

Research Article

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Author for correspondence:

Apantee Poonputta

✉ oomsin.putta@gmail.com

✉ Mahasarakham University, Thailand

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Causal Factors Influencing the Mathematical Reasoning Ability of Grade 6 Students

Kamonporn Khontee^{id}, Apantee Poonputta^{id}

Abstract

Background/purpose. This study aimed to develop and validate a causal model of factors influencing the mathematical reasoning ability of Grade 6 students in Thailand.

Materials/methods. The sample consisted of 530 students selected through multi-stage random sampling. Research instruments included a basic mathematics knowledge test, a mathematical reasoning ability test, and a set of validated scales measuring attitude toward mathematics, achievement motivation, mathematical self-efficacy, and learning behavior. Data were analyzed using descriptive statistics, confirmatory factor analysis (CFA), and structural equation modeling (SEM).

Results. The findings showed that prior knowledge in mathematics, learning behavior, achievement motivation, and attitude toward mathematics had significant direct effects on mathematical reasoning ability. Mathematical self-efficacy indirectly influenced reasoning through achievement motivation. The model demonstrated strong goodness-of-fit with the empirical data.

Conclusion. The results contribute to the understanding of reasoning ability as a distinct construct and emphasize the importance of cognitive, affective, and behavioral factors in mathematics education at the primary level in Thailand. Implications for curriculum design, classroom practice, and educational policy are discussed.

1. Introduction

Mathematics education in the 21st century has focused on supportive skills in developing mathematics competencies (Borovik et al., 2022; Seah et al., 2021). One of the skills playing a crucial role in the success of mathematical problem solving is the ability to reason mathematically, which enables learners to apply logical thinking to quantitative problems in a similar way and develop analytical skills applicable across disciplines. As mathematics education increasingly emphasizes understanding over rote memorization, the development of reasoning skills has gained critical attention among educators and policymakers worldwide (Hjelte et al., 2020; Sundstrom, 2003). For primary school students, equipping them with this ability at an early stage lays the foundation for higher-order thinking and future academic pursuits.

However, it must be noted that mathematical reasoning is a challenging task for both students and educators to manage (Amaliya et al., 2024; Herbert, 2021). Especially in primary education, where conceptual understanding is still forming, a certain number of students might struggle to make a connection between components in order to provide mathematical reasons (Hs et al., 2023). Scholars have identified various factors influencing mathematical reasoning, such as prior knowledge, self-efficacy, motivation, and learning behavior (Hartati et al., 2020; Montague, 2007; Sholihah & Listanti, 2022). However, the interplay among these factors and how they jointly affect students' reasoning abilities remains underexplored. Moreover, existing studies (De León et al., 2022; Ismail et al., 2024; Jabri et al., 2022; Sahrin & Muhammad, 2024; Sari et al., 2022; Tee et al., 2018) often focus on isolated variables rather than holistic models, limiting their ability to inform instructional practice in meaningful ways.

In Thailand, improving mathematics performance has become a national priority, particularly at the basic education level (Ministry of Education, 2008). According to recent national assessments, students in rural and semi-urban regions face persistent challenges in developing core mathematical competencies (Thongphat, 2012; Unicef, 2014). In fact, the whole mathematics education system has been proven to have problems by the evidence of test results (OECD, 2022), scholarly published studies (Tiengyoo et al., 2024), and the status of the country as a technology importer rather than an innovation developer. Understanding the underlying causal factors that contribute to students' reasoning skills in such contexts is vital for designing effective interventions, teacher training programs, and learning environments tailored to students' needs.

This study, therefore, seeks to investigate the causal factors influencing the mathematical reasoning ability of Grade 6 students in the Thai context. Utilizing structural equation modeling (SEM), the research aims to identify both direct and indirect influences of psychological, behavioral, and academic variables on students' reasoning ability. The study contributes to a more insightful understanding of how multiple elements interact to shape students' learning outcomes in mathematics, which could offer practical details for curriculum designers, educators, and educational administrators.

2. Literature Review

2.1. Mathematical Reasoning Ability

Mathematical reasoning ability is correlated with the cognitive capacity to establish logical connections between known facts and derive valid conclusions based on evidence and analysis (Negara et al., 2024). The process involves various reasoning forms, such as deductive, inductive, and abductive reasoning (Marasabessy, 2021), and recognizing patterns like validating statements and constructing arguments. According to Sundstrom (2003), reasoning can be considered a foundational process in constructing mathematical knowledge that also plays a critical role in intellectual activity, leading to reliable decision-making in both academic and everyday contexts. The National Council of

Teachers of Mathematics (NCTM, 2014) defines mathematical reasoning as the ability to analyze mathematical situations, form logical conclusions, and evaluate solutions, interpretations, and arguments. It could be noted that reasoning competence is considered an integral part of understanding and learning mathematics itself, not just a supporting skill.

The importance of mathematical reasoning becomes especially evident in the context of mathematical problem-solving. To demonstrate, students with strong reasoning skills are more capable of analyzing problems, identifying relevant information, and choosing appropriate strategies to arrive at solutions. The Thai Education's core curriculum (Ministry of Education, 2008) emphasized reasoning as a core objective, requiring students to analyze patterns, perform mathematical manipulations, construct logical arguments, and generalize findings. The competencies are strongly connected with worldwide standards, like PISA and TIMSS, which emphasize reasoning as a fundamental mathematical process. Consequently, reasoning ability serves both as a distinct learning objective and a conduit to advanced cognitive processes and mathematical success.

Regarding developing mathematical reasoning skills, studies (e.g., Negara et al., 2024; Seepiwsiw & Seehamongkon, 2023) suggest such components as inquiry, reflection, and justification as effective components of the learning environment. The classroom should be managed to encourage students to make conjectures, perform logical operations, explain their thought processes, and generalize findings that are essential for building reasoning competence. Moreover, students should be supplied with the opportunity to present assumptions with logical justifications, manipulating mathematical expressions, citing evidence for their claims, and formulating conclusions based on observed patterns.

Despite the known importance of mathematical reasoning, international assessments such as PISA, TIMSS, and OECD surveys have reported persistently low scores in mathematics among students in many countries, including Thailand (OECD, 2022). These results highlight an ongoing gap between curriculum goals and actual student performance. In particular, reasoning deficits are often cited as key contributors to underachievement in mathematics. This underperformance suggests that while reasoning is emphasized in national curricula, its practical development in classrooms remains insufficient. Thus, more focused efforts are needed to integrate reasoning-based practices in mathematics instruction, particularly at the primary level, where foundational skills are established.

2.2. Factors Influencing Mathematical Reasoning Ability

Research in mathematics education (e.g., Hartati et al., 2020; Montague, 2007; Sholihah & Listanti, 2022) consistently emphasizes that mathematical reasoning ability is influenced by various psychological, academic, and behavioral factors. Among these, attitudes toward mathematics, achievement motivation, mathematical self-efficacy, foundational mathematical knowledge, and students' learning behaviors have received substantial attention for their contributions to learners' cognitive development.

Attitudes toward mathematics are considered a critical affective component influencing students' participation and persistence in mathematical learning. Learners who hold positive attitudes toward mathematics tend to demonstrate greater interest and willingness to participate in reasoning-oriented tasks. According to Marasabessy (2021), favorable attitudes are often linked to students' ability to generalize patterns and validate statements through logical reasoning. Another prominent factor is achievement motivation, which reflects students' internal drive to succeed and their goal orientation in academic tasks. Research (e.g., Hossein-Mohand & Hossein-Mohand, 2022; Pantziara & Philippou, 2015; Saadati & Celis, 2023) suggests that students with high levels of motivation are more likely to engage in complex mathematical processes, including reasoning, problem-solving, and argumentation. Students with strong motivation put a full-potential effort to apply higher-order thinking skills to mathematical challenges.

Moreover, mathematical self-efficacy - students' beliefs in their capability to perform mathematics tasks has been associated with increased confidence in reasoning, a greater willingness to tackle unfamiliar problems, and persistence in overcoming difficulties (Montague, 2007). Self-efficacy is often seen as a mediator that enhances motivation, which in turn promotes reasoning ability. In addition, mathematical knowledge provides the conceptual and procedural understanding necessary for reasoning to occur. Students are less likely to form accurate generalizations or validate logical arguments without adequate mastery of core mathematical concepts. As highlighted in the NCTM (2014) and PISA in 2018 frameworks (OECD, 2019), reasoning and content knowledge are interdependent and should be developed simultaneously to ensure deep mathematical understanding.

Finally, mathematics learning behaviors, including active participation, task completion, self-regulation, and help-seeking, also play an important role in supporting reasoning development. Research (Mansi, 2003) underscores the role of classroom practices that encourage such behaviors in developing reasoning skills as those who exhibit effective learning behaviors are more likely to engage with reasoning-based tasks and reflect on their mathematical thinking.

2.3. Previous Studies on Mathematical Reasoning Factor Analysis

Recent studies (e.g., De León et al., 2022; Ismail et al., 2024; Jabri et al., 2022; Sahrin & Muhammad, 2024; Sari et al., 2022; Tee et al., 2018) have increasingly examined the various factors influencing mathematical abilities, particularly those related to reasoning skills, through the use of confirmatory factor analysis (CFA) and structural equation modeling (SEM). These investigations reveal that a single variable rarely determines mathematical performance; instead, it results from the interaction of multiple cognitive, affective, and behavioral elements. For example, Tee et al. (2018) conducted a study to investigate the direct and mediating effects of motivation-related factors—specifically, self-efficacy, task value, and mastery goal orientation—on mathematical reasoning ability. The study revealed that task value and critical thinking skills were significant predictors of reasoning performance, while critical thinking also served as a full mediator between mastery goal orientation and reasoning ability.

In a more instrument-focused study, Sari et al. (2022) applied second-order CFA to validate mathematical reasoning and proof instrument integrated with GeoGebra. Testing four key dimensions—creative mathematical reasoning (CMR), imitative reasoning (IR), formal proof (FP), and empirical proof (EP)—on 300 Indonesian high school students, they found that all items demonstrated unidimensionality and strong factor loadings. Similarly, Ismail et al. (2024) validated an instrument designed to assess higher-order thinking skills in mathematics—encompassing logic, reasoning, analysis, evaluation, creation, and decision-making among Indonesian junior high school students. Their findings further affirm the foundational role of reasoning within the broader structure of higher-order thinking. De León et al. (2022) analyzed the construct of number sense among second-grade students in Spain by using CFA and supported the idea that foundational mathematical knowledge—like number sense—is a latent factor that underlies early mathematical reasoning development.

Affective dimensions were also the focus of the study by Sahrin and Muhammad (2024), who explored students' interest across five mathematical content domains (number and operations, geometry, algebra, statistics and probability, and discrete mathematics). They suggested that students' interest in various domains can be reliably measured and potentially linked to reasoning engagement and performance. Jabri et al. (2022) used SEM and CFA to investigate four student-related dimensions—study habits, interest, language, and perception—influencing performance in Basic Mathematics at the college level in Oman. Among these, study habits emerged as the most significant predictor of achievement. The study emphasized the importance of cultivating effective

learning behaviors early in students' academic journeys to enhance mathematical reasoning and reduce dropout rates.

Although previous studies have contributed significantly to understanding the factors influencing mathematical ability through advanced statistical modeling such as CFA and SEM, the specific focus on mathematical reasoning ability remains underexplored. While several investigations have addressed general mathematical performance, higher-order thinking skills, or affective factors such as motivation and interest, few studies have isolated mathematical reasoning as the central construct for analysis. Moreover, most of the existing research has been conducted with secondary or higher education students, leaving a noticeable gap in the examination of reasoning abilities among primary school students, particularly those at the transitional stage of upper elementary education. Additionally, research on this topic within the context of Thai education is limited despite ongoing national concerns regarding mathematics performance in international assessments. These gaps underscore the need for studies that examine the causal factors of mathematical reasoning ability using rigorous analytical frameworks in primary-level Thai classrooms. Therefore, the present study aims to develop and validate a causal model to explain the factors influencing mathematical reasoning ability among Grade 6 students in Thailand. The purposes of the studies were to develop and validate a causal model of factors influencing the mathematical reasoning ability of Grade 6 students in Thailand and to examine the influence of factors affecting the mathematical reasoning ability of Grade 6 students in Thailand.

3. Methodology

3.1. Research Design

The current study employed a quantitative research design using structural equation modeling (SEM) to analyze the causal relationships between multiple observed and latent variables influencing students' mathematical reasoning ability. The design involved developing and validating a measurement model using confirmatory factor analysis (CFA), followed by structural model analysis to determine direct and indirect effects among variables.

3.2. Participants

The population of this study consisted of 3,665 Grade 6 students from 246 schools under the jurisdiction of the Mukdahan Primary Educational Service Area Office during the second semester of the 2024 academic year. Based on Kline's (2011) recommendation that sample size should be 10 to 20 times the number of observed variables in a model, and with 21 observed variables included in this study, the appropriate sample size was calculated to be at least 420. To enhance statistical power and ensure representation, the sample was expanded to 530 students.

A multi-stage random sampling technique was used to select participants. First, 50% of the districts within the Mukdahan Primary Educational Service Area were randomly selected using simple random sampling, yielding four districts. Next, schools within these districts were categorized by size—large (4 schools), medium (63 schools), and small (116 schools). A simple random sampling method was applied to each category to select 15% of schools, resulting in a sample of 1 large school, 9 medium-sized schools, and 17 small schools, for a total of 27 schools. The final sample included 530 students across 31 classrooms. The overview process of random sampling can be seen in Figure 1.

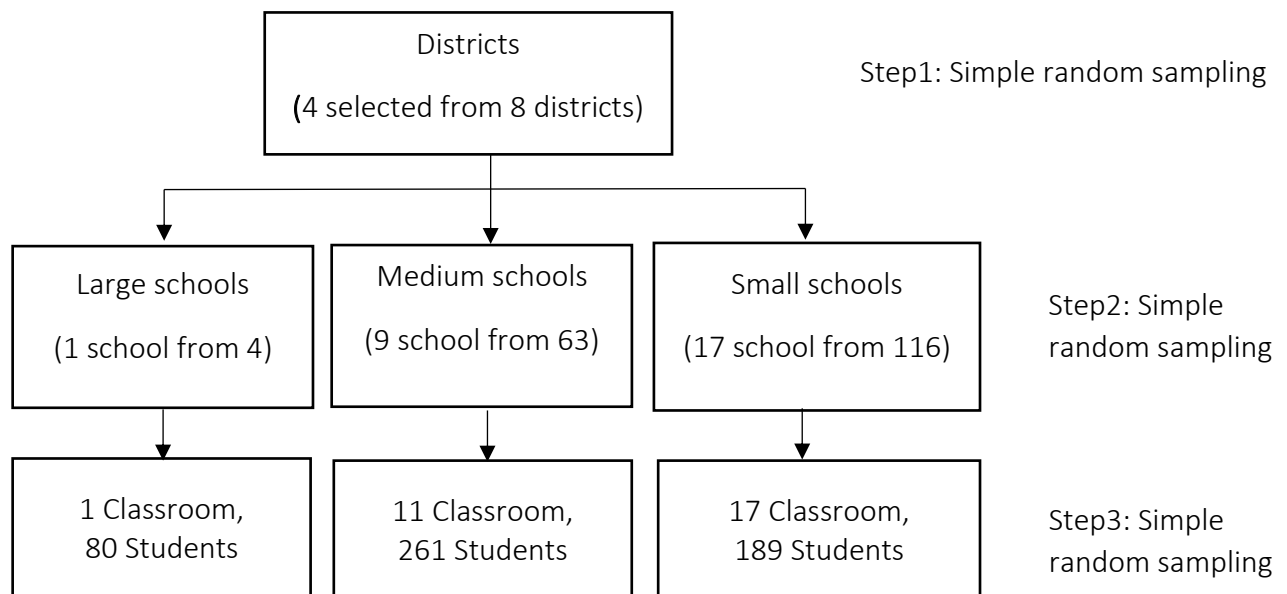


Figure 1. Overview of the Multi-Stage Random Sampling Process

3.3. Instruments

Three types of instruments were used in this study: two mathematics tests and one set of questionnaires measuring the influencing factors. Research instruments are presented in Table 1.

Table 1. Research Instruments

Types Instruments	Characteristics	Validity (IOC)	Difficulty (P)	Discriminant	Reliability
1. mathematics tests					
1.1 Mathematical Reasoning Ability Test (MRA)	Multiple choice, 30 item	0.60 - 1.00.	0.20-0.80	0.33-0.74	KR-20 = 0.92
1.2 Prior Knowledge in Mathematics Test (PKM)	Multiple choice, 20 item	0.60 - 1.00.	0.20-0.80	0.30-0.80	KR-20 = 0.95
2. questionnaires					
2.1 Attitude Toward Mathematics (ATM)	Rating Scale, 10 item	0.60 - 1.00.	-	0.36–0.65	α -coefficient = 0.84
2.2 Achievement Motivation (AM)	Rating Scale, 10 item	0.60 - 1.00.	-	0.51–0.65	α -coefficient = 0.84
2.3 Mathematical Self-Efficacy (MSE)	Rating Scale, 10 item	0.60 - 1.00.	-	0.33–0.81	α -coefficient = 0.90
2.4 Learning Behavior in Mathematics (LM)	Rating Scale, 10 item	0.60 - 1.00.	-	0.53–0.81	α -coefficient = 0.92

3.3.1. Mathematical Reasoning Ability Test

This test measured students' mathematical reasoning skills. The IOC values ranged from 0.60 to 1.00. The test was developed with the difficulty ($p = 0.20-0.80$), the discrimination ($r = 0.33-0.74$), and the reliability coefficient ($KR-20 = 0.92$).

3.3.2. Prior Knowledge in Mathematics Test

This instrument assessed students' foundational mathematical knowledge. The Index of Item-Objective Congruence (IOC) ranged from 0.60 to 1.00. The test was developed with a difficulty ($p = 0.20-0.80$), a discrimination ($r = 0.30-0.80$), and a reliability coefficient ($KR-20 = 0.95$).

3.3.3. Scale Measuring Factors Influencing Mathematical Reasoning Ability

This instrument consisted of four components: Attitude Toward Mathematics, Achievement Motivation, Mathematical Self-Efficacy, and Learning Behavior in Mathematics. The Attitude Toward Mathematics scale demonstrated content validity (IOC = 0.60–1.00), item discrimination ($r_{xy} = 0.36-0.65$), and reliability ($\alpha = 0.84$). The Achievement Motivation scale showed content validity (IOC = 0.60–1.00), item discrimination ($r_{xy} = 0.51-0.65$), and reliability ($\alpha = 0.84$). The Mathematical Self-Efficacy scale demonstrated content validity (IOC = 0.60–1.00), item discrimination ($r_{xy} = 0.33-0.81$), and reliability ($\alpha = 0.90$). The Learning Behavior in Mathematics scale demonstrated content validity (IOC = 0.60–1.00), item discrimination ($r_{xy} = 0.53-0.81$), and reliability ($\alpha = 0.92$).

3.4. Data Collection and Data Analysis

The validated instruments were administered to the sample group following coordination with school administrators and classroom teachers. The researcher collected data according to a predetermined schedule, with test administration supported by school staff to ensure consistency.

Following data collection, the analysis was carried out in several stages. First, the quality of the instruments was examined by analyzing item difficulty, discrimination indices, and reliability coefficients for both mathematics tests and the factor measurement scales. Next, descriptive statistics were computed, including means, standard deviations, and Pearson's correlation coefficients, to explore the relationships among the study variables. Subsequently, Confirmatory Factor Analysis (CFA) was employed to assess the validity of the measurement model and ensure that the observed variables accurately reflected their respective latent constructs. Finally, Structural Equation Modeling (SEM) was used to evaluate the proposed causal model's goodness-of-fit and examine the direct and indirect effects of the influencing factors on students' mathematical reasoning ability. The structural model was assessed following the following criteria in Table 2. (Byrne, 1994, 1998 ; Damrongpanit, 2012 ; Wiratchai, 1999).

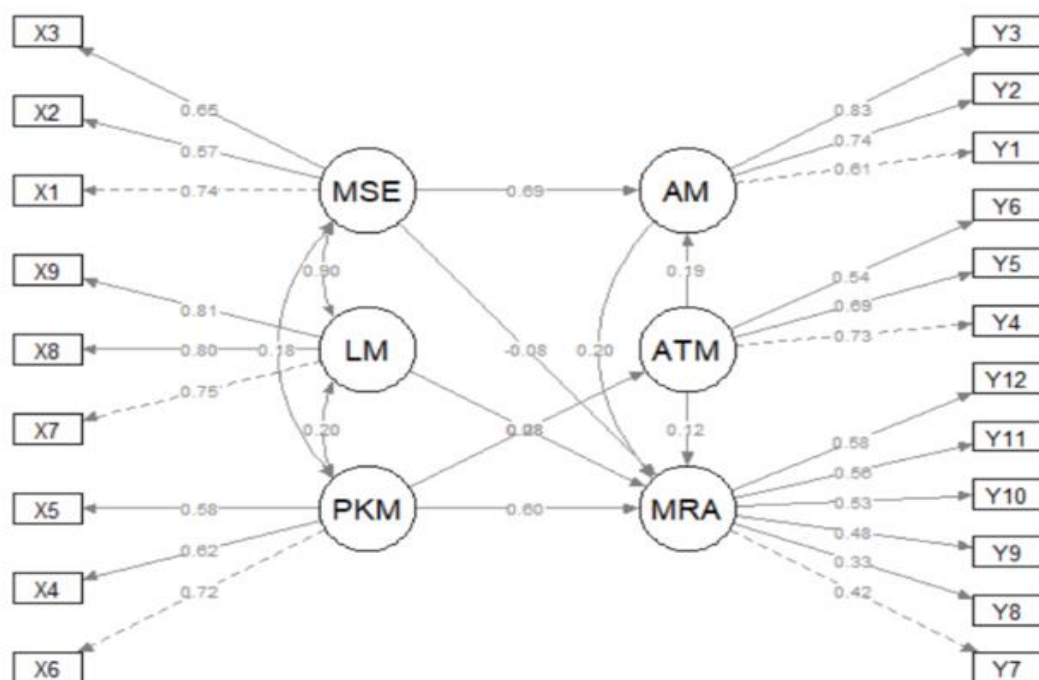
Table 2. Criteria for Assessing the Model's Alignment with Actual Data

Abbreviation	Full Name	Criterion
χ^2/df	Relative Chi-square	< 2 ,
P-value	Probability value	$> .05$
TLI	Tucker-Lewis Index	≥ 0.90
RMSEA	Root Mean Square Residual Error of Approximation	< 0.05
SRMR	Standardized Root Mean Square Residual	< 0.05
GFI	Goodness of Fit Index	> 0.90
AGFI	Adjusted Goodness Fit Index	≥ 0.90
CFI	Comparative Fit Index	≥ 0.95

4. Results

When analyzing the causal model influencing the mathematical reasoning ability of Grade 6 students under the jurisdiction of the Mukdahan Primary Educational Service Area Office prior to model modification, it was found that the P-value was less than .001, which does not meet the criterion of $p > .05$ (indicating non-significance). The Chi-square value was 360 with 178 degrees of freedom (df). According to the criterion, the Chi-square/df ratio should be less than 2.00, which this model meets. The RMSEA value was 0.044, which is acceptable as it approaches 0 (acceptable if $< .05$). However, the SRMR was 0.059, which exceeds the acceptable threshold ($< .05$). The GFI was 0.995 and the AGFI was 0.993, both of which met the required standards. Meanwhile, the CFI was 0.941, which falls short of the desired value ($\geq .95$), indicating that the model did not sufficiently fit the empirical data.

Based on these results, the hypothesized causal model influencing mathematical reasoning ability did not fit adequately with the observed data. Therefore, the researcher proceeded to modify the model by considering theoretical plausibility and consulting the Model Modification Indices (MMI), as illustrated in Figure 2.



Chi-square=360 , df=178 , P-value=0.001 , RMSEA=0.044

Figure 2. The Causal Model Influencing the Mathematical Reasoning Ability of Grade 6 Students (Before Model Modification)

After the model modification, the causal model influencing the mathematical reasoning ability of Grade 6 students under the jurisdiction of the Mukdahan Primary Educational Service Area Office demonstrated improved fit. The fit indices for the revised model were as follows: P-value = .656, indicating non-significance ($p > .05$), Chi-square = 137, with degrees of freedom (df) = 144, resulting in a Chi-square/df ratio of 0.951, which meets the acceptable criterion (< 2.00). The RMSEA value was 0.000, and the SRMR was 0.049, both indicating excellent fit as they are less than 0.05. Additionally,

the Goodness of Fit Index (GFI) = 0.998, Adjusted Goodness of Fit Index (AGFI) = 0.997, and the Comparative Fit Index (CFI) = 1.000, all of which meet or exceed the established thresholds.

These values confirm that the modified causal model is consistent with the empirical data and demonstrates a good fit. The final model is illustrated in Figure 3.

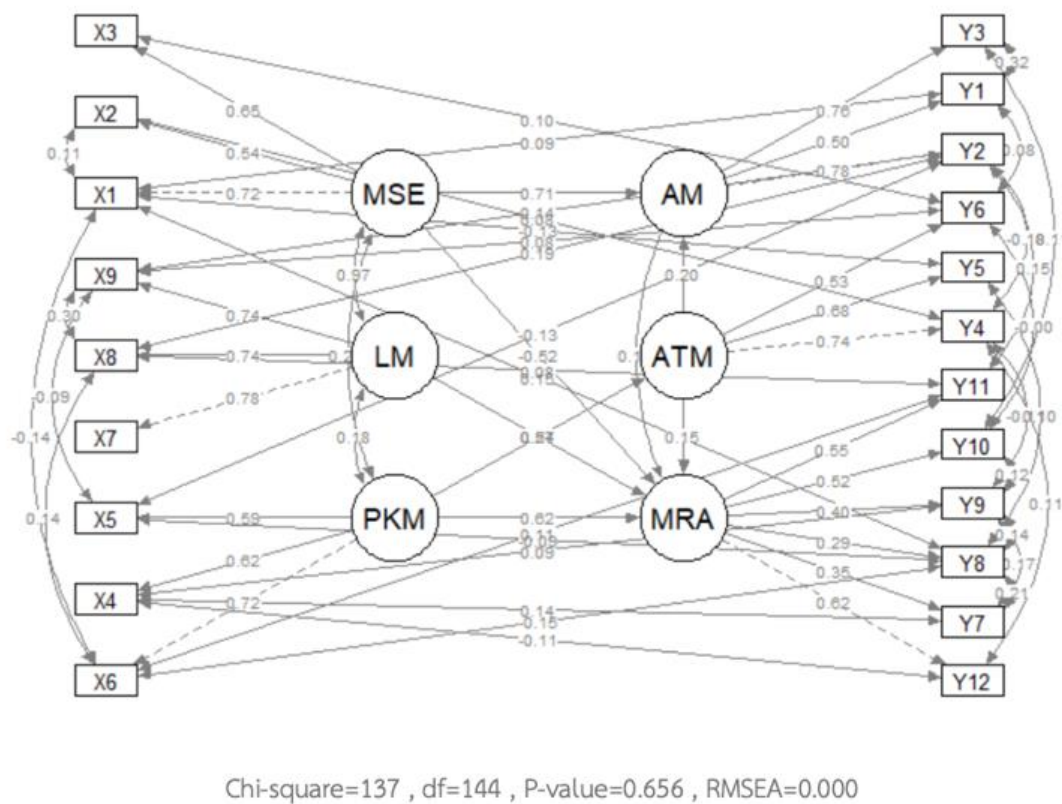


Figure 3. The Causal Model Influencing the Mathematical Reasoning Ability of Grade 6 Students (After Model Modification)

Results of the Model Fit Analysis of the Causal Factors Influencing the Mathematical Reasoning Ability of Grade 6 Students are presented in Table 1.

Table 1. Model Fit Indices of the Causal Factors Influencing the Mathematical Reasoning Ability of Grade 6 Students

Latent Variables	Observed Variables	R^2	Factor Loading			
			b_{SC}	S.E.	T	P
MSE	X1	.519	0.720	<- ->	<- ->	<- ->
	X2	.294	0.542	0.056	11.98	<.01
	X3	.423	0.650	0.061	13.50	<.01
PKM	X6	.5143	0.717	<- ->	<- ->	<- ->
	X5	.3477	0.590	0.067	10.04	<.01
	X4	.3848	0.620	0.078	10.12	<.01
LM	X7	.609	0.781	<- ->	<- ->	<- ->
	X8	.543	0.737	0.056	15.90	<.01

Latent Variables	Observed Variables	R^2	Factor Loading			
			b_{SC}	S.E.	T	P
MRA	X9	.551	0.743	0.056	16.01	<.01
	Y12	.386	0.542	<- ->	<- ->	<- ->
	Y8	.120	0.288	0.075	5.10	<.01
	Y9	.160	0.400	0.089	6.62	<.01
	Y10	.268	0.517	0.099	8.26	<.01
	Y11	.304	0.551	0.100	8.55	<.01
ATM	Y7	.122	0.552	0.091	6.07	<.01
	Y4	.542	0.736	<- ->	<- ->	<- ->
	Y5	.465	0.682	0.093	9.73	<.01
	Y6	.286	0.535	0.082	9.11	<.01
AM	Y2	.616	0.785	<- ->	<- ->	<- ->
	Y1	.249	0.499	0.055	9.30	<.01
	Y3	.584	0.764	0.067	13.50	<.01

$R^2 = 0.5286$

Chi-square = 137 , df=144, p = 0.656, $\chi^2/df = 0.951$ CFI = 1.00 TLI = 1.00

RMSEA = .000 , SRMR = .049, GFI=0.998, AGFI=0.997

Note: b_{SC} refers to standardized factor loadings. The symbol <- -> indicates constrained parameters; therefore, standard error (S.E.), t-value, and p-value are not reported.

Table 1 indicates that the factor loadings of all observed variables in the measurement model of the causal factors influencing mathematical reasoning ability were found to range from .288 to .785. All factor loadings were statistically significant at the .01 level.

The analysis of direct, indirect, and total effects of the predictor variables influencing mathematical reasoning ability is presented in Table 2.

Table 2. Direct, Indirect, and Total Effects in the Structural Equation Model

Predictor Variables	Direct Effect (DE)	Indirect Effect (IE)		Total effect (TE)
		ATM	AM	
Attitude Toward Mathematics (ATM)	0.146**	-	0.199**	0.345**
Achievement Motivation (AM)	0.157**	-	-	0.157**
Mathematical Self-Efficacy (MSE)	-0.524	-	0.709**	0.709**
Prior Knowledge in Mathematics (PKM)	0.622**	0.272**	-	0.894**
Learning Behavior in Mathematics (LM)	0.538**	-	-	0.538**

** $p < .01$

The results in Table 2 reveal that Prior Knowledge in Mathematics (PKM) had a direct effect on mathematical reasoning ability with a standardized coefficient of 0.622 ($p < .01$); Learning Behavior in Mathematics (LM) had a direct effect with a coefficient of 0.538 ($p < .01$); Achievement Motivation (AM) had a direct effect with a coefficient of 0.157 ($p < .01$); and Attitude Toward Mathematics (ATM) also had a direct effect with a coefficient of 0.146 ($p < .01$). In contrast, Mathematical Self-Efficacy (MSE) had a direct effect of -0.524 on mathematical reasoning ability, indicating a negative relationship. Regarding indirect effects, the results showed that MSE influenced AM with a coefficient of 0.709 ($p < .01$); PKM influenced ATM with a coefficient of 0.272 ($p < .01$); and ATM influenced AM with a coefficient of 0.199 ($p < .01$). In terms of total effects, the analysis indicated that PKM had the strongest total effect on mathematical reasoning ability, with a coefficient of 0.894, while AM had the weakest total effect, at 0.157.

The overall relationships among variables in the model are illustrated in Figure 4.

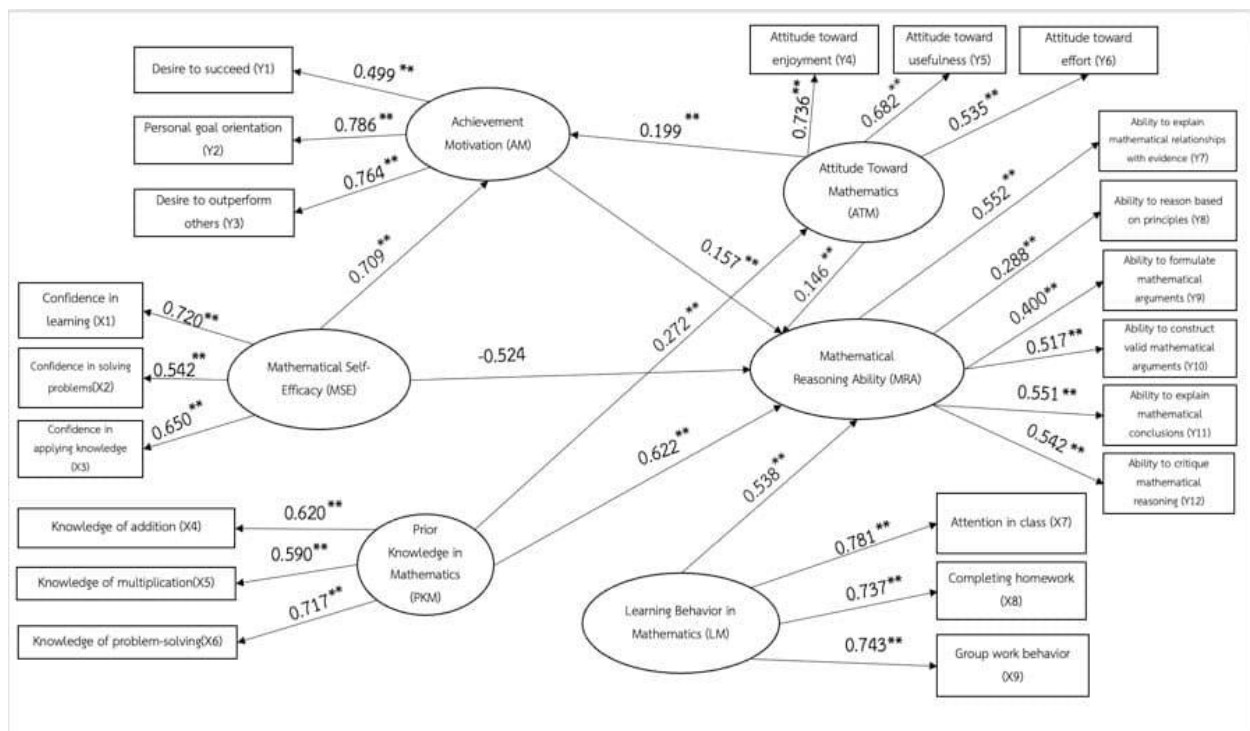


Figure 4. Causal Model Influencing the Mathematical Reasoning Ability of Grade 6 Students

5. Discussion

The results of this study revealed that mathematical reasoning ability (MRA) in Grade 6 students was influenced by both cognitive and affective-behavioral factors through direct and indirect effects. Specifically, prior knowledge in mathematics (PKM), learning behavior in mathematics (LM), achievement motivation (AM), and attitude toward mathematics (ATM) were found to have significant direct effects on MRA. Among these, PKM and LM had the strongest direct impacts, while AM and ATM contributed more moderately. Although mathematical self-efficacy (MSE) did not directly affect MRA, it exhibited a strong indirect effect through its influence on AM. Additionally, PKM indirectly influenced MRA through ATM, and ATM further influenced AM, forming a chain of interconnected effects that support the complexity of mathematical reasoning development.

Prior knowledge in mathematics (PKM) exerted the highest total influence on MRA. This indicates that students with strong foundational mathematical knowledge are more capable of generalizing, identifying patterns, and constructing logical arguments. As reasoning tasks often require retrieving and manipulating prior knowledge, a solid grasp of mathematical operations such as addition, multiplication, and problem-solving naturally facilitates reasoning. This finding is consistent with De

León et al. (2022), who emphasized the importance of number sense in explaining reasoning ability, and aligns with NCTM (2014), which regards reasoning and content knowledge as interdependent components of mathematical understanding.

Learning behavior in mathematics (LM) was the second strongest predictor of MRA. Students who consistently complete assignments, engage in class activities, and collaborate effectively with peers are more likely to internalize concepts and practice reasoning processes. Learning behaviors support cognitive development by promoting active engagement and deeper processing of mathematical tasks. Jabri et al. (2022) similarly found that study habits were a major contributor to math performance, and Sahrin & Muhammad (2024) and Udommontree (2012) validated that interest-driven engagement in mathematics is significantly linked to better outcomes.

Achievement motivation (AM) also showed a positive direct effect on MRA. Students who are driven by personal goals and a desire to succeed are more likely to persist through complex tasks and apply logical strategies to reach conclusions. Motivation enhances cognitive endurance and willingness to explore problem-solving paths, even in the face of difficulty. This supports the findings of Tee et al. (2018), who found that task value and motivation were significant predictors of reasoning performance, especially when mediated by critical thinking.

Attitude toward mathematics (ATM) was found to influence MRA both directly and indirectly through AM. Students who view mathematics as valuable and worthwhile are more inclined to engage meaningfully with mathematical content. Positive attitudes foster openness to learning and a readiness to reason through mathematical challenges. This dual pathway reflects the findings of Ismail et al. (2024) and Udommontree (2012), who argued that positive perceptions of mathematics enhance decision-making and higher-order thinking and support the Thai curriculum's emphasis on cultivating mathematical attitudes (Ministry of Education, 2008)

Mathematical self-efficacy (MSE) did not directly affect MRA; however, it played a significant indirect role by increasing achievement motivation. This suggests that students who believe in their mathematical abilities are more likely to develop internal motivation, which subsequently drives reasoning performance. Although unexpected in terms of its lack of direct effect, this result aligns with Tee et al. (2018), who also found that self-efficacy was not directly related to reasoning, despite of indirect influence of cognitive strategies.

6. Conclusion

This study aimed to develop and validate a causal model of factors influencing the mathematical reasoning ability of Grade 6 students in Thailand. The findings revealed that prior knowledge in mathematics, learning behavior, achievement motivation, and attitude toward mathematics directly influenced students' mathematical reasoning ability, while mathematical self-efficacy influenced it indirectly through motivation. The strongest predictor was prior knowledge, followed by learning behavior, whereas achievement motivation was weakest.

The study contributes to literature by addressing three key research gaps. First, it highlights mathematical reasoning as a distinct and underexplored construct, separated from general mathematics achievement. Second, it focuses on primary school students—an educational level often overlooked in reasoning research. Third, it provides insight into the Thai educational context, where few empirical studies have used structural equation modeling to examine reasoning ability.

However, studying is not without limitations. The sample was limited to students within a single provincial area, which may affect the generalizability of the findings. Additionally, the use of self-report instruments may be subject to bias. Future research should consider expanding the sample across multiple regions and employing longitudinal or mixed-method designs to explore the development of reasoning over time and in diverse classroom settings.

Declarations

Author Contributions. Kamonporn Khontee: Conceptualization, Literature review, Create tools for research, Data collection, Data analysis. Apantee Poonputta: Corresponding author, Methodology, editing, and manuscript preparation, Validation, and critical revisions. All authors have read and approved the final version of the article for publication.

Conflicts of Interest. The authors declare no conflict of interest.

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Ethical Approval. This study was conducted in compliance with ethical standards and was approved by Mahasarakham University under approval number 107-025/2567. All participants provided informed consent prior to participation, and their privacy and confidentiality were protected throughout the study.

Data Availability Statement. The data supporting the results reported in this study are available from the corresponding author upon reasonable request.

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About the Contributor(s)

Kamonporn Khontee, Teacher, Ban Nong Euan Dong Rat Songkroh School

Email: kamonporn.muay@gmail.com

ORCID: <https://orcid.org/0009-0002-3444-2627>

Apantee Poonputta, Assoc. Prof. Dr. Faculty of Education, Mahasarakham University, Mahasarakham, Thailand

Email: oomsin.putta@gmail.com

ORCID: <https://orcid.org/0000-0001-6182-7333>

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