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Mediating role of teacher numeracy in shaping conceptual mathematics teaching perceptions: Evidence from early elementary teachers

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Abstract

Strengthening mathematics learning that emphasizes conceptual understanding places teachers at the center of students' learning success. However, the mechanisms through which teacher competence shapes perceptions of conceptual mathematics teaching remain insufficiently explored, particularly among early elementary school teachers. This study investigated the relationships among mathematical pedagogical knowledge, teacher numeracy skills, and perceptions of mathematical conceptual teaching, as well as the mediating role of teacher numeracy skills. A quantitative survey was conducted involving 885 early elementary school teachers from various regions of Indonesia. Data were collected through an online questionnaire and analyzed using Structural Equation Modeling with a two-step approach. The results showed that mathematical pedagogical knowledge had significant positive effects on teacher numeracy Skills ($\beta = 0.698$, $p < 0.001$) and perceptions of mathematical conceptual teaching ($\beta = 0.172$, $p < 0.001$). Teacher numeracy skills also positively influenced perceptions of mathematical conceptual teaching ($\beta = 0.355$, $p < 0.001$) and partially mediated the relationship between mathematical pedagogical knowledge and perceptions of mathematical conceptual teaching (indirect effect $\beta = 0.248$, $p < 0.001$). This study provides a novel contribution by demonstrating that teacher numeracy skills function not merely as an independent professional competency but as an explanatory mechanism through which mathematical pedagogical knowledge is translated into teachers' perceptions of conceptually oriented mathematics instruction. These findings suggest that teachers' perceptions of conceptually oriented mathematics instruction are shaped not only by pedagogical knowledge but also by their ability to apply mathematics meaningfully in contextual situations. The study highlights the importance of strengthening both pedagogical and numeracy competencies in teacher education and professional development programs.

Keywords:
Mathematical conceptual, Numeracy, Pedagogical knowledge, Structural equation modeling

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1. INTRODUCTION

In recent years, attention has been growing to the quality of mathematics instruction in elementary schools. Various national and international assessment results indicate that students still experience difficulties when faced with problems that require reasoning, conceptual understanding, and the application of mathematics in everyday life situations. Overall, Indonesia's PISA 2022 results saw an increase of 5 to 6 positions compared to 2018, but the average scores for mathematics decreased (OECD, 2019a, 2019b, 2023; Wijaya et al., 2024). Although Indonesia's ranking in PISA 2022 improved by approximately five to six positions compared to PISA 2018, its average mathematics scores declined, indicating that the improved ranking was not accompanied by improved mathematics performance. This PISA condition is in line with the results of the Academic Ability Test released by the Ministry of Primary and Secondary Education, which stated that the national average for elementary school mathematics was 43.44 (Badan Kebijakan Pendidikan Dasar dan Menengah, 2026). These persistently low levels of achievement suggest that mathematics instruction in many classrooms continues to emphasize procedural practice and correct answers rather than mathematical reasoning, conceptual connections, and meaningful problem solving. Because teachers play a central role in shaping instructional practices, understanding the factors that influence their perceptions of conceptual mathematics teaching has become an important research priority. This situation indicates that mathematics instruction has not fully helped students develop a deep understanding of the concepts being studied (Ncube & Luneta, 2025; Schoenfeld, 2022). In many classrooms, learning is still dominated by procedural exercises and searching for correct answers (Urgo & Arguello, 2025), while opportunities to explore ideas, explain reasoning, and connect various mathematical concepts are relatively limited (Hatisaru, 2023; Herbert, 2021; Kitchen, 2022; Marasabessy, 2021; Rittle-Johnson & Siegler, 2022).

Strengthening numeracy skills is one of the strategic agendas in efforts to improve the quality of education. One form of implementation of this agenda is the Teacher training of mathematical "GEMBIRA" and the National Numeracy Movement by the Ministry of Primary and Secondary Education (Widdiharto et al., 2025). The strengthening program aims to improve the numeracy skills of students in Indonesia through numeracy mindsets, skillsets, and toolsets (Badan Standar Kurikulum dan Asesmen Pendidikan, 2026). Numeracy is not only defined as the ability to perform arithmetic operations, but also includes the ability to understand, interpret, and use mathematical concepts in various everyday contexts (Díez-Palomar et al., 2023; Hoogland, 2023; Westwood, 2021). This Skills is crucial to help students make decisions, solve problems, and comprehend information presented in the form of data and mathematical representations (Díez-Palomar & Hoogland, 2025; Reyna & Brainerd, 2023; Rosita et al., 2025). Because numeracy requires the ability to apply mathematical concepts in various real-world situations, its development cannot be separated from mathematics learning that is oriented towards conceptual understanding (Díez-Palomar et al., 2023; Hoogland, 2023; Rosita et al., 2026). Therefore, numeracy development cannot be separated from mathematics learning that is oriented towards conceptual understanding (Goos et al., 2012; Md-Ali et al., 2016). Students with good conceptual understanding tend to be more able to apply their mathematical knowledge flexibly in various situations, which ultimately supports the development of more meaningful numeracy skills (Dole & Geiger, 2020; Munaji et al., 2025; Rosita et al., 2026).

Various studies in mathematics education confirm that conceptual understanding is a crucial foundation for the development of students' mathematical abilities (Chen, 2025; Ncube & Luneta, 2025; Vinner, 2020). Students who understand concepts well are not only able to solve routine problems but can also use their knowledge to explain relationships between concepts, choose appropriate strategies, and solve problems in various contexts. Therefore, efforts to improve the quality of mathematics learning need to be directed at strengthening teaching practices that are oriented towards conceptual understanding (Widdiharto et al., 2025).

The success of conceptual teaching is strongly influenced by the teacher (Hatisaru, 2023; Rohaeti et al., 2023; Widdiharto et al., 2025). The teacher's perspective on the objectives of mathematics learning is reflected in the decisions made throughout the learning process, from assignment selection and learning strategies to classroom interactions and assessment methods (Murtafiah et al., 2023; Murtafiah et al., 2022; Widdiharto et al., 2025). Teachers who view mathematics as a collection of procedures tend to emphasize mechanistic exercises. Conversely, teachers who view mathematics as a system of interconnected ideas will encourage students to reason, discuss, and construct meaning from the concepts they learn. Therefore, teachers' perceptions of conceptual teaching are an important aspect to examine. In this context, teachers play a strategic role in developing students' numeracy skills and conceptual understanding (Dole & Geiger, 2020; Onoshakpokaiye & Eyetan, 2026). Teachers are not only tasked with delivering learning materials but also with designing learning experiences that enable students to construct meaning from the concepts they learn, connect mathematics to real-world situations, and develop critical thinking skills (Dolapcioglu & Doğanay, 2022; Nwosu, 2025). The success of these efforts is strongly influenced by the teacher's perspective on the objectives and nature of mathematics learning (Saha et al., 2024; Viro et al., 2020). Teachers' perceptions of the importance of conceptual understanding are reflected in assignment selection, learning strategies, classroom interaction patterns, and the forms of assessment used during the learning process (Viro et al., 2020).

One factor thought to contribute to the formation of this perception is teachers' mathematical pedagogical knowledge. Mathematical pedagogical knowledge is not only related to mastery of mathematical material, but also includes an understanding of how mathematical concepts are learned, the difficulties students often experience, the forms of misconceptions that may arise, and strategies that can be used to help students build understanding (Demir, 2025; Sintema & Marbán, 2020). Teachers with good mathematical pedagogical knowledge are generally more sensitive to students' thinking processes and are better able to design learning that focuses on conceptual understanding rather than merely mastering procedures (Irshid et al., 2023; Prediger et al., 2023).

However, the relationship between mathematical pedagogical knowledge and conceptual teaching does not appear to be as simple as a direct relationship between the two variables. In practice, teachers need to be able to use mathematical knowledge to understand quantitative information, interpret data, and connect mathematical concepts to various real-world situations faced by students (Kohen & Orenstein, 2021; Sujatha & Vinayakan, 2023).

These abilities are closely related to numeracy skills. With increasing attention to strengthening numeracy in national education policy, numeracy skills is no longer understood as the ability to calculate alone, but as the ability to use mathematical knowledge to understand and solve various problems in everyday life (Díez-Palomar & Hoogland, 2025; Díez-Palomar et al., 2023; Widdiharto et al., 2025).

For elementary school teachers, numeracy skills play a crucial role. Teachers with strong numeracy skills tend to more easily relate mathematical material to real-world contexts, utilize various mathematical representations, and encourage students to use reasoning to solve problems (Agbata et al., 2024; Kohen & Orenstein, 2021; Sujatha & Vinayakan, 2023). These experiences can shape teachers' perspectives on mathematics learning and reinforce the belief that meaningful learning must be oriented toward conceptual understanding (Kasa et al., 2024; Polman et al., 2021; Xie & Cai, 2021). Therefore, numeracy skills is thought to be a mechanism that bridges the relationship between mathematical pedagogical knowledge and teachers' perceptions of conceptual teaching.

Although numerous studies have been conducted on mathematical pedagogical knowledge and numeracy skills (Demir, 2022; Leong et al., 2015; Sintema & Marbán, 2020), research that positions numeracy skills as a mediating variable in the relationship between mathematical pedagogical knowledge and conceptual teaching perceptions is still relatively limited, especially in the context of early elementary school teachers. Most previous research has focused more on the influence of teacher competency on student learning outcomes (Brühwiler & Vogt, 2020; Pardede et al., 2024; Sudargini & Purwanto, 2020), meanwhile considerably less attention has been given to understanding how these competencies shape teachers' own perceptions of conceptual mathematics teaching. Moreover, empirical studies examining teacher numeracy skills as a mediating mechanism linking mathematical pedagogical knowledge to teachers' perceptions of conceptual mathematics teaching remain scarce, particularly in the context of early elementary education (Fukaya et al., 2025; Grigaliūnienė et al., 2025). Addressing this gap is important because it can provide a deeper understanding of not only whether teacher competencies influence instructional perceptions but also the mechanisms through which these competencies shape orientations toward conceptual mathematics instruction.

Based on the previous description, this study starts from the assumption that the way teachers view mathematics learning is not formed separately from their competencies. Teachers who have good mathematical pedagogical knowledge tend to better understand how mathematical concepts are learned, how students build understanding, and how to overcome various difficulties that arise during the learning process. Therefore, this study proposes the first hypothesis (H_1) that mathematical pedagogical knowledge influences teachers' numeracy skills. In addition, mathematical pedagogical knowledge is also thought to influence how teachers view learning oriented towards conceptual understanding, so the second hypothesis (H_2) is proposed that mathematical pedagogical knowledge influences perceptions of mathematical conceptual teaching. On the other hand, teachers who are able to use mathematics meaningfully in various learning contexts, connect concepts with real situations, and utilize mathematical reasoning in decision-making are expected to have a more positive perception of conceptual learning. Based on this argument, the third hypothesis (H_3) is proposed that teachers' numeracy skills influence perceptions of mathematical conceptual teaching. Furthermore, this study also assumes that the influence of mathematical pedagogical knowledge on perceptions of mathematical conceptual teaching is not entirely direct, but can be explained through teachers' abilities in using and applying numeracy in various learning contexts. Thus, the fourth hypothesis (H_4) states that teacher numeracy skills mediate the relationship between mathematical pedagogical knowledge and perceptions of mathematical conceptual teaching. The relationships between constructs proposed in this study are summarized in the conceptual model presented in Figure 1.

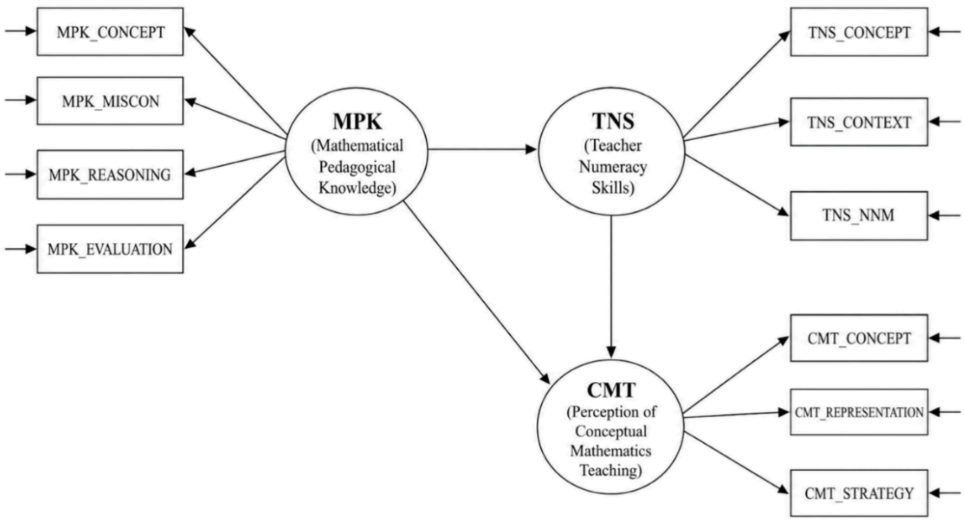

Figure 1. Structural equation model (SEM) of teacher mathematical knowledge, numeracy skills, and conceptual teaching perceptions

2. METHOD

This research is a quantitative study with a survey approach. Numerical data were collected from a large population sample using structured instruments such as questionnaires. The aim of this study was to examine the structural relationship between mathematical pedagogical knowledge, numeracy skills, and perceptions of conceptual teaching. Specifically, this study sought to determine whether perceptions of conceptual teaching acted as a mediator variable that strengthened the influence of mathematical pedagogical knowledge and numeracy skills in shaping teachers' professional competence.

2.1. Respondents

The population in this study consisted of all early elementary education teachers who teach at educational institutions in Indonesia and reside in Indonesia. The early elementary education teachers in this study were elementary school teachers teaching in Phase-A and teachers at the kindergarten/early childhood education level. In 2025-2026, they were targeted by the numeracy strengthening and conceptual understanding-based mathematics learning program (Mathematical GEMBIRA) organized by the ministry of primary and secondary education.

The respondents in this study were 885 teachers spread across Indonesia. The respondents in this study used convenience sampling with a voluntary participation approach. This sampling technique is a form of non-probability sampling that selects respondents based on ease of access and affordability for the researcher (Almusaed et al., 2025; Obilor, 2023). This technique was chosen because the study population is widely spread across various regions in Indonesia, so data collection was conducted through distributing questionnaires to easily accessible teachers, both in person and through online media. Furthermore, respondent participation was voluntary, so only teachers who were willing to take the time to complete the instrument were involved in the study. This technique allowed the researcher to obtain data more efficiently from a relatively large number of respondents in a limited time. Convenience sampling was considered appropriate because the primary objective of this study was to test theoretical relationships among latent constructs rather than estimate population parameters. Accordingly, obtaining an adequate sample size, sufficient statistical power, and high measurement quality was considered more important than achieving population representativeness for model testing. For covariance-based Structural Equation Modeling, obtaining an adequate sample size is essential to achieve sufficient statistical power, stable parameter estimation, and reliable model evaluation (Kline, 2023; Memon et al., 2025; Thakkar, 2020). With 885 respondents, the sample substantially exceeds the minimum recommendations for covariace-based Structural Equation Modeling. Furthermore, early elementary school teachers are geographically dispersed across Indonesia, making probability-based sampling logistically difficult and resource-intensive to implement within the available time and resources. Therefore, convenience sampling enabled efficient access to respondents from diverse provinces while providing an adequate sample for theory testing. This approach is consistent with SEM studies that prioritize theory testing and model evaluation, where adequate sample size, measurement quality, and statistical power are considered more critical than achieving population representativeness.

However, because it does not involve a randomization process, convenience sampling has the potential for bias in sample selection (Golzar et al., 2022; Lines et al., 2022). Therefore, the results of this study need to be interpreted with caution and are not intended to be fully generalized to the entire population of early elementary education teachers. Consequently, the findings should be interpreted as evidence supporting the proposed theoretical relationships rather than as nationally representative estimates of all early elementary school teachers in Indonesia (Kline, 2023; Memon et al., 2025; Thakkar, 2020). Accordingly, the findings should be interpreted as evidence supporting the proposed theoretical relationships rather than as nationally representative estimates of all early elementary school teachers in Indonesia.

In this study, we limited and ensured that the subjects used in this study were elementary education teachers (often referred to as teachers in the transition phase of kindergarten to primary school). This limitation was implemented to ensure the respondents' characteristics matched the research objectives. The researchers recognized limitations in the sampling process, as the questionnaire was distributed online through various media, such as WhatsApp groups, social media, and broadcast messages. Therefore, the opportunity for respondents to participate was highly dependent on the reach of the media used. This condition has the potential to create sample selection bias because not all members of the population have an equal opportunity to participate in the study. Nevertheless, to improve the quality of the data obtained, all respondents were required to provide informed consent before completing the questionnaire. On the consent form, respondents were asked to state their willingness to provide honest answers based on their understanding, experiences, and actual conditions. Only respondents who agreed with this statement could continue completing the questionnaire, and their data was used in the research analysis. The demographics of the 885 respondents involved in this study can be seen in Table 1.

Table 1. Demographics of subject

No	Demographic Types		Total
1	Gender	Male	117
		Female	768
2	Educational level	Master	76
		Bachelor	617
		Undergraduate diploma	73
		General High School Graduate	119
3	Employment status	Foundation Teacher	426
		Public school teacher	213
		Full-time Government Employee with Employment Agreement Teacher	206
		Part-time Government Employee with Employment Agreement teacher	40
4	Level of teaching	Kindergarten	378
		Primary school	505
		Not detected	2
5	Teacher competency status	Competent	626
		Not yet Competent	259
6	Province	Aceh	2
		North Sumatra	8
		West Sumatra	2
		Riau	3
		Riau Island	2
		Jambi	2
		South Sumatra	2
		Bangka Belitung Island	2
		Bengkulu	89
		Lampung	8
		DKI Jakarta	35
		West Java	88
		Central Java	149
		DI. Yogyakarta	65
		East Java	81
		Banten	25
		Bali	58

No	Demographic Types	Total
	West Nusa Tenggara	47
	East Nusa Tenggara	5
	West Kalimantan	2
	Central Kalimantan	2
	South Kalimantan	37
	East Kalimantan	3
	North Kalimanta	4
	North Sulawesi	2
	Gorontalo	2
	Central Sulawesi	2
	West Sulawesi	2
	South Sulawesi	124
	Southeast Sulawesi	2
	Maluku	2
	North Maluku	2
	West papua	15
	Sothwest Papua	2
	Papua	2
	Central Papua	2
	Highland Papua	3
	South Papua	2

Table 1 shows that this study involved 885 teachers from various regions in Indonesia. The majority of respondents were female (86.8%), had a bachelor's degree (69.7%), and were foundation teachers (48.1%). Based on teaching level, the majority of respondents taught in elementary schools (57.1%), while the remainder taught in kindergartens/early childhood education (42.7%). In terms of competency, 626 teachers (70.7%) were classified as competent and 259 teachers (29.3%) were not yet competent. Respondents were spread across 38 provinces, with the largest number coming from Central Java (16.8%), South Sulawesi (14.0%), Bengkulu (10.1%), West Java (9.9%), and East Java (9.2%). These characteristics indicate that the study sample was dominated by female teachers with bachelor's degrees and had a broad geographic coverage, thus providing a representative picture of the conditions of early elementary education teachers in Indonesia.

2.2. Research Instruments

The research instrument consisted of a structured questionnaire containing both dichotomous and Likert-type items. The item of questionnaire were developed through a comprehensive review of the literature on mathematical pedagogical knowledge, teacher numeracy skills, and conceptual mathematics teaching perceptions. The operational definitions of each construct were established first, followed by the development of measurement indicators based on the theoretical frameworks and empirical studies reported in previous research. The items of questionnaire were subsequently refined through iterative revisions to improve clarity, consistency, and contextual relevance for early elementary education teachers in Indonesia. The initial validation process focused on establishing content representativeness by ensuring that each questionnaire item corresponded to the operational definition and measurement dimension of its respective construct. The wording of the items was reviewed repeatedly by the research team to improve clarity, eliminate ambiguity, and ensure consistency with the Indonesian early elementary education context before large-scale data collection.

Because the instrument was newly developed based on theoretical frameworks and empirical findings reported in previous studies rather than directly adapted from an existing questionnaire, formal expert validation was not conducted. Instead, the psychometric properties of the instrument were evaluated empirically using Confirmatory Factor Analysis, including assessments of factor loadings, composite reliability, average variance extracted, and discriminant validity. To the best of our knowledge, the integrated questionnaire developed in this study has not previously been validated in the Indonesian context, particularly among early elementary school teachers. Therefore, construct validity and reliability were re-evaluated using Confirmatory Factor Analysis before testing the proposed structural model. All measurement properties satisfied the recommended criteria for construct validity and reliability before the structural model was evaluated. A separate pilot study was not conducted because the instrument was administered directly to a large sample for empirical validation using Confirmatory Factor Analysis, which enabled the assessment of construct validity and reliability within the study sample.

The Scale of mathematical pedagogical knowledge is a scale used to measure teachers' knowledge in understanding mathematical concepts, identifying student misconceptions, connecting various mathematical concepts, and designing and evaluating effective mathematics learning (Demir, 2025; Kleickmann et al., 2015; Leong et al., 2015; Sintema & Marbán, 2020). Based on this definition, the dimensions used in this scale are (1) mathematical concept understanding, (2) analysis of student misconceptions and errors, (3) connections between mathematical concepts and pedagogical reasoning, and (4) evaluation and impact of learning. In addition, the mathematical concept understanding scale consists of 20 items. Answers to all items refer to a correct score given a score of 1, while incorrect answers are given a score of 0.

The Scale of conceptual mathematics teaching perception is a scale that aims to reveal how a teacher's views, assessments, and beliefs regarding the importance of conceptual understanding—not just memorizing formulas—and how these concepts should be conveyed to students in order to achieve learning objectives (Ayeh, 2025; Gleasman & Kim, 2020; Hussein & Csíkos, 2023; Yurekli et al., 2020). Starting from this definition, this scale consists of three dimensions: (1) understanding and conceptual connections, (2) representation, argumentation, and misconceptions, and (3) learning strategies and conceptual assessment. In addition, the conceptual mathematics teaching perception scale consists of 20 items. Answers for all items adapt a Likert scale, namely a score of 1 (strongly disagree) to 4 (strongly agree).

The scale of teacher numeracy skills is the respondent's understanding of using numbers, symbols, and basic mathematical data in analyzing information and solving practical problems, which is implemented across disciplines to support logical, critical, and analytical thinking skills in everyday decision-making (Badan Standar Kurikulum dan Asesmen Pendidikan, 2026; Widdiharto et al., 2025). Departing from this definition, this scale consists of 3 dimensions, namely (1) Understanding numeracy concepts, (2) Contextual numeracy implementation, and (3) Systemic implementation of the national numeracy movement. In addition, the mathematical concept understanding scale consists of 20 items. Answers to all items refer to a correct score given a score of 1, while incorrect answers are given a score of 0.

2.3. Data Collection Procedures

Data were collected using an online survey via Google Forms. The online survey was used for its flexibility, compatibility with researchers' online work during the pandemic, and student activities. Furthermore, it is easily accessible and manageable using various devices. The survey was distributed after an evaluation process based on the results of an online focus group discussion involving five lecturers from two universities in Indonesia. The online survey was then disseminated through WhatsApp groups, email, and social media from February to March 2026. The researchers chose Google Forms to create the online survey due to its ease of use.

2.4. Data Processing Procedures

In this study, data analysis was conducted using Structural Equation Modeling (SEM) with the help of the LISREL program. The SEM method was chosen because it allows testing of structural relationships between latent variables simultaneously, including direct and indirect influences through mediating variables (Hidayat et al., 2023; Jöreskog & Sörbom, 1993; Kline, 2023). In this study, path analysis was integrated into the structural model to examine the relationship between mathematical pedagogical knowledge, numeracy skills, and perceptions of conceptual teaching in teachers of the transition phase of kindergarten to primary school. Specifically, the analysis was conducted to examine the effect of mathematical pedagogical knowledge on numeracy skills, the effect of numeracy skills on perceptions of conceptual teaching, and the direct effect of mathematical pedagogical knowledge on perceptions of conceptual teaching. In addition, this study also examined the mediating role of numeracy skills in the relationship between mathematical pedagogical knowledge and perceptions of conceptual teaching. This model is built on the assumption that teachers with better mathematical pedagogical knowledge tend to have higher numeracy skills, which ultimately forms a more positive perception of mathematics teaching oriented towards conceptual understanding.

Before testing the structural model, a measurement model was first tested using Confirmatory Factor Analysis (CFA) to ensure construct validity and reliability (Gatignon, 2010; Sujati et al., 2020; Widodo et al., 2020; Wood, 2008). Model feasibility was evaluated using several goodness of fit indices, such as Relative Chi-Square (χ^2/df), Chi-Square (χ^2), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Incremental Fit Index (IFI), Goodness of Fit Index (GFI), and Adjusted Goodness of Fit Index (AGFI). Mediation effect testing was conducted by analyzing the significance of the indirect effect on the structural model (Gonzalez et al., 2023). The mediation effect was declared significant if the t-value was ≥ 1.96 at a 5% significance level (Gonzalez et al., 2023; Hasbi et al., 2021). Because each latent construct in this study was represented by 20 observed indicators, item-level Structural Equation Modeling would have resulted in a highly complex measurement model with a large number of estimated parameters. Since the primary objective of this study was to evaluate the structural relationships among latent constructs rather than the psychometric performance of individual items, a parceling approach was considered more appropriate. Accordingly, the latent constructs, rather than individual questionnaire items, constituted the primary unit of analysis. Parceling reduces model complexity, improves parameter stability, facilitates model convergence, and provides greater statistical power, particularly when latent constructs contain a relatively large number of indicators (Little et al., 2022).

Furthermore, parceling is recommended when indicators within each construct adequately represent a single underlying dimension (Little et al., 2022). In this study, this assumption was supported by the satisfactory measurement model obtained during the initial Confirmatory Factor Analysis prior to parcel construction given the relatively large number of indicators, the analysis was conducted using a dimension-based parceling approach after the construct validation stage. Each dimension is used as an indicator for a second-order construct to obtain a more parsimonious and stable model.

3. RESULTS AND DISCUSSION

3.1. Results

This study uses a Structural Equation Modeling (SEM) approach with a Two-Step Approach procedure consisting of testing the measurement model and the structural model. In the first stage, the measurement model was tested using Second Order Confirmatory Factor Analysis (CFA) to confirm the structure of the constructs of Mathematical Pedagogical Knowledge (MPK), Teacher Numeracy Skills (TNS), and perception of Conceptual Mathematical Teaching (CMT). Next, the structural relationship between constructs was tested to test the research hypothesis.

3.1.1. Structural Model of Research

The SEM model estimation results show that Mathematical Pedagogical Knowledge directly influences teachers' numeracy skills and perceptions of mathematical conceptual teaching. Furthermore, teachers' numeracy skills also directly influence perceptions of mathematical conceptual teaching. The structural model of the estimation results is presented in Figure 2.

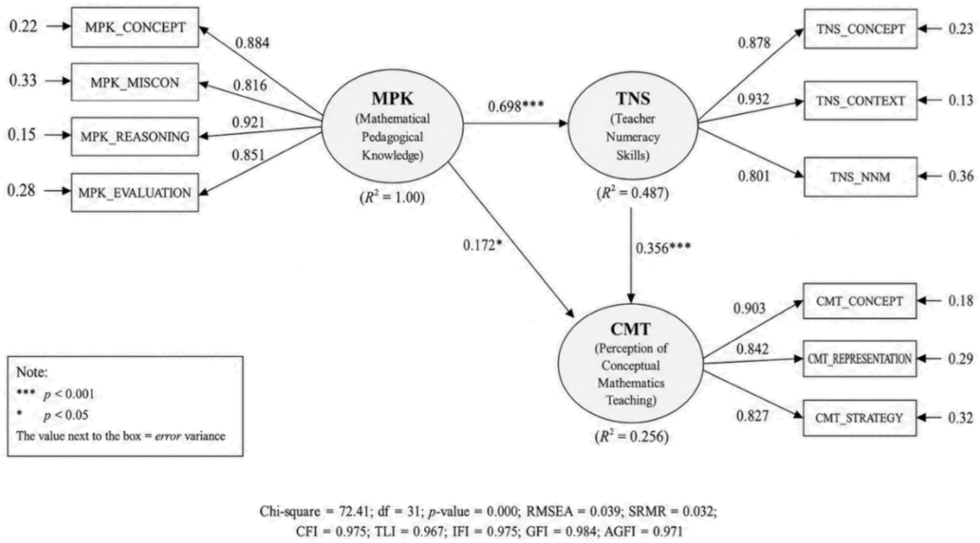

Figure 2. Structural equation model results of teacher mathematical knowledge, numeracy skills, and conceptual teaching perceptions

Based on Figure 2, it is known that Mathematical Pedagogical Knowledge (MPK) has a positive effect on Teacher Numeracy Skills (TNS) with a path coefficient of 0.698. Mathematical Pedagogical Knowledge (MPK) also has a direct effect on the perception of Conceptual Mathematical Teaching (CMT) with a coefficient of 0.172. Furthermore, Teacher Numeracy Skills (TNS) has a positive effect on the perception of Conceptual Mathematical Teaching (CMT) with a path coefficient of 0.356. The coefficient of determination shows that Mathematical Pedagogical Knowledge (MPK) is able to explain 48.7% of the variation in Teacher Numeracy Skills (TNS), while the combination of Mathematical Pedagogical Knowledge (MPK) and Teacher Numeracy Skills (TNS) is able to explain 25.6% of the variation in the perception of Conceptual Mathematical Teaching (CMT).

3.1.2. Measurement Model

Given that each construct in this study consists of a relatively large number of items, the analysis was conducted using a dimension-based item parceling approach (domain-representative parceling). This approach involves grouping items within the same dimension into a single composite indicator (parcel) after first ensuring validity and reliability through first-level CFA analysis. This strategy was chosen to reduce model complexity, increase the stability of parameter estimates, minimize random measurement error, and produce a more parsimonious model.

In the construct of Conceptual Mathematical Teaching (CMT), four parcels formed based on four dimensions, namely (a) Mathematical Concept Understanding, (b) Analysis of Student Misconceptions and Errors, (c) Connections between mathematical concepts and pedagogical reasoning, and (d) Evaluation and Impact of Learning. The construct of Teacher Numeracy Skills (TNS) represented by three parcels originating from the (a) Understanding Numeracy Concepts, (b) Contextual Numeracy Implementation, and (c) Systemic Implementation of the National Numeracy Movement. As for the construct of Teacher Perceptions of Conceptual Mathematical Teaching (CMT), it formed by three parcels which represented by (a) understanding and conceptual connections, (b) representation, argumentation, and misconceptions, and (c) learning strategies and conceptual assessment. Thus, in the second-order model, a total of ten parcels is used as indicators of the latent construct. The dimension-based parceling approach was chosen because each construct in this study is theoretically multidimensional and has a clear factor structure. Therefore, each parcel is considered capable of representing a distinct conceptual domain while maintaining the substantive validity of the construct being measured.

Prior to testing the structural model, all items were analyzed using first-order CFA to ensure their fit with their respective theoretical dimensions. The analysis showed that all items had adequate factor loadings and could be retained in the model. Next, parcels were formed based on the theoretical dimensions of each construct. Parcel values were obtained by averaging the item scores for each dimension and used as indicators in the second-order CFA and SEM structural models. The analysis showed that all dimensions had standardized loading factor values above 0.70, thus meeting the construct validity criteria. After indicator purification and parcel formation based on the dimensions, all constructs demonstrated good measurement quality. The results of construct validity and reliability in the measurement model can be seen in Table 2.

Table 2. Construct validity and reliability

Constructs	Dimension	Loading Factor
Mathematical Pedagogical Knowledge (MPK)	Mathematical Concept Understanding	0.884
	Analysis of Student Misconceptions and Errors	0.816
	Connections between mathematical concepts and pedagogical reasoning	0.921
	Evaluation and Impact of Learning	0.851
Teacher Numeracy Skills (TNS)	Understanding Numeracy Concepts	0.878
	Contextual Numeracy Implementation	0.932
	Systemic Implementation of the National Numeracy Movement	0.801
Perception of Conceptual Mathematical Teaching (CMT)	Understanding and conceptual connections	0.903
	Representation, argumentation, and misconceptions	0.842
	Learning strategies and conceptual assessment	0.827

Based on Table 2, all dimensions had factor loading values greater than 0.70. Thus, all dimensions were declared valid as forming their respective latent constructs. Next, construct reliability testing was conducted using Composite Reliability (CR) and Average Variance Extracted (AVE). The analysis results are presented in Table 3.

Table 3. Composite reliability and average variance extracted

Constructs	CR	AVE	Decision
Mathematical Pedagogical Knowledge (MPK)	0.914	0.727	Reliable
Teacher Numeracy Skills (TNS)	0.905	0.761	Reliable
Perception of Conceptual Mathematical Teaching (CMT)	0.893	0.736	Reliable

Based on Table 3, It was found that the Composite Reliability Value of all constructs was above 0.70 and the Average Variance Extracted (AVE) value was greater than 0.50. These results indicate that all constructs meet the reliability and convergent validity criteria. Furthermore, discriminant validity testing was conducted using the Fornell-Larcker criteria. The square root of the Average Variance Extracted (AVE) value for each construct was greater than the correlation between constructs, thus concluding that discriminant validity had been met. The results of the discriminant validity analysis using the Fornell-Larcker criteria are presented in Table 4.

Table 4. Discriminant validity based on Fornell-Larcker criteria

Constructs	CR	AVE	MPK	TNS	CMT
MPK	0.914	0.727	0.853		
TNS	0.905	0.761	0.698	0.872	
CMT	0.893	0.736	0.421	0.476	0.858

Based on Table 4, all AVE square root values are greater than the correlation between constructs so that discriminant validity is declared fulfilled. These findings indicate that each construct has unique characteristics and is able to explain the variance of its indicators better than the variance explained by other constructs in the model. Thus, the constructs of Mathematical Pedagogical Knowledge (MPK), Teacher Numeracy Skills (TNS), and Perception of Conceptual Mathematical Teaching (CMT) can be empirically distinguished from each other, even though all three have interrelated conceptual relationships. These results indicate that there is no excessive overlap between constructs, so that the measurement model has an adequate level of discriminant validity and is suitable for use in structural relationship analysis in the next stage.

3.1.3. Goodness of Fit

After obtaining a valid and reliable measurement model, the next step is to test the overall level of model fit. A summary of the goodness of fit test results is presented in Table 5.

Table 5. Goodness of fit model summary

Indeks of fit	Estimated Value	Criteria	Decision
χ^2	72.41	low	Fit
df	31	-	-
χ^2/df	2.34	< 3.00	Fit
RMSEA	0.039	≤ 0.08	Fit
SRMR	0.032	≤ 0.08	Fit
CFI	0.975	≥ 0.90	Fit
TLI	0.967	≥ 0.90	Fit
IFI	0.975	≥ 0.90	Fit
GFI	0.984	≥ 0.90	Fit
AGFI	0.971	≥ 0.90	Fit

Based on the test results in Table 5, all goodness of fit indices met the recommended criteria. Therefore, the SEM model used can be said to have a good level of fit with the empirical data. These results indicate that the measurement and structural models adequately represent the relationships between latent variables and explain the covariance patterns present in the data. Therefore, the proposed model can be considered suitable for further analysis. Meeting all model feasibility indicators also provides a strong basis for further hypothesis testing and evaluating the structural relationships between constructs, as the resulting parameter estimates can be considered valid, reliable, and substantively meaningful in accordance with the research's conceptual framework.

3.1.4. Structural Model Testing

After the measurement model met the fit criteria, testing continued on the structural model to examine the relationships between latent constructs. The results of the structural model testing are presented in Table 6.

Table 6. The result of structural relationship test

Relationship between Variables	Path Coefficient (β)	t-value	Decision
MPK → TNS	0.698	16.87	Significant
MPK → CMT	0.172	3.54	Significant
TNS → CMT	0.356	7.21	Significant

The results of the structural model analysis (see Table 6) show that Mathematical Pedagogical Knowledge (MPK) has a positive and significant effect on Teacher Numeracy Skills (TNS) because it obtained $\beta = 0.698$ and $t = 16.87$. Mathematical Pedagogical Knowledge (MPK) also has a positive and significant effect on the perception of Conceptual Mathematical Teaching (CMT) because it obtained $\beta = 0.172$ and $t = 3.54$. In addition, teacher numeracy skills (TNS) have a positive and significant effect on Perceptions of Mathematical Conceptual teaaching (CMT) because it obtained $\beta = 0.356$ and $t = 7.21$.

3.1.5. Mediation Effect Testing

The indirect effect (also known as mediation effect analysis) of mathematical pedagogical knowledge on perception of mathematical conceptual teaching through teachers' numeracy ability is calculated using the multiplication of path coefficients, as presented in Table 7.

Table 7. Direct, indirect, and total effects

Relationship Path	Direct	Indirect	Total effect
MPK → TNS	0.698	-	0.698
MPK → CMT	0.172	0.248	0.420
TNS → CMT	0.356	-	0.356

Based on Table 7, it shows that the indirect effect of Mathematical Pedagogical Knowledge (MPK) on the Perception of Conceptual Mathematical Teaching (CMT) through Teachers' Numeracy Skills (TNS) is 0.248. This value is greater than the direct effect of 0.172.

However, because the direct effect remains significant, Teachers' Numeracy Skills (TNS) acts as a partial mediator in the relationship between Mathematical Pedagogical Knowledge (MPK) and Perception of Conceptual Mathematical Teaching (CMT).

3.2. Discussion

This study shows that Mathematical Pedagogical Knowledge has a significant influence on teachers' numeracy skills. These results suggest that teachers' abilities to understand mathematical concepts, recognize student misconceptions, develop mathematical reasoning, and evaluate the learning process are important assets in building numeracy skills. This is in line with previous research which emphasizes the importance of teachers' ability to understand mathematical concepts in depth, recognize student misconceptions, develop mathematical reasoning, and evaluate the learning process on an ongoing basis (Dole & Geiger, 2020; Wakhata et al., 2023). These abilities are important assets in building students' numeracy skills because they help them connect mathematical knowledge with problem situations, use appropriate representations, and apply concepts meaningfully in problem solving (Szabo et al., 2020; Torres-Peña et al., 2025; Wakhata et al., 2023). Teachers who understand how mathematical concepts are learned and taught tend to be more easily able to use mathematical knowledge in various contexts, whether to explain phenomena, interpret data, or solve problems related to everyday life (Charalambous et al., 2020; Schoenfeld, 2020).

The use of dimension-based parceling in this study also provides methodological advantages in SEM testing. With a large number of respondents and multidimensional constructs, parceling allows for a reduction in model complexity without eliminating the conceptual meaning of each dimension. The loading factor results in this study were obtained for each parceling (dimension) exceeding 0.70 (see Table 2), indicating that each dimension is able to represent the latent construct strongly and consistently. This finding is consistent with previous research stating that a loading factor value of at least 0.70 indicates that the parcel has good measurement quality and is able to represent latent variables validly and reliably (Hidayat et al., 2023; Kyle et al., 2026; Little et al., 2022; Widodo et al., 2020). Thus, these results provide empirical support for the use of dimension-based parceling in this study and strengthen the validity of the measurement model used as the basis for testing the structural relationships between constructs.

Substantively, this relationship can be understood because numeracy ability is not only related to the ability to perform calculations, but also the ability to use mathematical knowledge flexibly and meaningfully. Mastery of mathematical pedagogy helps teachers understand the structure of concepts and relationships between mathematical ideas, so that they are better prepared to integrate aspects of numeracy in learning activities. Thus, increasing mathematical pedagogical abilities has the potential to encourage the development of teachers' numeracy skills. These findings align with numerous studies showing that mathematical pedagogical knowledge is an important foundation for teachers' ability to integrate mathematical concepts into meaningful learning contexts (Aderinoye-Rabiu et al., 2025; Delgado-Rebolledo & Zakaryan, 2020). Previous research has reported that teachers with a strong understanding of mathematical concepts and how students learn mathematics tend to be better able to develop learning activities that support the use of reasoning, representation, and problem-solving in a variety of contextual situations (Basid et al., 2024). Therefore, improving teachers' numeracy skills can be understood as a logical consequence of their increased ability to connect mathematical knowledge with learning practices. These findings reinforce the argument that developing teachers' numeracy is inseparable from strengthening their mathematical pedagogical knowledge.

The direct influence of Mathematical Pedagogical Knowledge on Perceptions of Mathematical Conceptual Teaching also shows that teachers' perspectives on mathematics learning are closely linked to the quality of their knowledge. Teachers with a strong understanding of mathematical concepts and students' thinking tend to view learning as a process of building understanding, rather than simply practicing procedural skills (Rittle-Johnson & Siegler, 2022). They are more aware of the importance of using diverse representations, providing mathematical reasoning, class discussions, and developing connections between concepts in the learning process (Mainali, 2021; Niyazul Hague, 2024). These findings also provide an explanation for the problem identified in the introduction, namely the continued dominance of procedurally oriented mathematics learning. Teachers with better mathematical pedagogical knowledge tend to exhibit more positive perceptions of conceptual teaching, potentially reducing learning practices that focus solely on mastering algorithms and final answers (Dole & Geiger, 2020; Irshid et al., 2023; Onoshakpokaiye & Eyetan, 2026; Prediger et al., 2023; Urgo & Arguello, 2025). In other words, improving the quality of mathematical pedagogical knowledge can be a strategy to encourage the transformation of mathematics learning toward more meaningful learning oriented toward conceptual understanding.

Beside that, these findings demonstrate that perceptions of conceptual teaching do not emerge spontaneously, but rather develop through teachers' professional experience and knowledge. These results align with previous research, which found that teachers' perceptions and beliefs about learning are the result of a gradual professional development process (McChesney & Aldridge, 2021). Teachers' mathematical pedagogical knowledge not only serves as technical competence but also serves as a foundation for shaping how they interpret the goals and processes of mathematics learning (Association of Mathematics Teacher Educators, 2020; Delgado-Rebolledo & Zakaryan, 2020; McChesney & Aldridge, 2021). When teachers understand why students experience difficulties or misconceptions on a topic, they are more likely to value learning that emphasizes conceptual understanding rather than simply achieving correct answers. Therefore, strengthening mathematical pedagogical knowledge is a strategic step to encourage the development of more conceptual learning practices. The results of this study indicate that teachers' perceptions of conceptual teaching are not characteristics that emerge instantly, but rather develop through a continuous professional process. Teachers' mathematical pedagogical knowledge contributes to shaping how they understand the nature of mathematics learning, interpret student learning difficulties, and determine appropriate learning approaches. Thus, perceptions of conceptual teaching can be understood as the result of the accumulation of professional experience and knowledge acquired by teachers during their teaching practices.

The results of this study are also consistent with various studies which show that teachers' beliefs and perceptions regarding mathematics learning are influenced by the quality of their professional knowledge (Yang & Kaiser, 2022). This finding is also in line with the mathematics teacher competency model which places professional knowledge as the foundation for the formation of professional beliefs and teaching behavior (Depaepe et al., 2020). The model explains that the quality of teachers' professional knowledge influences how they understand the nature of mathematics, the student learning process, and the learning objectives they wish to achieve, which are ultimately reflected in their beliefs, perceptions, and classroom learning practices. Empirical support for this relationship can be shown in the results of other studies which found that teacher professional development programs were able to increase self-efficacy, epistemological beliefs, and pedagogical knowledge of mathematics (Lee & Vongkulluksn, 2023). In addition, the results of the analysis by Lee and Vongkulluksn (2023) show that teachers' self-efficacy and epistemological beliefs contribute to the learning practices implemented. These findings indicate that increasing professional knowledge not only strengthens teachers' technical competence, but also shapes their perspective on mathematics learning. Teachers who have a strong conceptual understanding tend to view learning as a process of knowledge construction involving reasoning, representation, and meaning of concepts, whereas teachers with more limited knowledge tend to emphasize mechanistic procedures and exercises. The similarity of these results strengthens research findings that mathematical pedagogical knowledge not only functions as technical competence in managing learning, but also plays a role in shaping teachers' perceptions of the nature of mathematics learning. Therefore, teachers who have better mathematical pedagogical knowledge tend to develop more positive perceptions of teaching that is oriented towards understanding concepts.

The research results also show that teachers' numeracy skills significantly contribute to their perceptions of mathematical conceptual teaching. This finding is interesting because it suggests that numeracy skills are not only related to teachers' academic competence but also influence how they understand the objectives of mathematics learning. This finding is in line with several experts who state that teachers with strong numeracy skills tend to view mathematics as a tool for understanding and explaining various real-world situations (Geiger et al., 2015; Haylock, 2024; Kasa et al., 2024). This view encourages the belief that mathematics learning should be directed at conceptual understanding, reasoning, and problem-solving skills.

In practice, teachers with better numeracy skills typically find it easier to connect subject matter to everyday contexts. As stated by previous researchers that the numeracy is the ability to use mathematical knowledge to face various demands of personal and social life, not only oriented towards mastering mathematical concepts and procedures, but also the ability to apply these concepts in a meaningful context, so that good numeracy tends to be better able to connect learning material with everyday life situations and encourage students to use mathematical reasoning to understand various contextual problems (Coffey & Sharpe, 2023; Dole & Geiger, 2020; Geiger et al., 2015). They are also more accustomed to using data, graphs, tables, and other mathematical representations to explain concepts. This experience ultimately shapes the perception that learning oriented toward conceptual understanding has greater value than learning that focuses solely on procedures and algorithms. These findings reinforce the underlying assumption of the national numeracy movement and the teacher training of Mathematical GEMBIRA, namely that strengthening numeracy skills not only impacts academic competence but also contributes to how teachers view mathematics learning (Widdiharto et al., 2025). Teachers with good numeracy literacy tend to be more aware of the importance of learning oriented toward conceptual understanding, reasoning, and problem-solving (Dole & Geiger, 2020; Geiger et al., 2020). Thus, the results of this study provide empirical support for numeracy strengthening policies currently being developed through various national programs to encourage more meaningful and contextual mathematics learning.

However, several previous studies have reported that enhanced numeracy competence does not automatically translate into more positive perceptions of conceptual teaching. This finding is consistent with research showing that beliefs about mathematics and beliefs about the teaching and learning of mathematics are distinct constructs that may develop at different rates (Liljedahl et al., 2021). As a result, teachers may become more proficient in using mathematics while still maintaining traditional views of instruction, suggesting that changes in pedagogical perceptions often require broader professional experiences and reflective practice. These differences are likely influenced by contextual factors such as school culture, curriculum, teaching experience, and the professional support teachers receive. In the context of this research, the numeracy strengthening program currently developing within national education policy is suspected of strengthening the relationship between numeracy skills and perceptions of conceptual teaching. Therefore, the relationship found in this study needs to be understood within the context of an education system that is currently placing significant emphasis on numeracy strengthening and meaningful learning.

Apart from the significance of the relationship between variables, the coefficient of determination value also provides information regarding the model's ability to explain endogenous variables. The results of the research show that mathematical pedagogical knowledge is able to explain 48.7% of the variation in teacher numeracy skills, which shows that the predictive ability of the model is quite strong in the category. Meanwhile, the combination of mathematical pedagogical knowledge and teacher numeracy skills was only able to explain 25.6% of the variation in Conceptual Mathematical Teaching Perceptions. These findings indicate that teachers' perceptions of conceptual teaching may also be influenced by various other factors that have not been included in the model, such as teaching beliefs, teaching experience, school culture, professional support, curriculum characteristics, and experience participating in professional development. Therefore, future research needs to consider these variables to gain a more comprehensive understanding of the factors that shape teachers' perceptions of mathematics teaching that is oriented towards conceptual understanding.

One of the important findings in this study is the role of teachers' numeracy skills as a partial mediator in the relationship between mathematical pedagogical knowledge and perceptions of mathematical conceptual teaching. These results indicate that the influence of mathematical pedagogical knowledge on perceptions of conceptual teaching is not entirely direct. Part of this influence works through improving teachers' numeracy skills. In other words, good mathematical pedagogical knowledge will be more effective in shaping perceptions of conceptual teaching if accompanied by adequate numeracy skills. The results of this partial mediation support the theoretical argument, namely that numeracy literacy is a bridge between mastery of mathematical concepts and their application in various real-life contexts (Díez-Palomar et al., 2023; Hoogland, 2023; Westwood, 2021). Teachers with sound mathematical pedagogical knowledge do not necessarily develop strong perceptions of conceptual teaching (Dole & Geiger, 2020; Munaji et al., 2025; Rosita et al., 2026). This knowledge must first be transformed into the ability to use, interpret, and contextualize mathematics in meaningful learning situations.

Interestingly, the coefficient of the direct effect of mathematical pedagogical knowledge on perceptions of mathematical conceptual teaching is relatively small ($\beta = 0.172$) compared to the indirect effect through teachers' numeracy skills ($\beta = 0.248$). This finding indicates that mastery of mathematical pedagogical knowledge does not automatically shape teachers' perceptions of conceptual-oriented teaching. This knowledge needs to be transformed first into the ability to use mathematics contextually through numeracy skills. In other words, teachers may understand how a concept is taught, but a strong perception of conceptual learning only develops when this knowledge is used to explain real phenomena, analyze quantitative information, and connect mathematics to everyday life. Therefore, numeracy skills function as a mechanism that strengthens the influence of mathematical pedagogical knowledge on the formation of conceptual teaching perceptions.

These findings directly address the research gap identified in the Introduction. While previous studies have primarily examined the direct effects of mathematical pedagogical knowledge or teacher numeracy skills on teaching quality and student learning outcomes, they have provided limited evidence regarding the mechanism through which pedagogical knowledge shapes teachers' perceptions of conceptual mathematics teaching. The present study demonstrates that teacher numeracy skills function as a significant mediating mechanism linking mathematical pedagogical knowledge to conceptual teaching perceptions. This finding extends previous literature by explaining not only whether mathematical pedagogical knowledge influences teachers' instructional orientations, but also how this influence occurs, particularly among teachers in the transition phase from kindergarten to primary school.

These findings illustrate that teacher competency is an interconnected system. Mathematical pedagogical knowledge provides a foundation for understanding how mathematics is taught and learned, while numeracy skills strengthen teachers' ability to use mathematics contextually. These two aspects then contribute to shaping teachers' perspectives on mathematics learning, which emphasizes conceptual understanding. Therefore, efforts to improve teacher quality should not be undertaken in isolation, but rather through the development of mutually supportive competencies.

The findings regarding the partial mediation role of teachers' numeracy skills provide an important theoretical contribution. Most previous studies tend to view mathematical pedagogical knowledge and learning perceptions as two constructs that are directly related (Charalambous et al., 2020; König et al., 2021; Yang et al., 2020). The results of this study indicate that there is a psychopedagogical mechanism that bridges this relationship, namely teachers' ability to use mathematics contextually through numeracy skills. Thus, numeracy skills can be positioned not only as a result of teachers' professional competence but also as a mechanism that helps transform professional knowledge into beliefs and perceptions about effective learning practices. More importantly, this study extends previous literature by demonstrating that teacher numeracy skills should not be viewed merely as an independent competency or a direct predictor of instructional quality. Instead, numeracy skills operate as an explanatory mechanism through which mathematical pedagogical knowledge is translated into teachers' perceptions of conceptual mathematics teaching. This perspective provides a new theoretical understanding of teacher competence by explaining the process underlying the relationship between professional knowledge and instructional perceptions, an aspect that has received limited empirical attention in previous studies.

Overall, the findings of this study support the perspective that teacher competency is an interconnected system that develops simultaneously. Mathematical pedagogical knowledge, numeracy skills, and conceptual teaching perceptions do not operate as stand-alone constructs, but rather form a series of interconnected processes. This perspective provides a more comprehensive understanding of how teacher professional competency develops and how it contributes to the quality of mathematics learning in the classroom. This finding is in line with recent studies which confirm that teacher competence is a complex and multidimensional construct, which includes cognitive, instrumental, and affective aspects that develop dynamically throughout a teacher's professional career (Zhang & Tian, 2025). From this perspective, the development of one competency cannot be separated from other competencies because each aspect interacts to shape the quality of learning practices. Therefore, teacher professional development needs to be viewed as a holistic and ongoing process, not as a separate competency strengthening exercise.

From a practical perspective, the results of this study have implications for teacher education institutions and continuing professional development programs. Strengthening mathematical pedagogical knowledge needs to be balanced with developing numeracy skills through various activities that enable teachers to use mathematics in real-world contexts. This approach is expected to help teachers develop learning that is not only oriented toward mastering procedures but also encourages students to develop deeper conceptual understanding, reasoning skills, and problem-solving skills. From an educational policy perspective, these findings are also relevant to efforts to improve the quality of mathematics learning at the elementary level, which still faces various challenges, as reflected in national assessment results that indicate students' low mastery of mathematics. The results of this study indicate that strengthening teachers' mathematical pedagogical knowledge and numeracy literacy can be a strategy that needs to be prioritized in teacher competency improvement programs. By strengthening these two aspects, teachers are expected to be able to develop more meaningful, contextual, and conceptually oriented learning, ultimately contributing to improving students' mathematical abilities.

One of the main contributions of this study lies in explaining the mechanism linking mathematical pedagogical knowledge to conceptual teaching perceptions through teachers' numeracy skills. This finding extends previous research, which has generally focused on the direct relationships among these variables without considering the mediating role of numeracy skills. More specifically, this study contributes to the mathematics education literature in three important ways. First, it provides empirical evidence that teacher numeracy skills function as a significant mediator between mathematical pedagogical knowledge and conceptual teaching perceptions. Second, it shifts the perspective from examining direct relationships among teacher competencies toward understanding the underlying mechanisms through which these competencies shape teachers' instructional orientations. Third, by focusing on teachers in the transition phase from kindergarten to primary school, this study expands the limited body of evidence concerning conceptual mathematics teaching at the early elementary level.

4. CONCLUSION

This study demonstrates that mathematical pedagogical knowledge plays a significant role in shaping teachers' numeracy skills and perceptions of mathematical conceptual teaching in early elementary school teachers. Teachers who are better at understanding mathematical concepts, identifying student misconceptions, developing mathematical reasoning, and evaluating learning tend to have better numeracy skills and more positive perceptions of conceptual-oriented mathematics instruction.

The results also show that teachers' numeracy skills positively influence perceptions of mathematical conceptual teaching. This finding indicates that the ability to use mathematics in various real-life contexts contributes to how teachers view the goals and practices of mathematics instruction. Teachers with strong numeracy skills tend to value instruction that emphasizes conceptual understanding, reasoning, mathematical representation, and problem-solving. Furthermore, teachers' numeracy skills were shown to act as a partial mediator in the relationship between mathematical pedagogical knowledge and perceptions of mathematical conceptual teaching. This finding suggests that the influence of mathematical pedagogical knowledge on perceptions of conceptual teaching occurs not only directly but also through improvements in teachers' numeracy skills. Thus, teacher competency development needs to be carried out in an integrated manner by strengthening mathematical pedagogical knowledge and numeracy skills. More importantly, this finding extends previous research by demonstrating that teachers' numeracy skills function not merely as an independent professional competency but as an explanatory mechanism through which mathematical pedagogical knowledge is translated into teachers' perceptions of conceptual mathematics teaching. This study therefore moves beyond identifying direct relationships among teacher competencies by explaining the underlying process through which professional knowledge shapes instructional perceptions.

This research contributes to the development of teacher competency studies by demonstrating that teachers' numeracy skills are an important mechanism linking mathematical pedagogical knowledge to conceptual teaching perceptions. By focusing on teachers in the transition phase from kindergarten to primary school, this study also provides new empirical evidence from an educational context that has received relatively limited attention in previous research. These findings offer a stronger theoretical foundation for designing teacher education and professional development programs that integrate mathematical pedagogical knowledge and numeracy skills to support conceptually oriented mathematics instruction. However, this study used a convenience sampling technique, so the results should be interpreted with caution. Future research could involve more representative sampling techniques, expand the research context to other educational levels, and test the same model using a longitudinal design to gain a deeper understanding of teacher competency development over time.

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Declarations

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