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Factors influencing the attitude of undergraduate students towards mathematical reasoning: An approach using AMOS-structural equation modelling

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Abstract

Studies on mathematics achievement status show that mathematical reasoning in Malaysian education is critical, especially among university students. Students' attitude toward mathematics is affected by affective, behavioural and cognitive factors. The present research investigated the connections between these variables and their impact on individuals' attitudes towards mathematics reasoning. A statistical analysis method, namely, AMOS-Structural Equation Modelling, was used in this approach. The survey method involving 378 university education students around the Klang Valley was selected using a proportional stratified random sampling technique. The respondents must complete the mathematics reasoning assessment and answer the questionnaire consisting of three components: affective, behavioural and cognitive towards mathematics reasoning. AMOS-Structural Equation Modelling (AMOS-SEM) was applied using data obtained from questionnaires. Results demonstrated that the measurement models showed acceptable validity and reliability by removing some indications from the scales. The findings illustrate the relationship between students' attitudes and mathematical reasoning. Moreover, attitude is significantly related to students' mathematical reasoning performance in university education. The next study's recommendation involves an interview session to explore more findings that might impact their learning in mathematical reasoning.

Keywords:
AMOS-SEM, Attitude towards mathematics, Mathematics reasoning, Undergraduate

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1. INTRODUCTION

The urgency of research in attitude and mathematical reasoning among university students is underscored by the significant impact that students' attitudes towards mathematics have on their academic performance and future career choices. Moreover, the prevalence of mathematics anxiety among students is a pressing concern that necessitates further investigation. Research indicates that students with negative attitudes towards mathematics often experience higher levels of anxiety, which can adversely affect their performance and lead to avoidance of mathematics-intensive courses (Núñez-Peña et al., 2013). This anxiety is not only detrimental to immediate academic outcomes but can also influence long-term career trajectories, as students may shy away from fields that require strong mathematical skills. Consequently, understanding the factors that contribute to negative attitudes and anxiety is essential for developing effective interventions that can enhance students' confidence and performance in mathematics (Shakya & Maharjan, 2023; Tak et al., 2022).

Various factors can influence the negative attitude towards mathematics amongst university students. Research has shown that students' attitudes towards mathematics considerable impact their learning achievement (Rozgonjuk et al., 2020). A negative attitude toward mathematics can lead to difficulties in information processing and problem solving, which may be compounded by feelings of panic, depression and insecurity (Radmehr et al., 2020). Studies have also demonstrated that math anxiety and negative attitudes towards mathematics can impact university students' success in mathematical courses (Zanabazar et al., 2023).

Weak mathematical reasoning skills amongst university students can significantly affect their academic performance. Studies have shown that students with learning difficulties in mathematics often exhibit specific weaknesses in mathematical reasoning (Ragudo, 2024). This issue is further compounded by a lack of confidence in mathematics and low quantitative reasoning ability, particularly in subjects, such as statistics (Din, 2020). Research has indicated that many university students struggle with mathematical reasoning, scoring low on tests that measure this skill (Singh et al., 2020). This lack of foundational mathematical skills can hinder students' success in higher education. In addition, students pursuing careers in mathematics education have been reported to struggle with communication skills and developing mathematical connections, indicating weaknesses in their mathematical reasoning abilities (Cresswell & Speelman, 2020).

Gap analysis in attitude and mathematical reasoning among university students is a critical area of research that seeks to identify discrepancies between students' expectations and their actual experiences in mathematics education. This studies analysis is essential for understanding how students perceive their mathematical reasoning abilities and the instructional methods employed in their courses, which can significantly influence their academic performance and attitudes towards mathematics. Similarly, the importance-satisfaction gap analysis has been adapted in various studies to assess the quality of educational experiences, highlighting the need for alignment between student expectations and institutional offerings (Ching et al., 2021).

Moreover, the purpose of research in attitude and mathematical reasoning among university students is multifaceted, aiming to improve student learning outcomes, and foster a positive learning environment. Understanding students' attitudes towards mathematics reasoning is crucial as these attitudes significantly influence their engagement, persistence, and overall achievement in the subject. This correlation underscores the need for educators to assess and address students' attitudes to cultivate a more conducive learning atmosphere. By focusing on these areas, researchers aim to create a more supportive and effective learning environment that fosters positive attitudes and improves mathematical reasoning skills among students.

1.1. Mathematics Reasoning

Mathematics education at the university level encompasses various dimensions of critical thinking, algebraic reasoning, geometry and fractions. Critical thinking is crucial in mathematical problem-solving, requiring students to remember concepts, recognise relationships and draw original conclusions swiftly and wisely (Marhami et al., 2020). This ability to think critically has been found to enhance the learning of mathematics reasoning amongst university students (Campos-Fabian, 2020). Moreover, mathematical reasoning, critical thinking and mathematical literacy skills are essential for mastering mathematics at the university level (Haeruman et al., 2024).

Understanding fractions, ratios and proportionality is fundamental in mathematics education. Teaching approaches incorporating frameworks and computer software to support trial-and-error methods have improved students' comprehension of these mathematical concepts (Livy & Herbert, 2013). In addition, the ability to think mathematically is vital for academic success and crucial for developing algebraic reasoning and critical thinking habits that contribute to sustainable development in learning (Satiti & Wulandari, 2021). Furthermore, fostering mathematical critical thinking skills through problem-centred learning approaches can significantly impact students' mathematical comprehension and algebraic learning experience. University students must develop strong critical thinking skills to navigate mathematical challenges effectively (Boonsathirakul & Kerdsomboon, 2021).

Algebraic reasoning involves the quantitative manipulation of data, progressing from basic quantitative reasoning to advanced reasoning in areas, such as analytic geometry, calculus and differential equations (Eriksson & Sumpter, 2021). Students engage in algebraic reasoning by identifying patterns in mathematical problems, establishing relationships between quantities and making generalisations through formal representations and symbolic manipulation (Ahmadah, 2020). This process aids in developing students' ability to solve algebra problems, thereby enhancing their problem-solving skills (Indraswari et al., 2018).

Geometry is essential for students to comprehend mathematics' axiomatic structure and acquire reasoning skills (Ramazan & Seher, 2015). Learning geometry can significantly enhance students' mathematical abilities, particularly reasoning and spatial skills (Risnawati et al., 2019). Integrating learning theories and discovery learning in geometry has improved students' reasoning, mathematical communication and self-confidence. Moreover, students' perseverance influences their mathematical reasoning, especially in proving geometric theorems (Aisyah et al., 2023).

In summary, the synthesis of these references underscores the importance of critical thinking, algebraic reasoning, geometry and fraction comprehension in the mathematics education of university students. Students can enhance their problem-solving abilities, deepen their understanding of mathematical concepts and ultimately excel academically by honing these skills.

1.2. Attitude towards mathematics

Attitudes towards mathematics amongst university students encompass affective, behavioural and cognitive dimensions that significantly influence their learning outcomes and academic performance. Affective dimensions refer to students' emotional disposition towards mathematics, including their feelings, likes and dislikes related to the subject (Di Martino & Zan, 2011). Behavioural dimensions involve students' actions and behaviour towards mathematics, such as their engagement, effort and persistence in learning the subject (Kovács & Maričić, 2023). Cognitive dimensions pertain to students' thoughts, beliefs and perceptions about mathematics, including their confidence, motivation and perceived competence (Elçi, 2017).

Research has shown that students' attitudes toward mathematics are influenced by various factors, including their experiences in mathematics classes, interactions with teachers and personal beliefs about their mathematical abilities (Ajisuksmo & Saputri, 2017). Positive attitudes toward mathematics have been linked to higher academic achievement and better problem-solving skills, whereas negative attitudes may hinder students' progress and willingness to engage with mathematical tasks (Vlasenko et al., 2020).

Moreover, students' attitudes towards mathematics can be categorised into cognitive, behavioural and affective components, each playing a crucial role in shaping the students' overall disposition towards the subject (Svenningsson et al., 2022). Understanding and addressing these components are essential for promoting positive attitudes and improving the students' performance in mathematics (Alibraheim, 2021).

In summary, attitudes towards mathematics amongst university students are multifaceted, encompassing affective, behavioural and cognitive dimensions that interact to influence the students' learning experiences and academic outcomes. Comprehending these dimensions enables educators to cultivate positive attitudes towards mathematics, enhance student engagement and promote success.

1.3. Understanding the Relationship between Attitude and Mathematics Reasoning for Academic Success

Attitudes and mathematical reasoning amongst university students are crucial aspects that impact their learning outcomes and overall success in mathematics education. Students' attitudes towards mathematics, engagement and self-regulated learning strategies have influenced their mathematics achievement (Layco & Parico, 2019). Research has shown that their attitudes towards mathematics are essential to their mathematics achievement (Bakar & Ayub, 2020).

Attitudes towards mathematics encompass affective, cognitive and behavioural dimensions, reflecting the students' feelings, knowledge and behaviour toward the subject (Ceballos-Bejarano et al., 2023). Furthermore, the importance of reasoning ability in learning mathematics is highlighted, emphasising that activities focusing on reasoning and problem-solving are closely related to excellent student achievement (Tak et al., 2021; Wahyuni & Jamaris, 2021).

In summary, attitudes towards mathematics and mathematical reasoning play significant roles in shaping the learning experiences and outcomes of university students in mathematics. Understanding and fostering positive attitudes and enhancing mathematical reasoning abilities are essential for improving students' performance in mathematics education.

2. METHOD

2.1. Participants

The research attempts to ascertain the direct, indirect and overall impacts of factors influencing students' attitudes towards mathematical reasoning. This quantitative and cross-sectional study uses a questionnaire to obtain data. Questionnaires are commonly employed to assess pupils' personality traits towards mathematics (Tapia & Marsh, 2004). A questionnaire was adapted using three dimensions: affective, behavioural and cognitive. The dimensions of attitude were selected using appropriateness for the context of this study to measure different constructs. The mathematics reasoning evaluation consisted of 8 questions that evaluated reasoning skills in the areas of critical thinking, algebraic reasoning, geometry, and fractions. The professionals conducted a thorough face validation of the tools and evaluation set.

2.2. Data Collection

The survey method involving 378 university education students around the Klang Valley, Malaysia was selected using a proportional stratified random sampling technique. The researchers obtained authorisation from the office of the Heads of Departments of Education in the universities engaged in the study. After obtaining authorisation to conduct the research, the researcher proceeded to distribute informed consent forms to all the participants. The purpose of carrying out in order as to guarantee that all the participants provided their explicit agreement to take part in the research. Subsequently, the instruments were distributed to the participants in their respective universities with the assistance of students. The completed questionnaires were collected at the outcome of the oversight activity and organised for data analysis.

In this research, there were 378 participants from few local universities located in Klang Valley, Malaysia. The following demographic of studies were explored in order to indicate the gender and stream of research participants. In terms of participant gender, there were 213 female students (56.3%) and 165 male students (43.7%). As for discipline stream, 113 of the participants (29.9%) were scientific and mathematics stream undergraduates, whereas 265 (70.1%) were non-science and mathematics stream participants in the research.

2.3. Data Analysis

Data from the questionnaire were keyed using SPSS Version 23 software and analysed with AMOS. AMOS is particularly advantageous for structural equation modeling (SEM), which allows researchers to assess complex relationships between observed and latent variables. This capability is vital for researchers aiming to validate theoretical models and understand the underlying constructs influencing data of this studies (Awang, 2018). Therefore, AMOS is an excellent option for researchers looking to test models and demonstrate model fit due to its robust analytical capabilities, user-friendly interface, and support for advanced statistical techniques. By leveraging AMOS, researchers can effectively validate these studies contribute valuable insights to mathematics education research fields.

3. RESULTS AND DISCUSSION

3.1. Results

In order to establish whether or not there was a significant association between the variables, the SPSS correlation analysis was utilised to test the correlation between students' mathematical reasoning achievement and their attitude towards mathematics. Before conducting the Pearson correlation test, the normality of the data was determined. The skewness and kurtosis values in Table 1 indicate the degree of normality that each variable indicates. A normal distribution is shown when the values of skewness and kurtosis fit within the range of ± 2 (Wagner, 2019; Wijaya, Cao, Weinhandl, et al., 2022).

Table 1. Normality assumption derived from skewness and kurtosis

Variables	Skewness	Kurtosis
Attitute toward Mathematics		
Affective	-.765	.748
Behavioural	-.691	.707
Cognitive	-.610	-.032
Mathematics Reasoning		
Critical Thinking	-.652	.105
Algebraic Reasoning	-1.193	1.630
Geometry	-1.574	1.133
Fraction	-1.742	1.171

The assessment of the measurement model relies on examining convergent and discriminant validity (Awang, 2018). Convergent validity refers to how different measurements of the same notion align inside a structural equation model. The evaluation is determined by factor loading, composite reliability (CR) and average variance extracted (AVE). Awang (2018) stated that a model is considered fit when the factor loading exceeds 0.60 to achieve statistical significance. The CR values represent the extent to which the indicators of a construct accurately reflect the underlying construct, with values ideally exceeding 0.60.

Since the factor loading for exploratory factor analysis had determined at pilot study for these studies. Therefore, the confirmatory factor analysis is utilized for test whether a set of observed variables accurately reflects the number of latent constructs specified by the researcher. This method is particularly valuable after conducting a pilot test, as it allows researchers to validate the factor structure derived from exploratory analyses and ensure that the model aligns with theoretical expectation (Tabachnick & Fidell, 2019; Teo, 2013). Confirmatory Factor Analysis also provides estimates of factor loadings, which indicate how strongly each observed variable correlates with its respective latent variable. High factor loadings above 0.5 suggest that the observed variables are good indicators of the latent construct, while low loadings may indicate that certain items should be revised or removed from the model (Awang, 2018; Verma & Verma, 2024).

By contrast, according to Awang (2018), the AVE value must exceed 0.5. Internal consistency is measured using the Cronbach's Alpha coefficient. Constructs with high coefficient values indicate that the items within the constructs reflect similar ranges of value and definition. The coefficient should have a minimum value of 0.7 in the initial stage and 0.8 or 0.9 for the subsequent research phases. Values less than 0.6 indicate a lack of reliability (Awang, 2018). Discriminant validity refers to the extent to which the measurements of separate concepts are distinguishable. The test assesses whether the objects being measured exclusively capture the intended construct, as determined by Fornell and Larcker (1981). From Table 2, analysis is considered valid if the square root of the AVE for each latent construct is greater than the correlations of any other latent constructs, according to Fornell and Larcker (1981).

Table 2. Indicator outer loading assessment

Construct	Outer Loading	Decision
Affective (AF)	All indicators with OL >0.7	All indicators are accepted
Behavioural (TL)	Four items with OL>0.7, one item with 0.5	The consideration of one item for removal
Cognitive (KG)	All indicators with OL >0.7	All indicators are accepted
Critical Thinking (TC)	All indicators with OL >0.7	All indicators are accepted
Algebraic Reasoning (AR)	All indicators with OL >0.7	All indicators are accepted
Geometry (GM)	All indicators with OL >0.7	All indicators are accepted
Fraction (FC)	All indicators with OL >0.7	All indicators are accepted

The Heterotrait-Monotrait (HTMT) ratio of correlations is a crucial metric in quantitative research, particularly in the context of structural equation modeling (SEM) and psychometric assessments (Franke & Sarstedt, 2019; Henseler et al., 2015). This ratio serves as an indicator of discriminant validity, which is essential for establishing that constructs are distinct from one another (Henseler et al., 2015). Values below 0.85 are generally considered indicative of good discriminant validity, suggesting that the constructs are sufficiently distinct (Henseler et al., 2015; Wijaya, Cao, Bernard, et al., 2022). Based on Table 3, Heterotrait-monotrait analysis, all the constructs' values below threshold of 0.85 are considered indicative of good discriminant validity.

Table 3. Heterotrait-monotrait (HTMT) analysis results

	Affective	Behavioural	Cognitive	Critical Thinking	Algebraic Reasoning	Geometry	Fraction
Affective	-						
Behavioural	0.33	-					
Cognitive	0.38	0.29	-				
Critical Thinking	0.39	0.40	0.33	-			
Algebraic Reasoning	0.30	0.37	0.28	0.29	-		
Geometry	0.38	0.35	0.32	0.34	0.45	-	
Fraction	0.39	0.41	0.37	0.37	0.50	0.49	-

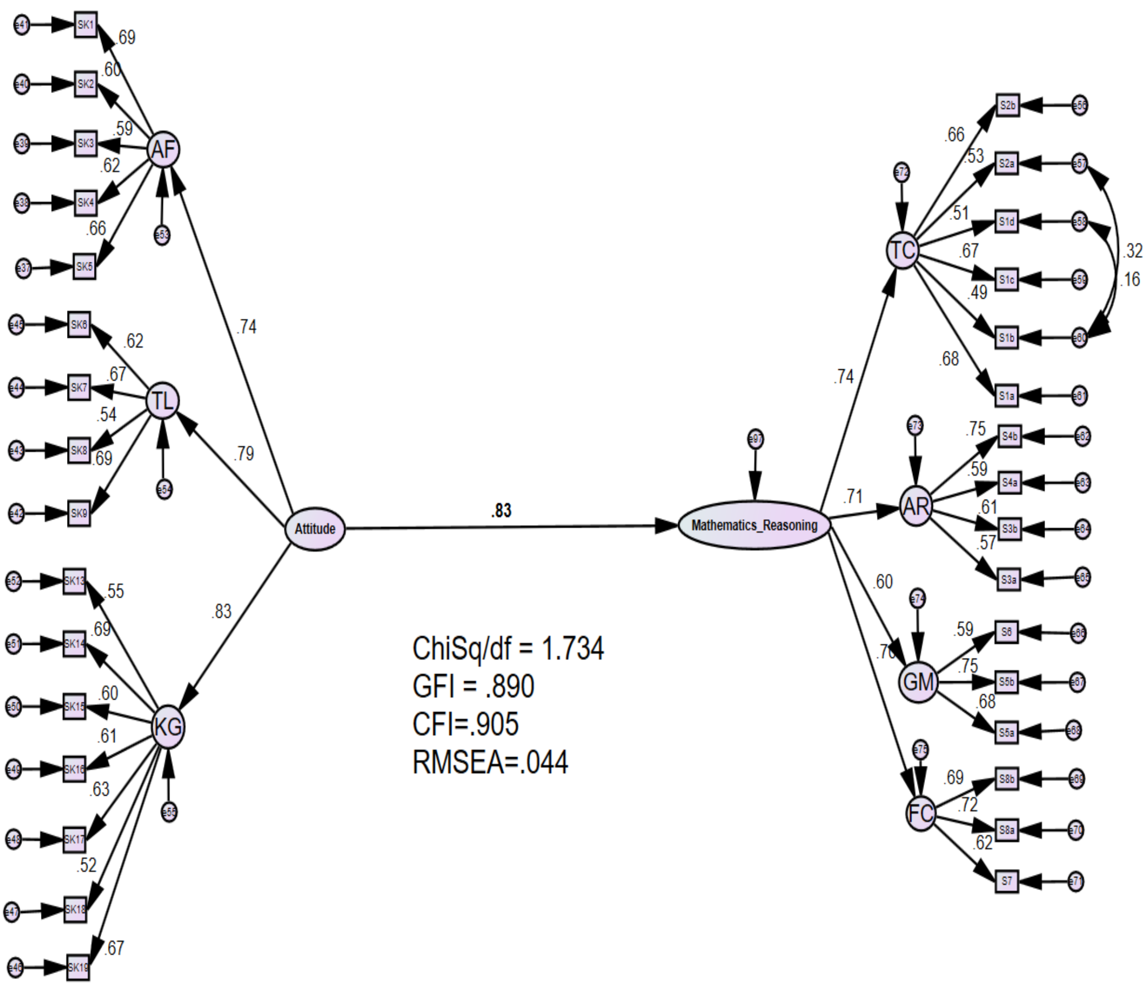

Figure 1. Measurement model indicating the various dimensions within every scale of the latent variables

Figure 1 illustrates the measurement model, indicating the subdimensions within every dimension of the latent variables. The dimensions of affective (AF), behavioural (TL), and cognitive (KG) represent the attitute constructs, illustrating the decision criteria of a reflective or formative measurement model proposed by Fennema and Sherman (1976) and Tapia and Marsh (2004). Meanwhile, the dimensions of critical thinking (TC), Algebraic Reasoning (AR), Geometry (GM), and Fraction (FC) represents the mathematics reasoning construct. Constructs attitude are indicators that demonstrate a strong correlation with mathematics reasoning.

For validating the constructs being measured, the fit of the measurement model is often evaluated using indices such as the degrees of freedom (χ^2/df), Goodness of Fit Index (GFI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). Degrees of freedom (χ^2/df) with a ratio of 5 or less, CFI and TLI value above 0.80 typically indicate a good fit, while an RMSEA value below 0.08 is considered acceptable (Takele et al., 2023). The structural equation model implemented in this study demonstrates a good fit between the research model and the data.

The coefficients indicate the strength and direction of the relationships in structural model. For instance, a path coefficient of 0.5 suggests a moderate positive relationship, while a coefficient of -0.3 indicates a moderate negative relationship (Takele et al., 2023). The significance of these coefficients is typically tested using p-values, where a p-value less than 0.05 indicates statistical significance. The structural model represented in Figure 1 indicated that path coefficient of 0.83 has strong positive relationship between attitude and mathematics reasoning and p-value less is 0.00 indicated statistical significance in model of this studies.

Table 4. Measurement model composite reliability and average variance extracted

Construct	CR	AVE
AF	.92	.70
TL	.82	.53
KG	.92	.93
TC	.75	.51
AR	.82	.53
GM	.84	.63
FC	.76	.51

Table 4 illustrates the identified outcomes of CR and AVE for each construct. The findings indicate that each construct's CR ranges within an interval of .75 to .92, above the minimum acceptable level of 0.7. Consequently, the study revealed that the items used in evaluating the components achieved acceptable results. The AVE analyses the degree to which the measurement model demonstrates convergent validity. All constructs demonstrated an AVE greater than 0.5, indicating acceptable convergent validity (Mueller & Hancock, 2018; Ullman & Bentler, 2012).

Table 5. Findings derived from the Fornell–Larker analysis of the measurement model

Construct	AF	TL	KG	TC	AR	GM	FC
AF	**.84**						
TL	.45	**.72**					
KG	.50	.49	**.96**				
TC	.30	.38	.39	**.70**			
AR	.37	.35	.41	.33	**.73**		
GM	.28	.32	.38	.38	.29	**.79**	
FC	.29	.34	.37	.39	.40	.33	**.72**

Table 5 shows the discriminant validity of the model using the Fornell–Larker approach. This approach involves manually calculating the square root of the AVE and comparing it with the inter-correlations amongst the components (Hair et al., 2019). In Table 5, the highlighted elements indicate the square root of the AVE. By contrast, the non-bolded values show the inter-correlation values between the constructs. The data demonstrate that all off-diagonal elements are smaller than the square roots of AVE. The analysis results indicate that the measurement model satisfies the criteria for discriminant validity.

3.2. Discussion

The finding indicated that affective, behavioural and cognitive dimensions positively relate to mathematics reasoning. This finding empirically supports Di Martino and Zan's (2011) claim that students have feelings about mathematics reasoning in the affective dimension. Meanwhile, students believe that they engage more often, exert effort and persist in learning mathematics reasoning in behavioural dimensions. These results are similar to those of the previous research by Kovács and Maričić (2023). Elçi (2017) also believed that cognitive dimensions pertain to students' thoughts, beliefs and perceptions about mathematics. This result has several possible explanations, including their high confidence, motivation, and perceived competence towards mathematics reasoning.

Critical thinking, algebraic reasoning, geometry and fractions are utilised as dimensions strongly related to mathematics reasoning. This finding parallels the view of Marhami et al. (2020) that critical thinking plays a crucial role in mathematical problem solving, requiring students to remember concepts, recognise relationships and draw original conclusions swiftly and wisely in mathematics reasoning. On the contrary, the interpretation of this finding is similar to that of Ahmadah (2020), indicating that students can engage in algebraic reasoning by identifying patterns in mathematical problems, establishing relationships between quantities and making generalisations through formal representations and symbolic manipulation (Ahmadah, 2020).

Meanwhile, the interpretation of dimension geometry in mathematics reasoning is consistent with the findings of Risnawati et al. (2019). Similarly, geometry can significantly enhance students' mathematical abilities, particularly reasoning and spatial skills (Risnawati et al., 2019). Livy and Herbert (2013) stated that students comprehend these mathematical concepts in ratios and proportionality; understanding fraction concepts is fundamental in mathematics reasoning. The findings of this research are similar to the statements of Livy and Herbert (2013).

This research is the first step towards a more profound understanding of attitudes towards mathematics reasoning amongst university students. A strong relationship is found between attitude and mathematics reasoning, confirming the findings of Ceballos-Bejarano et al. (2023) and Wahyuni and Jamaris (2021). Wahyuni and Jamaris (2021) have noted the importance of reasoning ability in learning mathematics by emphasising that activities focus on reasoning and problem-solving. On the other hand, these results reflect Ceballos-Bejarano et al. (2023) found that attitudes towards mathematics are associated with affective, cognitive and behavioural dimensions that reflect students' feelings, knowledge and behaviour towards mathematics reasoning.

These findings indicate that affective, behavioural and cognitive dimensions significantly contribute to mathematics reasoning, supporting Di Martino and Zan's (2011) claim about students' emotional responses to mathematics. It aligns with the research by Kovács and Maričić (2023) and Elçi (2017), showing that higher confidence, motivation and perceived competence enhance mathematical reasoning. The study highlights the importance of critical thinking, algebraic reasoning, geometry and fractions in developing mathematical skills, paralleling views from Marhami et al. (2020), Ahmadah (2020), Risnawati et al. (2019) and Livy and Herbert (2013). This research provides a foundational understanding of university students' attitudes towards mathematics reasoning. Their findings suggest that positive attitudes in affective, cognitive and behavioural dimensions can enhance reasoning abilities, as reflected in the studies of Ceballos-Bejarano et al. (2023), Tak et al. (2021) and Wahyuni and Jamaris (2021).

Future studies should explore the specific instructional strategies and interventions that effectively enhance the affective, behavioural and cognitive dimensions of mathematics reasoning. This approach includes investigating methods to boost students' confidence, motivation and perceived competence in mathematics, as well as developing activities that encourage persistence and active engagement. In addition, the research should examine the impact of integrating critical thinking, algebraic reasoning, geometric understanding and fraction concepts into the curriculum on students' overall mathematical abilities. Longitudinal studies could provide insights into how these dimensions evolve over time and influence long-term academic outcomes. In the future, these areas can be addressed by building on the current findings, thereby contributing to a deeper understanding of how to foster positive attitudes and improve reasoning skills in mathematics education.

4. CONCLUSION

The findings indicated that perceived affective, behavioural and cognitive factors significantly influence individuals' attitudes towards mathematics reasoning. The research model successfully forecasted the interconnections amongst the components at a reasonable degree. The results align with those of the previous studies, indicating that the three factors are crucial and statistically significant drivers of individuals' attitudes towards mathematics reasoning. Hence, the relational model, built and analysed using structural equation model analysis, can be further explored by incorporating other psychological constructs.

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Declarations

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	Conceptualization, Data curation, and Formal analysis, Software and Resources.
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