R^2	0.05		0.02		0.04		0.04	
Model 2								
LIKE	2.61**	0.45	-1.39*	0.51	2.34**	0.48	0.37	0.44
CONF	12.93**	0.43	14.93**	0.49	14.08**	0.46	13.90**	0.42
R^2	0.08		0.06		0.08		0.08	
Model 3								
LIKE	0.98	0.50	-3.20**	0.57	0.30	0.54	-0.72	0.49
CONF	12.75**	0.43	14.73**	0.49	13.85**	0.46	13.78**	0.42
VALUE	2.69**	0.38	2.99**	0.43	3.38**	0.40	1.80**	0.37
R^2	0.09		0.06		0.09		0.08	

Note. LIKE: liking to learn mathematics. CONF: confidence in mathematics. VALUE: valuing mathematics. Prob: probability **$p < .001$. *$p < .01$

Cognitive Domains

Model 1

Liking to learn mathematics has a significant positive relationship with students' achievement in mathematics in all cognitive domains. The regression coefficients for knowing (B=11.53, $p < .001$), applying (B=9.78, $p < .001$), and reasoning (B=9.46, $p < .001$) indicate that when liking learning mathematics increases, students' achievement in mathematics cognitive domains will increase.

R^2 values suggest that the scale liking to learn mathematics" explains 5%, 3%, and 4% of the variation in students' knowledge, applying, and reasoning achievement, respectively (see Table 4).

Model 2

In the second model, the regression analysis shows that there is a significant positive relationship between liking to learn mathematics and students' achievement in the knowing domain (B=1.42, $p < .01$) and the reasoning domain (B=1.23, $p < .01$), so when like learning mathematics increases, students scores in knowing and reasoning domains will increase. Liking to learn mathematics has no significant relationship with students' achievement in the applying domain.

Confidence in mathematics has a significant positive relationship with students' achievement in all cognitive domains. The regression coefficients for the knowing domain (B=15.01, $p < .001$), the applying domain (B=13.67, $p < .001$), and the reasoning domain (B=12.22, $p < .001$) suggest that when "like learning mathematics" increases, students’ scores in cognitive domains will increase.

The R^2 values show that the model's independent variables explain 10% of the variance in the knowing domain, 8% of the variance in the applying domain, and 7% of the variance in the reasoning domain.

المجلة الدولية للأبحاث التربوية - جامعة الإمارات العربية المتحدة
المجلد (49) العدد (2) مايو 2025

Model 3

The relationship between attitudes toward learning mathematics and mathematics achievement in the cognitive domains is similar to that between attitudes toward learning mathematics and content domains. Liking to learn mathematics scale has no significant relationship with students' achievement in any cognitive domain.

Confidence in mathematics has a significant positive relationship with all cognitive domains. The regression coefficients for the knowing domain (*B*=14.81, $p < .001$), the applying domain (*B*=13.52, $p < .001$), and the reasoning domain (*B*=12.04, $p < .001$) indicate that when confidence in mathematics increases, students' achievement in the cognitive domains will increase.

Also, valuing mathematics has a significant positive relationship with students' achievement in all cognitive domains. The regression coefficients for the knowing domain (*B*=3.02, $p < .001$), the applying domain (*B*=2.30, $p < .001$), and the reasoning domain (*B*=2.80, $p < .001$) indicate that if the valuing mathematics scale increases, then students' achievement in the cognitive domains will increase.

The values of R^2 show that the independent variables in the model explain 10% of the variation in students' achievement in the knowing domain, 8% of the variation in students' achievement in the applying domain, and 8% of the variation in students' achievement in reasoning domain is (see Table 4).

Table 4
Attitudes Toward Learning Mathematics Predicting Mathematics Achievement (cognitive domains).

Variables	Knowing		Applying		Reasoning	
	B	SE	*B*	SE	*B*	SE
Model 1						
LIKE	11.53**	0.35	9.78**	0.36	9.46**	0.33
R^2	0.05		0.03		0.04	

Variables	Knowing		Applying		Reasoning	
	B	SE	*B*	SE	*B*	SE
Model 2						
LIKE	1.42*	0.45	0.57	0.46	1.23*	0.43
CONF	15.01**	0.43	13.67**	0.44	12.22**	0.41
R^2	0.10		0.08		0.07	
Model 3						
LIKE	-0.40	0.50	-0.81	0.51	-0.46	0.48
CONF	14.81**	0.43	13.52**	0.44	12.04**	0.41
VALUE	3.02**	0.37	2.30**	0.38	2.80**	0.36
R^2	0.10		0.08		0.08	

Note. LIKE: Liking to learn mathematics. CONF: Confidence in mathematics. VALUE: Valuing mathematics. $^{**}p < .001$. $^{*}p < .01$

Discussion and Conclusion

By comparing the models in the regression analysis, we can conclude that the third model is the best because it has two independent variables from three with a significant effect on the dependent variables rather than one variable in the first and second models.

Unexpectedly, the results show no significant relationship between a liking to learn mathematics and mathematics achievement in both content and cognitive domains. From these results, we can conclude that a liking to learn mathematics is not enough to achieve high scores in mathematics. Students may like mathematics because they enjoy mathematics lessons or because of many factors related to the teacher or the classroom environment. This is inconsistent with Balfaqeeh et al. (2022), which indicates a negative relationship between liking learning mathematics and mathematics performance. Also, it is inconsistent with Hwang and Son's (2021) findings, which found a positive relationship between liking mathematics and mathematics achievement.

Valuing mathematics has a low positive effect on achievement in mathematics, which means increasing the perceived value of learning mathematics in students may help their achievement in mathematics slightly. This result confirms Ethington's (1992) finding, which indicated that there is a positive relationship between valuing mathematics and mathematics achievement (*B* = 0.12, *p* <0.01) for boys; however, in the current study, valuing mathematics has a stronger effect on mathematics achievement than in Ethington's study. This means that when valuing mathematics increases by 1, mathematics achievement is expected to increase by 12.

Confidence in mathematics has the highest effect on students' achievement in mathematics. When students have high confidence in their ability and skills in mathematics, this will reflect in their high achievement in mathematics. This result is in line with Hart and Walker's (1993) finding, which mentioned that students' confidence in mathematics is essential and related to their achievement in mathematics. Teachers should find strategies and methods to help their students improve their confidence in mathematics.

Content domains are vital since they are the central resource where students can build their mathematical knowledge and develop their learning (Dossey, 1992). Students' cognitive abilities, such as knowing, understanding, and reasoning, affect their performance in content domains like algebra, geometry, data, and measurement (Cato, 2020). Therefore, teachers should include different cognitive domains in their instruction, classroom activities, and assessment to improve their students' cognitive abilities.

The study revealed that there is a strong positive relationship between mathematics achievement in cognitive and content domains. This indicates that students with high cognitive abilities will likely obtain high scores in mathematics content domains. No previous research has studied the relationship between the mathematics cognitive domains. However, Pogoy et al. (2015) revealed that students' performance in mathematics has a moderate to strong relationship with both cognitive and content domains.

Recommendations and implications

Since students' mathematics achievement is related to their confidence in mathematics, mathematics teachers could consider using strategies to improve their students' confidence in mathematics. For example, Rustanuarsi (2019) found that using the think-pair-share strategy in mathematics lessons increases students' confidence in mathematics. Also, teachers can use constructive feedback to improve students' confidence in mathematics learning (Jung et al., 2015). Moreover, teachers should incorporate cognitive and content domains into the teaching process to ensure the development of cognitive and content domains. While covering essential content areas such as algebra, geometry, and measurement, teachers should design lessons that incorporate cognitive processes: knowledge, understanding, and reasoning. In order to improve both domains of mathematics, teachers and curriculum planners should use a variety of problems and assessments that challenge students' reasoning capabilities.

Teachers can also create an environment that fosters valuing mathematics in the classroom. For instance, giving students the opportunity to solve real-world problems using mathematics will highlight the value of mathematics learning. Moreover, it is essential to increase motivation and value for mathematics and recognize and celebrate student achievements, no matter how small. Also, teachers should receive training to learn how to teach mathematics cognitively and in content domains, utilizing strategies that can improve students' attitudes toward learning mathematics and improve students' engagement in mathematics.

Limitations and further research

The first limitation of this study is the problem of multicollinearity; Farrar and Glauber (1976) mentioned that multicollinearity causes variance for the intercorrelated independent variables, and this is why the significant effect of liking learning mathematics is missed in the second and third models. The second limitation is the time factor. Since the independent and dependent variables were measured simultaneously, evidence of the causal relationship between them is absent (Solem, 2015). The third limitation is that since the independent variables are measured using surveys, social desirability bias could threaten the study's validity. For example, some students want to show that they like or value learning mathematics even if they do not. Also, self-reported data could be a reason for inappropriate correlation and association between the variables in the model (King & Burner, 2000). Finally, this study's results may not be generalized since they relate to students from the UAE with different cultural characteristics.

In a further study, the researcher will investigate variables related to students' achievement, such as gender, socioeconomic status, behavior, and other variables related to school, teacher, and parent academic levels.

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