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Undergraduate Students' Attitudes and Mathematical Reasoning During the Pandemic: The Mediating Role of Metacognitive Awareness

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Abstract: During the Covid-19 pandemic, this study investigated the role of metacognitive awareness as a mediator in the correlation between attitude and mathematical reasoning among undergraduates who are first year university students. These studies distribute mathematical reasoning assessments, metacognitive awareness questionnaires, and attitude surveys as research data. One hundred eighty-four undergraduate students from one public institution in Malaysia's Klang Valley area participated in the research. The impact of metacognitive awareness on attitude and mathematical reasoning was studied using Version 25 of the Statistical Packages for the Social Sciences. The findings indicated that undergraduate mathematics and science education students excelled in non-mathematics and science education students in mathematical reasoning capacity. According to the findings, undergraduate mathematics and science education students had good metacognitive understanding and used more approaches in mathematical reasoning assessment. Further study implies that more research should be conducted to assess different demographics, such as institute training teachers' metacognitive awareness and attitude towards mathematical reasoning.

Keywords: *Attitude, mathematics reasoning, metacognitive awareness, undergraduate.*

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Introduction

The Covid-19 pandemic had a significant impact on educational institutions. To ensure the health of students, teachers, and staff, universities have had to shift to remote instruction. This transformation has generated many issues in mathematical education. One crucial issue is that some students may not have access to personal tutoring, making it impossible to receive rapid feedback on their assignments (Castro et al., 2020). Some students have lost motivation as they struggle to adapt to the new format following the abrupt shift to online learning (Bakker et al., 2021).

To address these issues, institutions have implemented several methods to help students learn mathematics throughout the pandemic. Many educational institutions have expanded the availability of online resources such as video tutorials and virtual meeting rooms (Abdelsalam et al., 2021). Some universities have also introduced new technologies, such as online collaboration tools, to facilitate group work. These strategies have aided in increasing accessibility and encouraging student participation in mathematics studies (Sulistyani et al., 2021).

The research aims to investigate the levels of metacognitive awareness and attitudes towards mathematics reasoning among undergraduate students at a university. According to particular research, it was seen that all students exhibited a considerable level of awareness and use of metacognitive reading methods. Furthermore, no significant differences were observed between male and female students (Deliany & Cahyono, 2020). A further investigation was conducted to examine metacognitive abilities in several domains, revealing significant differences in most metacognitive capabilities. These findings support domain-specific and domain-general perspectives (Gutiérrez de Blume & Montoya Londoño, 2021). Furthermore, a research investigation on undergraduate learners revealed a negative correlation between metacognitive awareness and the academic level of study. Specifically, the study discovered that metacognitive control is strongly associated with the academic level of study (Anumudu et al., 2019). Nevertheless, the overviews presented needed to include a clear mention or discussion of attitudes towards mathematics.

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Implementing research on the relationship between attitude, metacognitive awareness, and mathematical reasoning among university students is essential to get insights into various aspects of their academic performance and learning strategies. Research has shown that self-efficacy and metacognitive awareness are significant contributors to the development of students' mathematical reasoning skills (Chan et al., 2021). Furthermore, empirical investigations have shown that students who do poorly experience lower confidence levels in their performance assessments, suggesting a certain degree of metacognitive awareness of their inadequate calibration (Nederhand et al., 2021). Moreover, it has been shown through research that there exists variability among university students in terms of their attitudes, knowledge, and degrees of awareness on certain subjects (Selamat et al., 2021). Furthermore, prior studies have shown that the extent to which university students possess metacognitive awareness of learning methods, experience research anxiety, and have a positive attitude towards research greatly influences their academic self-efficacy (Wajid & Jami, 2020). Previous studies have shown a positive correlation between problem-solving skills and accomplishment motivation, metacognitive awareness, and attitudes towards learning in the context of undergraduates (Yunus et al., 2021). Hence, researching these issues might provide significant insights to improve students' academic mathematics performance and learning benefits.

Metacognitive awareness refers to monitoring and controlling one's cognitive processes. This can include understanding the strengths and limitations, how to approach a problem, and the ability to meditate on one's education (Chan et al., 2021). In university, where students may encounter more complex and abstract concepts, metacognitive awareness can be vital for mathematical reasoning. Meanwhile, mathematical reasoning is the capacity to analyze, evaluate, and create logical connections within mathematical concepts and solve problems using mathematical principles. It is an essential component of critical thinking in mathematics. Understanding the links between distinct mathematical ideas, finding patterns, and drawing accurate deductions and conclusions based on mathematical rules and qualities are all required (Tak et al., 2022a).

Mathematics is a discipline of mathematical understanding that stipulates logical thinking. Mathematical reasoning is understanding new skills using mathematical symbols, ideas, or connections. Inductive, deductive, comparative, and generalising reasoning are all types of mathematics understanding (Simanjuntak et al., 2019). Reasoning is an important element of mathematics and one of the essential criteria in mathematics education, according to the National Council of Supervisors of Mathematics (n.d.). All pupils should practice reasoning, which is a mathematical concept. Metacognition is at the core of cognitive behaviour. Metacognition is the process of thinking that implies the person is aware of and regulates his or her cognitive processes. The phrases cognition and self-control are typically used to define metacognition. Individuals with excellent attitudes may use suitable cognitive techniques to govern their thinking and learning processes (Primi et al., 2020; Tak et al., 2022a).

Metacognitive Awareness in Mathematics Reasoning

Flavell (1979) defined metacognition as the awareness of how one learns, knowledge of how to use information in achieving a goal, and the capacity to judge the cognitive demands of a specific assignment. In contrast, Brown (1987) defined it as the awareness of one's knowledge and the ability to understand, control, and manipulate cognitive processes. Additionally, Brown (1987) expanded on the concept, highlighting that higher-order thinking entails active control over the cognitive processes involved in learning. Furthermore, Grogory and Sperling (1994) stated that metacognition includes metacognitive knowledge and regulation. Metacognitive knowledge refers to a person's cognitive knowledge, including declarative, procedural, and conditional knowledge. Meanwhile, metacognitive regulation refers to individuals' control over their learning including planning, monitoring, and assessing (Tak et al., 2022b).

Metacognition is also characterised as students' awareness and modulation of cognitive processes throughout planned learning events and problem-solving. Reasoning is the ability to make estimates or predict something; planning is the ability to develop answers; monitoring is an individual's comprehension of understanding and carrying out tasks; and evaluating is the ability to assess the solutions and process of one's learning settings (Misu et al., 2019). Metacognitive awareness has also been linked to a variety of problem-solving indicators, including (1) identifying what is known from a given mathematical problem; (2) associating the problem with a previous problem; (3) evaluating the problem with a previous problem; (4) understanding what to do; and (5) knowing what has been done. These metacognitive awareness indicators are often utilised to solve problems with mathematics (K. E. Lestari et al., 2022).

Previous research indicates that individual variations in mathematics are driven by metacognitive knowledge (Salam et al., 2020). Metacognition is made up of two parts: regulation and knowledge. Metacognitive knowledge includes information on the learner's learning mode, qualities of performance, learning approaches, and when and how to use them. Learning, thinking, and operating are all mental aptitudes that include cognitive processes and are essential to comparing, deducing, and retaining knowledge. The use of cognitive techniques is vital not just for solving mathematical problems but also for attaining specific objectives. Several metacognitive approaches are critical in organising the learning process, using appropriate skills and problem-solving strategies, assessing the process, and conducting acceptable self-assessments (Abdelrahman, 2020).

A broad category of thought may be defined as the "mental process of knowing" and encompasses features such as judgment, perception, or anything that can be recognised by intuition, reasoning, perception, and knowledge. Reasoning transpires in various ways; the thinking process is meaningful and based on actual evidence, the term 'perception.' Mathematics reasoning might be about something concrete, or it can be about abstracting real things and attributes (Chan et al., 2021). Perception is the intermediary between the learner and factual reality; perceived items might be actual objects, concepts, or abstractions. Although it influences their reasoning in analyzing their thinking outcomes, metacognitive awareness is vital in enabling learners to solve difficulties. In learning activities, developing students' logical thinking abilities is critical. It may be beneficial for instructors to organise their instruction based on students' cognitive awareness (Nurjanah et al., 2020).

The demand for further knowledge about university students' reasoning, paired with the critical significance of tests at this level, leads to several possible and relevant research problems. This research examines the reasoning that Malaysian university students in mathematics must apply to get through test assignments and pass exams. Reasoning skills include a metacognitive procedure depending on the consciousness of cognitive capacities and the capacity to evaluate and govern reasoning procedures (Grogory & Sperling, 1994). According to Chan et al. (2021), metacognitive awareness is the capacity to consider, interpret, and regulate learning. Furthermore, metacognitive awareness comprises two major components: cognition knowledge and cognition management. It represents the wisdom of learners' capability judgments. Students with firm metacognitive knowledge comprehend their mathematical skills, degree of knowledge, techniques, and tactics for problem-solving activities (Chan et al., 2021). Metacognitive regulation includes planning, monitoring, and assessing operations.

When students engage in mathematical argumentation, which includes generating and defending mathematical arguments, they use reasoning (K. E. Lestari et al., 2022). Deductive reasoning is the type of thinking that aims to convince another that a justification is valid (Nurjanah et al., 2020). In both real-world and symbolic situations, students are prone to discover patterns, regularities, and structures. Individuals guess and test whether the patterns are random or intentional. Consequently, a mathematics educator must have a tool to measure students' reasoning abilities (Long & DeTemple, 2002; Naufal et al., 2021).

Tak et al. (2022a) stated that one of the reasons students fail to become active and independent learners is a lack of metacognitive awareness and skills. Salam et al. (2020) state that good instruction organization helps develop students' metacognitive skills. Chan et al. (2021) investigated the correlation between metacognitive abilities and learning outcomes in first-year university students. They looked into students' metacognitive strategies that benefitted their academic success. Their findings demonstrated that metacognitive tactics for understanding texts could increase the academic performance of undergraduates.

Metacognitive processes, such as self-modification and self-monitoring need the ability to form ideas, emotions, and reasoning skills. Metacognitive awareness is an individual's understanding of their cognitive abilities. In other words, metacognitive awareness is learning and using metacognitive thinking abilities that an individual will need throughout their life (Abdelrahman, 2020). Metacognition is required for effective learning since cognition is about doing something, and metacognition is about knowing how to do something. The results revealed that metacognitive teaching might successfully increase students' performance in reasoning with academic challenges. It has also been scientifically shown that including metacognitive abilities in reasoning and instructions is both doable and practical. Individuals with higher reasoning ability also had better metacognitive performance(Salam et al., 2020).

Metacognition plays a role in increasing learning acquisition, understanding, retention, and application, according to Amir MZ et al. (2021). It also affects learning efficiency, problem-solving, and critical thinking abilities. K. E. Lestari et al. (2022) defined metacognitive awareness as increasing awareness of a person's tasks and strategy knowledge through reflective thinking. Moreover, several varieties of imitative reasoning have been identified through empirical research, and they are summarised in memorised and algorithmic reasoning. Memorised reasoning is used to describe reasoning in a task solution based on recalling a complete response from memory. Subsequent algorithmic reasoning is used to describe reasoning in a task solution when the strategy choice is based on recalling by memory a set of instructions that ensures the right solution may be attained (K. E. Lestari et al., 2022).

Metacognitive Awareness as a Mathematical Mediator

When metacognitive awareness is included in the mediation model, problem-solving skills continue to positively and significantly influence mathematical achievement. According to Wajid and Jami (2020), metacognitive awareness affects the correlation between students' mathematics performance and problem-solving skills. Problem-solving and metacognition are both complicated cognitive processes. The procedures of metacognitive awareness differ based on cognitive. Metacognitive methods are used by individuals with excellent reasoning skills (Wajid & Jami, 2020).

Metacognitive knowledge significantly moderates the relationship between internal control points and mathematics performance. Research also revealed that an external control point is directly and substantially related to mathematics achievement even when metacognitive knowledge is not utilised (Primi et al., 2020). Another explanation for previous findings is that developing an internal control point, defined as the capability to handle and regulate occurrences, necessitates acquiring metacognitive knowledge. This knowledge enables students to achieve higher levels of mathematics performance (Primi et al., 2020).

Wafubwa and Csíkos (2022) studied the correlation between collaborative and metacognitive conversations and their capacity to influence mathematics learning directly. The researchers discovered that metacognitive conversation, more than any other kind of communication, was more likely to satisfy the conditions for cooperation. In addition, whether previous knowledge was non-transitive or transitive significantly influenced the likelihood of following a metacognitive conjunction in mathematics learning (Wafubwa & Csíkos, 2022).

Differential Attitudes in Mathematical Reasoning

Mathematics Attitude, or Attitude Towards Mathematics, explains mathematical learning. Students having a positive attitude towards mathematics perform better than those with a negative attitude (Duque & Tan, 2018; Turra et al., 2019). Previous research has shown that 21st-century classroom teaching methods (such as STEM or Task-based) result in students developing mathematics attitude, mathematics achievement, analytical thinking, and mathematical process skills (Blotnicky et al., 2018). According to León-Mantero et al. (2020), attitude correlates with individual behaviours, resulting in the predictability of mathematics learning performance. In addition, Wajid and Jami (2020) discovered that attitude is a mediator when utilising instruction to assess students' mathematics problem-solving abilities.

Attitudes are essential in mathematics since it has historically been regarded as one of the most challenging issues. Mathematics reasoning is used while attempting to grasp an issue, connecting and representing ideas in the problem to individual prior mathematics knowledge, creating conjectures and generalisations, and attempting to prove conjectures produced. Reasoning and creating meaning are two interrelated mathematical actions that are the foundation for other mathematical procedures. It is expected that by going through all of the procedures, the person would gain self-confidence and an optimistic mindset towards mathematics (Nurjanah et al., 2020).

Another goal of proof in reasoning is to provide evidence that theorems are a priori implications of how statements are specified (Tak et al., 2023). In context with this goal, Battista (2017, p.16) suggested that "the point of proof is not so much about conviction, but the way one can clarify the bases of the reasoning utilised". W. Lestari and Jailani (2018) stated that mathematicians' value of prior knowledge could account for proof-related behaviours in mathematics educational institutions, such as an instructor's insistence on proving a statement whose truth value seems clear. For another example, a geometry statement can be clearly shown with a dynamic geometry software package, and students should avoid appealing to their own experiences when writing proof (Chan et al., 2022).

The creation of a theoretical framework for emotions, views, and attitudes has become essential in light of the growth in impact research and the resulting increase in awareness of the importance of affect in mathematics learning, especially in the context of the problem of the absence of precise and widely accepted definitions. (Niepel et al., 2018). These researchers seek to uncover a cause-or-effect correlation between good attitude and mathematical accomplishment rather than investigating a relationship between mathematics reasoning learning and attitude (Izadi et al., 2018).

Attitudes are the most visible components of a person's social life. Education experts recognise the importance of attitudes in an individual's educational development. Instructions have a role in facilitating learning via the scaffolding approach by providing indirect suggestions or offering stimulating questions to assist students in using their reasoning and attitude to look for possible solutions to intermediate or even concluding challenges. It is time for students to learn a variety of thinking abilities in order to solve issues in mathematics, other fields, and even in ordinary life (Primi et al., 2020).

Memorisation should not be a method used to impart knowledge of mathematics. Instead, it should be done in an approach that encourages mathematical reasoning. Although excellent tests result in mathematical proficiency, they do not always indicate that learners are learning effectively. Mathematics cannot be learned and requires interpretation in mathematics learning(Naufal et al., 2021). According to Turra et al. (2019), all learners should be able to grasp and make sense of mathematics. Mathematics reasoning is deriving a conclusion from outcomes, judgments, facts, propositions, or the progression of thought and the approach to reaching conclusions.

In a broader sense, mathematics learning could assist students in developing reasoning skills that can be used in any context, such as logical thinking, systematic, creative, objective, and sensible problem-solving. Students with strong mathematical and analytical skills must demonstrate strong mathematical competence and success (Misu et al., 2019). The ability to make mathematical allegations, the ability to conclude, construct a proof, and give reasons for the accuracy of answers, the ability to find patterns or traits of mathematical problems to make generalising, and the capacity to determine the validity of a point of view are all examples of reasoning (Risnawati et al., 2019).

Mathematical reasoning is the capacity to create mathematical predictions, develop and analyze mathematical conversations, and present mathematical material in several ways: infer conclusions from aggregate evidence (Nurjanah et al., 2020). As observed from those dimensions, mathematical reasoning is essential to cultivating an optimistic mindset. The view or proclivity of students towards mathematics as an object comprises features of intellect, attachment, and action. Aspects of cognition include a perspective of mathematics as a discipline, a view of the advantages of mathematics, and a view of mathematics learning (K. E. Lestari et al., 2022).

Attitude refers to an individual's emotions, feelings, and readiness for responding to situations. It occurs when an individual experiences, recognises and evaluates issues. Attitude is an autonomous belief that leads to participating in or operating from observed items. (Kuznetsova, 2019). According to the theory of planned behaviour (Ajzen, 1991; Niepel et al., 2018), attitude is one of the three fundamental factors (Subjective Norm, Attitude, Perceived Behavioural Control) used to characterise the trend of individual behaviour. Individuals can use it to predict the success or failure of a person (Turra et al., 2019).

Proofs in reasoning are essential in mathematicians' practice because they show why mathematical theorems are proven. According to several mathematics educators, proof should serve a comparable function in mathematics courses. Zayyadi and Kurniati (2018) describe a learning environment intervention in which students learn to evaluate proofs for their explanatory ability. There is no agreement on what it means for proof to be explanatory for a learner, which is a fundamental problem in this field.

In an academic university, attitude towards mathematics research generally investigates the correlations between attitude behaviour associated with psychological categories and mathematics achievement. Second, examine the correlation between behavioural affective, and cognitive (Izadi et al., 2018; Primi et al., 2020). Individuals with a positive attitude towards mathematics have better academic performance and tend to pursue science or mathematics-related professional sectors (Sevgi & Orman, 2020).

Research Hypothesis

The research hypothesis is that there is a relationship between attitude, metacognitive awareness and mathematics reasoning among mathematics and science students and non-mathematics and science students, and its relationship is examined using structural equation modelling.

Methodology

Research Design

The correlational research design methodology is used in the present research to evaluate the relationships between two or more variables without manipulation. Specific outcomes are shown by the association coefficients (Creswell & Creswell, 2018). The hypothesised relationships between attitude and mathematical reasoning were examined in the present research, with metacognitive awareness modelling as a mediator between variables.

Sample and Data Collection

This research investigation included 182 undergraduate education students selected using a simple random approach. Undergraduate participants in mathematics and science education comprised 51% (n = 92) of the students, while non-undergraduate participants in mathematics and science education comprised 49% (n = 90). Participants are randomly selected from varied socioeconomic backgrounds at a university in Malaysia's Klang Valley. Before field data collection, the research ethics committee approved the current research, and all volunteers gave informed permission.

The researcher adapted the mathematical reasoning assessment from Long and DeTemple (2002). There are eight open-ended questions on the mathematical reasoning assessment. The evaluation takes around 90 minutes to complete. A rubric is used to grade the answers to the maths reasoning problems on a scale of 0 to 4. The scoring was peer-reviewed by two maths researchers. The scorers agreed almost perfectly (kappa = .86). A consensus was reached by assessing the results where there was no agreement among the scorers. The evaluation assigns a score of 0 to each question and a maximum score of 4. High scores show superior mathematical reasoning skills. In this study, Cronbach's alpha value for the mathematical reasoning instrument was .71.

Table 1. Scoring Rubric for Mathematics Reasoning

Score	Description
4	Some answers adequately describe the strategy for addressing the problem and its justification, express their ideas using exact mathematical symbols and notation, clarify the logic correctly, and display a thorough grasp.
3	Some answers are accurate except for minor flaws or misconceptions in solving and discussing the problem, utilising appropriate mathematical symbols and notation, articulating how they reasoned, and saying they completely grasped it.
2	Whereas the approach for resolving the issue and its justification shows that the problem is somewhat grasped, individual replies show that the participant is unaware of specific solution explanations.
1	Some answers show a lack of comprehension of the technique and explanation for addressing the obstacle.
0	Some solutions incorrectly solve the issue or leave it unresolved.

The researcher employed the Metacognitive Awareness Inventory, established by Grogory and Sperling (1994) and Rahman et al. (2014). The 6-dimensional measure employed a 5-point Likert Scale (1 = strongly disagree, 5 = strongly agree). The metacognitive awareness sub-dimension of the assessment, which included 30 items, was employed in this study. Higher scores indicate that metacognitive techniques for mathematical reasoning are used more often—Cronbach's alpha for the metacognitive awareness questionnaire was .85 in the current study. Moreover, the researcher employed the Fennema and Sherman (1976) and Tapia and Marsh (2004) Attitude Inventory to assess university students' attitudes towards mathematical thinking. The measurement inventory is organised in three dimensions. The measure is a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The attitude of three inventory sub-dimensions comprised 17 items in this study. Higher scores indicate a more positive attitude, belief, or confidence in mathematical reasoning learning—Cronbach's alpha for the Attitude Inventory was .85 in the current research.

Analyzing of Data

The Skewness and Kurtosis Coefficients were employed in this research to investigate the distribution of metacognitive awareness, attitude scores, and mathematics reasoning assessment. Kurtosis Coefficients and Skewness in the range ± 1 imply that the scores are distributed normally (Denis, 2021). Table 2 shows that the Kurtosis Coefficients and Skewness were within acceptable bounds. Based on the data analysis, the scores show univariate normal distributions. The Pearson Correlation coefficients were utilised in the following study to investigate the links between attitude, metacognitive awareness, and mathematical reasoning assessments. The correlation coefficient has a value in the range ± 1. Coefficients between 0 and .30 indicate low-level correlations. Furthermore, values between .30 and .70 suggest moderate-level correlations, whereas coefficients between .70 and 1 indicate high-level correlations (Tabachnick & Fidell, 2019).

Table 2. The Kurtosis Coefficients and Skewness

Variables	Skewness		Kurtosis	
	z	SE	z	SE
Mathematics Reasoning	-.071	.166	-.589	.336
Metacognitive Awareness	.072	.177	.037	.357
Attitude	-.404	.175	.019	.345

Table 2 demonstrates the skewness of mathematical reasoning and attitude, with values of -.40 and .07, demonstrating that the distribution was skewed to the left. Furthermore, the skewness of metacognitive awareness is .07, indicating that the distribution was right-skewed. The kurtosis of mathematical reasoning, metacognitive awareness, and attitude is -.59, .04, and .02, respectively, showing that the distribution was less extreme than average. Furthermore, the correlation coefficients for mathematical reasoning, metacognitive awareness, and attitude indicate moderate levels.

Results

Table 3 illustrates undergraduate education students' mean attitude, metacognitive awareness, and mathematical reasoning scores. Mathematics reasoning ($M = 28.56$, $SD = 5.33$) was substantially higher in Mathematics and Science education undergraduate students than in non-Mathematics and Science education undergraduate students ($t(76.43) = .46$, $p < .001$). The mean metacognitive awareness score of Mathematics and Science education undergraduate students ($M = 113.46$, $SD = 14.36$) was substantially higher than that of non-Mathematics and Science education undergraduate students ($t(112.22) = .92$, $p < .001$). Mathematics and Science education undergraduate students' attitudes ($M = 51.63$, $SD = 8.65$) score was considerably higher than non-Mathematics and Science education undergraduate students' attitudes ($t(83.52) = .62$, $p < .001$).

Table 3. Standard Deviations and Mean of the Variable

Variables	Non-Mathematics and Science students (n=90)		Mathematics and Science students (n=92)		All (n=182)			
	M	SD	M	SD	M	SD	Min	Max
Mathematics Reasoning	25.89	4.24	28.56	5.33	27.20	4.82	13	37
Attitude	48.56	7.58	51.63	8.65	65	50.13	26	65
Metacognitive Awareness	113.46	14.36	115.67	13.86	114.54	13.54	80	150

The researcher obtained Pearson Correlation coefficients to examine the correlations between attitude, metacognitive awareness, and mathematical reasoning scores. Table 4 illustrates the results of the correlation coefficient analysis.

Table 4. Pearson Correlation between All Variables

No.	Variables	1.	2.	3.
1.	Attitude	1		
2.	Metacognitive Awareness	.16	1	
3.	Mathematics Reasoning	.16	.65	1

**$p < 0.01$, N=182

Table 4 shows that attitude with metacognitive awareness ($r = .16$, $p < .01$) and mathematics reasoning ($r = .16$, $p < .01$) were positively correlated. Mathematics reasoning with metacognitive awareness ($r = 0.64$, $p < .01$) correlated more positively.

The researcher used Amos version 25 to investigate metacognitive awareness's function in mediating attitude's influence on mathematical thinking. Figure 1 depicts a typical mediation model; the path coefficient (.25), also known as the impact of metacognitive awareness of attitude on mathematics reasoning or residual effect, is the term for the direct influence of attitude on mathematics reasoning. The path coefficient (.61), the first stage effect, indicates attitude on metacognitive awareness. Path coefficient (.36), also known as the second stage effect, is the impact of metacognitive awareness on mathematical reasoning. Complete mediation occurs when the direct influence of attitude on mathematical thinking after the inclusion of metacognitive awareness is inadequate.

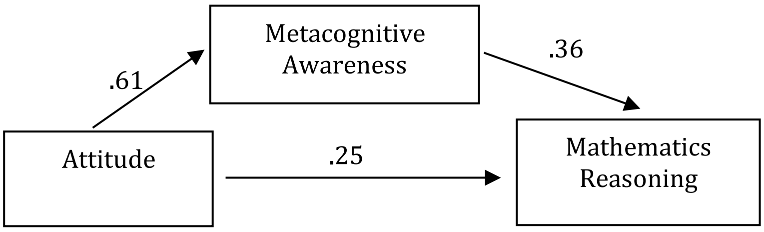

Figure 1. Attitude on Mathematics Reasoning as Direct Effect

The impact path of attitude on mathematics reasoning is illustrated in Figure 2, and the path coefficient (.14) also refers to the overall effect of attitude on mathematics reasoning. The present investigation investigates when another component, the mediator variable, represented by metacognitive awareness, influences mathematical reasoning. As an outcome of this research, the mediation analysis includes at least three variables: attitude, metacognitive awareness, and mathematical reasoning.

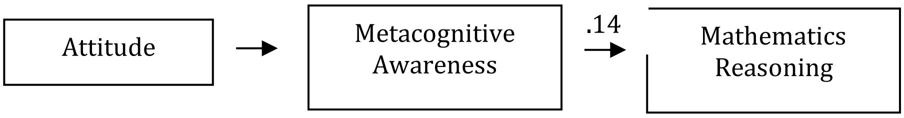

Figure 2. Attitude on Mathematics Reasoning as Indirect Effect

Table 5 illustrates the path coefficients for direct and indirect impacts. The first model investigates the influence of attitude on metacognitive awareness (F(11.836)=62.19, R = .60, $p < .01$). The absence of a zero value in the confidence interval (94% CI= .766, 1.046) indicated that the observed impact was substantial (Denis, 2021). Attitude influenced metacognitive awareness positively, significantly, and substantially ($\beta = .628$, $p < .001$). The findings indicate that attitude has an immediate beneficial impact on metacognitive awareness. The standard deviation of undergraduate students' metacognitive awareness was 14.737, whereas the standard deviation of attitude among undergraduate education students was 7.941. The research hypothesis is accepted that a relationship exists between attitude and metacognitive awareness among mathematics and science students and non-mathematics and science students.

Table 5. Direct and Indirect Effects of the Research Model

Model	β	t	B	SE	Sig	ULCI	LLCI
AT →MA (Direct Effect) **Model 1**	.628	10.884	1.056	.097	.00***	1.247	.865
AT→MR (Direct Effect) **Model 2**	.179	2.274	.097	.043	.024	.167	.013

Table 5. Continued

Model	β	t	B	SE	Sig	ULCI	LLCI
MA→MR (Direct Effect) **Model 3**	.152	2.287	.058	.025	.023	.118	.007
AT →MA→MR (Indirect Effect) **Model 4**		6.793	23.126	2.960	.00***	28.446	15.345

*** p < .005, MA= Metacognitive Awareness, AT= attitude, MR= Mathematics Reasoning, ULCI = Upper Limit of the Confidence Interval, LLCI= Lower Limit of the Confidence Interval

The influence of attitude on mathematical reasoning has been demonstrated in Model 2 (F (2.274) = 20.13, R = .18, p < .01). The estimated confidence intervals for attitude and mathematical reasoning (95% CI = .01, .17) did not include zero values, suggesting that the indicated effects were significant statistically (Denis, 2021). Attitude (β = .18, p < .001) substantially impacted mathematical reasoning. The research hypothesis is accepted that a relationship exists between attitude and mathematics reasoning among mathematics and science students and non-mathematics and science students.

The influence of metacognitive awareness on mathematical reasoning (F (2.287) = 21.44, R = .15, p <.001) is significant in Model 3. The absence of a zero value in the confidence interval (95% CI = .07, .12) indicated that the identified impact was significant (Denis, 2021). Metacognitive awareness influenced mathematical reasoning positively and significantly (β = .15, p < .001). Furthermore, the standard deviation of metacognitive awareness was 3.28, whereas the standard deviation of mathematical reasoning was 4.05. The research hypothesis is accepted that a relationship exists between metacognitive awareness and mathematics reasoning among mathematics and science students as well as non-mathematics and science students.

The subsequent examination in Model 4 investigated the indirect influence of attitude on mathematical reasoning abilities. As the confidence interval (95% CI = 15.35, 28.45) demonstrated, the indirect effect (β = 23.13, p < .001) was statistically significant. According to the considerable indirect impact, metacognitive awareness mediated the association between attitude and mathematical reasoning. The research hypothesis is accepted that a relationship exists between attitude, metacognitive awareness, and mathematics reasoning among mathematics and science students and non-mathematics and science students.

Discussion

The current research examines the relationship between attitude, metacognitive awareness, and mathematical reasoning among Mathematics and Science education undergraduate students and non-Mathematics and Science undergraduates. It also investigated whether attitude prompted variations in metacognitive awareness towards mathematical reasoning. The results demonstrated that a relationship exists between attitude and mathematics reasoning among mathematics and science students and non-mathematics and science students. University course instruction is critical in mathematics education and may lead to variances in attitude toward achievement in mathematics. Several researchers, however assert that there is no distinction in the attitude towards mathematics courses (Niepel et al., 2018; Turra et al., 2019). This present finding is aligned with earlier research attributing the attitude of mathematics learning differ according to learning or other environmental factors (Duque & Tan, 2018; León-Mantero et al., 2020)

Previous studies revealed that students' mathematical reasonings vary. Unlike previous research, the current study contends that the difference may be in mathematics comprehension (Battista, 2017; Tak et al., 2022a). Several students' interpretations of the sequences are less comprehensive, and they often misinterpret the practices and reach inaccurate interpretations (Kartono & Shora, 2020; K. E. Lestari et al., 2022). Some students use traditional algorithmic reasoning techniques (Nurjanah et al., 2020; Risnawati et al., 2019). Furthermore, some students performed better than others in forming proper assumptions about mathematical sequences, comprehending mathematical issues, and assessing the quality of solutions (Simanjuntak et al., 2019; Zayyadi & Kurniati, 2018).

An understanding of mathematics requires solid cognitive skills. One of the conclusions drawn from this study is that a relationship exists between metacognitive awareness and mathematics reasoning among mathematics and science students and non-mathematics and science students. These findings align with other researchers who found that students knew more about metacognitive techniques (Brown, 1987; Flavell, 1979). According to earlier studies (Abdelrahman, 2020; Amir MZ et al., 2021; Asy'ari et al., 2019; Naufal et al., 2021; Ramli et al., 2019; Tak et al., 2022a), there are differences in students' cognitive approaches to mathematics.

One important finding from the present research is that metacognitive awareness partly influences the attitude difference in mathematical reasoning. Students who lack metacognitive abilities cannot carry out cognitive activities such as planning, evaluating, and assessing learning progress. In this sense, despite these undergraduates being intelligent and motivated, they are less likely to excel academically. According to the findings, students with a high degree of mathematical metacognition can analyze, manage, and regulate cognitive processes in mathematics reasoning (W. Lestari & Jailani, 2018; Tak et al., 2022b, 2023).

The present research examines the relationship between attitude and mathematical reasoning and the role of metacognitive awareness as a mediator. The research findings indicate that metacognitive awareness can influence mathematical reasoning performance, and high metacognitive awareness impacts undergraduates' mathematical reasoning skills based on the present research findings. The research suggested that instructors incorporate critical thinking in mathematics education to establish attitudes and increase students' mathematical reasoning abilities. This research also suggests further investigation of model studies with varied populations. In order to increase students' attitudes and metacognitive awareness, the researcher advises various learning methodologies for mathematical reasoning.

Conclusion

The current research found that metacognitive awareness moderated attitude differences in mathematical reasoning. Academic knowledge that aids mathematical reasoning has demonstrated variations in attitude and metacognitive awareness among undergraduate students. The present research solely includes undergraduate education students, which limits the generalisability of the findings. This research may generalise and clarify the links between mathematical reasoning, metacognition awareness, and attitude among undergraduates. Finally, this research discovered that attitude-mediated metacognitive awareness in mathematical reasoning was positively significant among undergraduate students.

Recommendations

The present study results show that increased metacognitive awareness influences mathematical reasoning performance. The study also proposed that including reasoning elements in instruction in mathematics increases students' metacognitive awareness, which helps them improve their mathematical reasoning abilities. The following research should undertake a broader and diversified model research.

Limitations

The current research is the limitation to education undergraduates in Klang Valley, Malaysia, and does not generate pre-service teachers in Teacher Training Institutions in the same area.

Ethics Statements

The studies involving individuals were evaluated and authorised by the University of Malaya (Reference no: UM.TNC2/UMREC_1907). The participants gave their written informed permission to participate in this research.

Authorship Contribution Statement

Each author contributed significantly to the article's idea or design or the collection, analysis, or interpretation of data for the research and produced or revised it critically for important intellectual content.

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