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Conceptual Understanding of Mathematics among Pre-service Teachers: A Socio-Metacognitive Structural Model Generation

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Abstract

The study developed a best-fit structural model of pre-service teachers' (PSTs) conceptual understanding of mathematics by examining factors like mathematical mindsets, school climate, and metacognition. Conducted in three teacher education institutions in Northern Mindanao, Philippines, the study involved 823 PSTs during the 2022-2023 school year. Four research instruments were used: a mathematics conceptual understanding test and scales for measuring mathematical mindset, school climate, and metacognition, all validated by experts and tested for reliability. Data analysis included using the mean to assess levels of the key factors, Pearson correlation to explore relationships, and regression to identify predictors of conceptual understanding. Structural equation modeling (SEM) was employed to generate the best-fit model based on goodness of fit indices. Results showed that PSTs had an incomplete level of conceptual understanding of mathematics, despite high levels of mathematical mindsets, positive school climates, and strong metacognition. All three factors were significantly and positively correlated with conceptual understanding. The model revealed that mathematical mindsets, school climate, and metacognition significantly predicted PSTs' conceptual understanding. The best-fit model, called the Socio-Metacognitive Conceptual Understanding Model for PSTs (SCUMPT), suggested that PSTs' conceptual understanding is shaped by the reciprocal interaction between their metacognitive skills and awareness within a supportive school environment.

Introduction

Conceptual understanding is a fundamental aspect of mathematics education, and it plays a crucial role in developing pre-service teachers' (PSTs') mathematical proficiency. In mathematics education, conceptual understanding refers to students' ability to explain and solve problems with sound knowledge of the underlying mathematical concepts in different contexts (O'Dwyer et al., 2015). Thus, developing PSTs' conceptual understanding is a critical goal of mathematics education. The National Council for Teachers in Mathematics, the world's most extensive mathematics education organization, articulates that mathematics must be learned with understanding (Smith et al., 2018). In the Philippines, the Mathematics Framework for Philippine Basic Education reinforced the idea that to be

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mathematically competent, one may not only have the ability to perform mathematical procedures but can distinguish patterns and understand the interrelationship of ideas (DOST-SEI & MATHTED, 2011).

A plethora of research studies on conceptual understanding of mathematics revealed limited understanding among PSTs (Andaya, 2014; Junsay, 2016). These poor mathematics results also resonated in their performance in teacher licensure examinations (Malaluan, 2017; Nool & Ladia, 2017). However, similar results were also disclosed among in-service teachers' content knowledge assessment (World bank, 2016), college students (Taqwa et al., 2022), and basic education learners' PISA, TIMMS, and NAT results (Moraña et al., 2017). PSTs demonstrated poor conceptual understanding of various areas of mathematics. PSTs often have a limited understanding of algebraic concepts and struggle with solving algebraic equations (Turgut, 2019). Similarly, PSTs were not able to use the mathematical language adequately and were usually not able to explain the concepts using symbols (Gurefe, 2018).

Most PSTs provided either insufficiently detailed or incorrect answers for the geometric concepts of circle, circular region, and sphere (Unlu, 2021). Furthermore, PSTs showed a limited comprehension of geometric transformations and a fragmented understanding of geometric concepts, as evidenced by their inability to connect diverse geometry components (Gueudet & Pepin, 2018). Consequently, among the mathematics content areas tested by Trends in International Mathematics and Science Studies (TIMSS), Filipinos received the lowest rating in geometry and measurement (Punzalan & Buenaflor, 2017). In Teacher Education Institutions (TEIs) like Bukidnon State University, it was observed that some PSTs enrolled in Mathematics classes need help to understand mathematical concepts and operations. They can arrive at correct answers in mathematical tasks, but when asked why, they usually fail to explain fully the underlying concepts. Other PSTs use algorithms to solve problems without completely understanding the mathematical concepts.

The Commission on Higher Education (2004) stresses that quality pre-service teacher education is critical to Philippine education. Teacher Education Institutions are mandated to provide quality and relevant education to future teachers. As teacher preparation institutions, TEIs have to equip PSTs with the needed conceptual understanding. PSTs must be exposed to a curriculum that facilitates and enrich their understanding of the learning content as well as the art of teaching for them to rightfully share their knowledge with the students (Somblingo, 2014). Mathematics education researchers and academicians have studied factors affecting the conceptual understanding of PSTs. They conveyed that the conceptual understanding of mathematics is affected by PSTs' mathematical mindset (Flores-Gonzalez et al., 2021; Hachfeld et al.,2019), school climate (Gellor, 2019; Gustafsson & Nilsen, 2016), and metacognition (Fauzi & Sa'diyah, 2019; Yorulmaz et al., 2021).

A mathematical mindset is the flexibility or stability of human characteristics related to mathematical ability, intelligence, and talent (Saefudin et al., 2023). Many research scholars have focused their studies on the relationship between mathematical mindset and conceptual understanding in their quest for greater student performance. An increasing body of data indicates that mathematical mindset is important in students' conceptual understanding, which leads to mathematics achievement (Brougham & Kashubeck-West, 2017). On the other hand, school climate refers to the quality and character of school life, including teaching and learning, safety, institutional environment, interpersonal relationships, and social media (National School Climate Center, 2021). The growing research on school climate support the notion that learners' context matters, a safe learning environment, and social and emotional learning are necessary to learn (Thapa, 2013). School climate is considered as a leading factor in explaining student understanding and achievement (Maxwell et al., 2017).

Moreover, metacognition is the process of thinking about one's thinking and learning, which involves self-monitoring and correcting oneself (Proust, 2010). Key findings in the literature cite those students lack conceptual understanding and problem-solving skills because they are not using their wide range of metacognitive processes (Alzharani, 2017). Some studies asserted that performance in mathematics is significantly affected by students' metacognitive strategies (Gaylo & Dales, 2017; Sahin & Kendir, 2013), and those struggling students are the ones who lack metacognition (Coles, 2013). The three factors above increased PSTs' conceptual understanding individually (Flores-Gonzalez et al., 2021; Hachfeld et al., 2019; Taskin & Bahadir, 2021; Ozcakmak et al., 2021). However, a dearth of studies looked into the interplay of the three factors toward PSTs' conceptual understanding of mathematics. In addition, a clear link between mathematical mindset, school climate, and metacognition on PSTs' conceptual understanding is not well-established in the literature. Most of the structural equation models developed consider conceptual understanding as an exogenous or input variable rather than the endogenous or output variable (Yudhanegara & Lestari, 2016).

With these, the researcher determines a best-fit structural model of conceptual understanding of mathematics for PSTs in consideration with the cited factors. The generated model can be used to understand further the complexities on enhancing PSTs' conceptual understanding of mathematics. It will allow mathematics education key players across countries like teachers, specialists, and professors to initiate programs, strategies, and policies to advance the pre-service teacher education. The international academic community, may utilize the generated framework for developing interventions that foster better mathematical understanding among pre-service teachers. The study's findings, especially the role of a supportive learning environment and metacognitive strategies, can guide curriculum reforms, teacher training programs, and policy formulation aimed at enhancing mathematics education globally. Additionally, the model serves as a foundation for comparative studies across different educational contexts, promoting collaboration and knowledge-sharing among the global education research community.

Objectives

This study aims to develop an optimal structural model of conceptual understanding in mathematics among pre-service teachers (PSTs) by examining the influence of their mathematical mindset, school climate, and metacognition. Conducted within teacher education institutions in Northern Mindanao during the 2022–2023 academic year, the study specifically seeks to address the following questions:

1. What is the level of PSTs' conceptual understanding in mathematics across the five strands: number sense, measurement, geometry, patterns and algebra, and statistics and probability?

2. How do PSTs' mathematical mindsets manifest in terms of self-beliefs about mathematical intelligence and ability?

3. How is the school climate experienced by PSTs, considering aspects of teaching and learning, safety, institutional environment, interpersonal relationships, and social media influence?

4. How do PSTs demonstrate metacognitive skills, including declarative, procedural, and conditional knowledge; planning; information management strategies; comprehension monitoring; debugging strategies; and evaluation?

5. Are there significant relationships between PSTs' conceptual understanding in mathematics and their mathematical mindset, school climate, and metacognition?

6. Which of the variables—mathematical mindset, school climate, and metacognition—best predict PSTs' conceptual understanding in mathematics?

7. What structural model provides the best fit for explaining PSTs' conceptual understanding in mathematics?

Hypotheses

The study tests the following hypotheses at a 0.05 level of significance:

1. There is no significant relationship between PSTs' mathematical mindset, school climate, metacognition, and their conceptual understanding in mathematics.

2. None of the variables; mathematical mindset, school climate, or metacognition, significantly predict PSTs' conceptual understanding in mathematics.

3. There is no best-fit structural model for PSTs' conceptual understanding in mathematics.

Conceptual Framework

The study is grounded in Bandura's (1986) social cognitive theory, which posits that learning occurs within a social context through the dynamic and reciprocal interaction among personal, environmental, and behavioral factors. This framework suggests that the conceptual understanding of mathematics among pre-service teachers (PSTs) is shaped through the continuous interplay between their mathematical mindset, metacognition, and a supportive school climate. As PSTs engage with their school environment, their understanding of mathematics is progressively shaped by their cognitive and behavioral actions (Nahdi & Jatisunda, 2020). Social cognitive theory further implies that PSTs learn by observing, imitating, and modeling the behaviors, attitudes, and outcomes of others, including peers and professors. However, it remains unclear how the influence of these factors varies in strength (Lamorte, 2022). This study addresses these gaps by examining mathematical mindset as the personal factor, school climate as the environmental factor, and metacognition as the behavioral factor, all contributing to PSTs' conceptual understanding of mathematics as a learning outcome.

Vygotsky's (1978) sociocultural theory reinforces Bandura's view, emphasizing that cognition develops through socially mediated interactions. Vygotsky argued that PSTs acquire cultural values, beliefs, and problem-solving strategies through collaborative dialogue with knowledgeable others within the learning environment. Consequently, PSTs' conceptual understanding of mathematics develops with the guidance of teachers and peers and is further enhanced by a growth mindset and metacognitive skills. Dewey (1938) also supports the social nature of learning, asserting that schools serve as social institutions that foster learning through active participation. He argued that PSTs thrive when they can engage directly with the curriculum, emphasizing that all students should have opportunities for active, self-directed learning. Dewey's perspective on social learning remains influential in contemporary education (Flinders & Thornton, 2013).

Table 1 presents the study's endogenous and exogenous variables along with their respective codes. Each latent variable is measured through observed variables, which are represented by rectangular nodes in the hypothesized structural models, while latent variables are depicted in circles or ellipses. The study proposes five structural models, each illustrating potential causal relationships between the exogenous variables: mathematical mindset, school climate, and metacognition and the endogenous variable, conceptual understanding of mathematics. Figures 1 through 5 depict the hypothesized models.

Hypothesized Structural Model 1 (Figure 1) illustrates a network of causal relationships between three exogenous variables and one endogenous variable. The endogenous variable, conceptual understanding of mathematics (CUND), is comprised of five dimensions: numbers and number sense (NUM_CU), measurement (MEA_CU), geometry (GEO_CU), patterns and algebra (PAT_CU), and statistics and probability (STA_CU).

The three exogenous variables are:

1. Mathematical Mindset (MSET), defined by mathematical intelligence self-beliefs (MIS_MM) and mathematical ability self-beliefs (MAS_MM);

2. School Climate (SCLIM), encompassing teaching and learning (TEA_SC), safety (SAF_SC), institutional environment (INS_SC), interpersonal relationships (INT_SC), and social media influence (SOC_SC); and

Table 1 List of Endogenous and Exogenous Variables of the Study

Variables	Code	Role Type
Conceptual Understanding on Math	CUND	Endogenous - Latent
Number and Number Sense	NUM_CU	Endogenous - Observed
Measurement	MEA_CU	Endogenous - Observed
Geometry	GEO_CU	Endogenous - Observed
Patterns and Algebra	PAT_CU	Endogenous - Observed
Statistics and Probability	STA_CU	Endogenous - Observed
Mathematical Mindset	MSET	Exogenous - Latent
Mathematical Intelligence Self-Beliefs	MIS_MM	Exogenous - Observed
Mathematical Ability Self-Beliefs	MAS_MM	Exogenous - Observed
School Climate	SCLIM	Exogenous - Latent
Teaching and Learning	TEA_SC	Exogenous - Observed
Safety	SAF_SC	Exogenous - Observed
Institutional Environment	INS_SC	Exogenous - Observed
Interpersonal Relationship	INT_SC	Exogenous - Observed
Social Media	SOC_SC	Exogenous - Observed
Metacognition	META	Exogenous - Latent
Declarative Knowledge	DEC_MCK	Exogenous - Observed
Procedural Knowledge	PRO_MCK	Exogenous - Observed
Conditional Knowledge	CON_MCK	Exogenous - Observed
Planning	PLA_MCR	Exogenous - Observed
Information Management Strategies	INF_MCR	Exogenous - Observed
Comprehension Monitoring	COM_MCR	Exogenous - Observed
Debugging Strategies	DEB_MCR	Exogenous - Observed
Evaluation	EVA_MCR	Exogenous – Observed

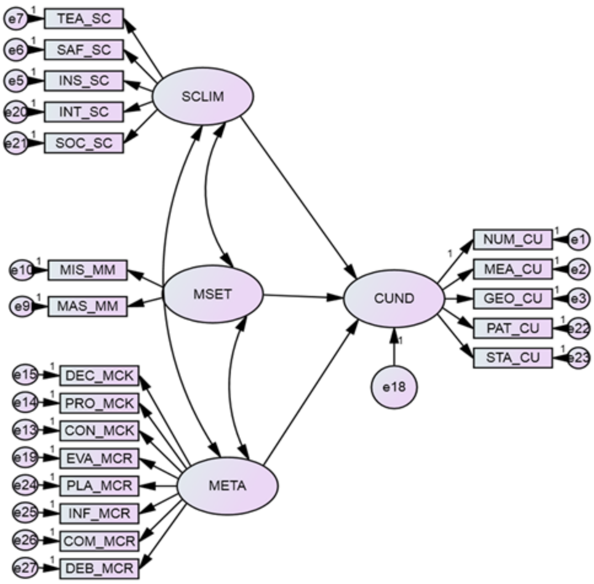

Figure 1 Hypothesized Model 1 on PSTs' Conceptual Understanding of Mathematics

3. Metacognition (META), which includes declarative knowledge (DEC_MCK), procedural knowledge (PRO_MCK), conditional knowledge (CON_MCK), planning (PLA_MCR), information management strategies (INF_MCR), comprehension monitoring (COM_MCR), debugging strategies (DEB_MCR), and evaluation (EVA_MCR)

This structural model aims to identify and clarify the pathways through which these exogenous variables influence PSTs' conceptual understanding of mathematics.

On the other hand, Hypothesized Structural Model 2, as shown in Figure 2, only considered two exogenous variables toward the endogenous variable, conceptual understanding of mathematics and the five indicators. The two exogenous variables are metacognition and the eight indicators, and school climate and the five indicators.

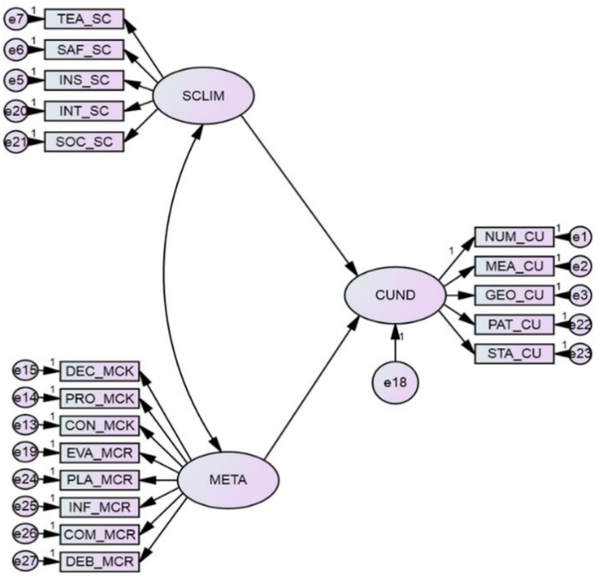

Figure 2 Hypothesized Model 2 on PSTs' Conceptual Understanding of Mathematics

The Hypothesized Structural Model 3, as presented in Figure 3, is similar with Model 2.t. However, the two exogenous variables considered are school climate with five indicators and mathematical mindset with two indicators toward the endogenous variable, conceptual understanding of mathematics and the five indicators.

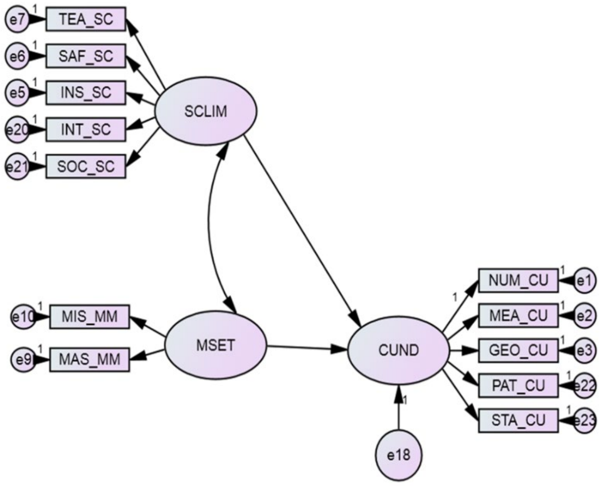

Figure 3 Hypothesized Model 3 on PSTs' Conceptual Understanding of Mathematics

As illustrated in Figure 4, Hypothesized Model 4 has a similar structure with Models 2 and 3. They vary in the two exogenous variables, which on this model are mathematical mindset with two indicators and metacognition with eight indicators.

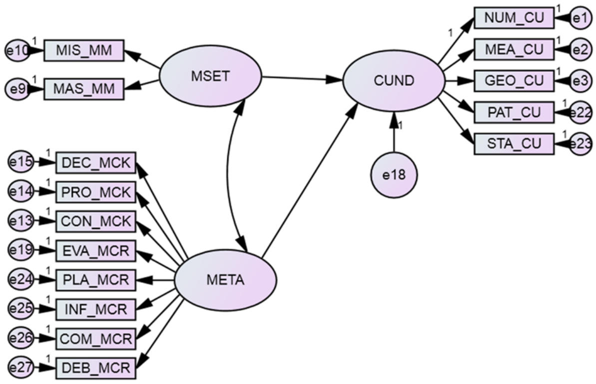

Figure 4 Hypothesized Model 4 on PSTs' Conceptual Understanding of Mathematics

Consequently, Hypothesized Model 5, as visualized in Figure 5, is similar with Model 2 but differs in the number of indicators included in each variable. In this model, metacognition is composed of three indicators namely: procedural knowledge, comprehension monitoring, and evaluation. School climate includes only three indicators, which are teaching and learning, institutional environment, and interpersonal relationship. Also, conceptual understanding of mathematics is limited to two indicators which are measurement and geometry.

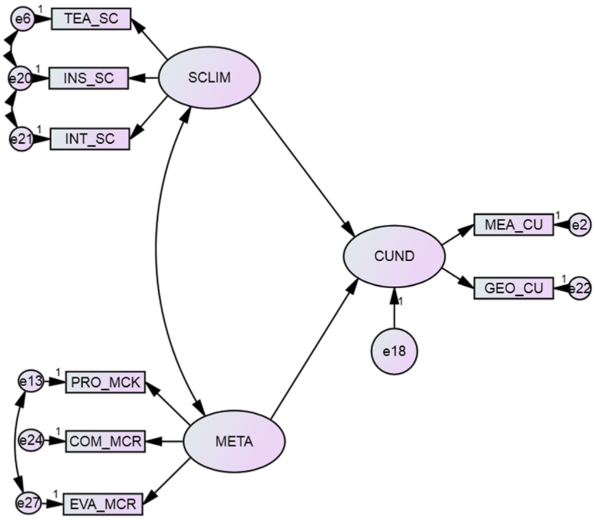

Figure 5 Hypothesized Model 5 on PSTs' Conceptual Understanding of Mathematics

Research Methodology

Research Design

The study used descriptive-correlational and causal-comparative quantitative research designs. Descriptive-correlational research helps identify the attributes of a particular phenomenon based on observation or the exploration of the correlation between two or more phenomena (Creswell, 2002). Hence, this study examined the relationship between PSTs' conceptual understanding of mathematics, mathematical mindset, school climate, and metacognition.

Moreover, in causal-comparative research, the researcher examined how the independent variable affects the dependent variable and involves cause-and-effect relationships (Salkind, 2010). Concerning this study, the researcher determined which independent or exogenous variables predicted the dependent or endogenous variable. If any independent variable is a predictor of the dependent variable, the result can be interpreted as for every unit of increase in the independent variable; there is a corresponding increase or decrease in the dependent variable.

Population and Samples

This study was conducted in the teacher education institutions in Northern Mindanao. The study utilized cluster sampling to randomly select three teacher education institutions from different geographic locations and school types: a local college, a state university, and a private college. In the selection of the participants, the researcher utilized a complete enumeration of the three sample teacher education institutions (TEIs). However, due to time and availability constraints, only a limited number of PSTs per TEIs were able to answer the research instruments. As a result, only those who were present during the data gathering and willing to participate in the study were considered. In that case, 823 pre-service teachers participated in the study.

Research Instrument

Data were collected using two-tiered tests for conceptual understanding of mathematics and scales for assessing mathematical mindset, school climate, and metacognition. A researcher-developed 30-item, two-tiered test in Basic Mathematics assessed PSTs' conceptual understanding. This test included six items each for number and number sense, measurement, geometry, patterns and algebra, and statistics and probability. The first tier consisted of multiple-choice questions, while the second required participants to justify their initial responses.

The School Climate Scale was adopted from the National School Climate Center (2021) and included five dimensions: teaching and learning, safety, interpersonal relationships, institutional environment, and social media. Each dimension contained five items aligned with the respective construct. Metacognition was assessed using a modified version of the Metacognitive Awareness Scale by Schraw & Dennison (1994). This scale was divided into two categories: knowledge of cognition (encompassing declarative knowledge, procedural knowledge, and conditional knowledge, each with five items) and regulation of cognition (including planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation, each with five items). To assess Mathematical Mindset, scales from Dweck (2006) and Boaler (2015) were adapted to capture PSTs' self-belief in mathematical intelligence and ability, with five items each dedicated to these dimensions.

Each instrument underwent rigorous validity and reliability testing. A panel of content, methodological, and language experts reviewed the initial instruments, and their feedback guided further refinement. The instruments were then pilot-tested in a teacher education institution in the Zamboanga del Sur region. The 40-item conceptual understanding test was refined to 30 items, achieving a Cronbach's alpha of 0.85, indicating reliability. The scales for mathematical mindset, school climate, and metacognition demonstrated Cronbach's alphas of at least 0.90, 0.92, and 0.91, respectively.

Collection of Data

Before conducting the study, the researcher obtained necessary approvals. An endorsement letter from the Dean of the College of Education at Bukidnon State University was sent to the presidents of participating universities and colleges in Region X with teacher education programs. After obtaining authorization, the researcher coordinated with College Deans, program chairpersons, and practice teaching supervisors.

Eligible participants were briefed on the study, and informed consent was secured, ensuring voluntary participation and the option to withdraw at any time. Participants completed the conceptual understanding test and scales for mathematical mindset, metacognition, and school climate within a 90-minute session. Collected data were subsequently analyzed, and all materials were securely stored to ensure data privacy.

Data Analysis

The data were analyzed using various statistical tools. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were employed to characterize PSTs' conceptual understanding of mathematics, mathematical mindset, school climate, and metacognition. Pearson Product Moment Correlation was used to examine relationships between PSTs' conceptual understanding of mathematics, mathematical mindset, school climate, and metacognition. Multiple Linear Regression identified which exogenous variables significantly predicted the endogenous variable.

Structural Equation Modeling (SEM) was conducted to test the hypothesized model and identify the best-fit model. Model fit was evaluated using the following indices: CMIN/DF, Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), Normed Fit Index (NFI), and Goodness of Fit Index (GFI). A non-significant chi-square ($p > 0.05$) was expected, with a chi-square minimum to degrees of freedom ratio (χ^2/df) of less than 2.00. Additionally, values for NFI, TLI, CFI, and GFI were required to exceed 0.95, and RMSEA values to be below 0.05 (Hu & Bentler, 1999; West et al., 2012).

Results and Discussion

Conceptual Understanding of Mathematics

Table 2 presents PSTs' conceptual *understanding* of mathematics. The results show that PSTs have an incomplete understanding of mathematics. Findings suggest that the PSTs demonstrated *little to no understanding* of key mathematical concepts. They struggled to apply basic mathematical procedures and algorithms accurately. They relied heavily on memorization or rote procedures and needed to understand the underlying concepts genuinely. Major misconceptions are observed in their responses. On the other hand, about a quarter of the PSTs have a *partially* complete understanding, while less than five percent reached the *complete understanding* level. It suggests that one-fourth of the participants committed minor misconceptions, and only a few completely understood the tested mathematical concepts. Looking at the five content areas of the K to 12 Mathematics curriculum, it is evident that PSTs had an *incomplete understanding* of the five areas: numbers and number sense, measurement, geometry, patterns and algebra, and statistics and probability. The content area on patterns and algebra got the *highest* mean, while measurement had the *lowest.*

Table 2 PSTs Level on Conceptual Understanding of Mathematics

Level of Conceptual Understanding	Content Areas in Mathematics						
	Score Range	Patterns and Algebra	Number and Number Sense	Probability and Statistics	Geometry	Measurement	Overall
		f (%)	*f (%)*	*f (%)*	*f (%)*	*f (%)*	*f (%)*
Complete Understanding	13-18	66 (8.00%)	40 (4.90%)	52 (6.30%)	45 (5.50%)	34 (4.10%)	31 (3.80%)
Partially Complete Understanding	7-12	226 (27.50%)	186 (22.60%)	177 (21.50%)	143 (17.40%)	156 (19.00%)	208 (25.30%)
Incomplete Understanding	0-6	531 (64.505)	597 (72.50%)	594 (72.10%)	635 (77.10%)	633 (76.90%)	584 (70.90%)
Mean		5.81	5.06	5.01	4.59	4.41	4.98
SD		3.95	3.54	3.71	3.64	3.61	3.34
QD		*Incomplete Understanding*					

Findings suggest that the PSTs needed to demonstrate more understanding of essential concepts of *patterns and algebra.* Major misconceptions are observed in their responses. PSTs were asked about the correct translation of $3n-1$. Most of the PSTs who responded incorrectly answered *"thrice n less than 1"*. They explained that it is less than that means minus. However, that is a misconception. The answer should be *"one less than thrice n or three n less 1"*. Results suggest this misconception led them to derive incorrect mathematical equations in word problems. This misconception is also documented by Tan et al. (2013) from De La Salle University – Manila. They disclosed that less than 50% of the students reached a sound understanding of variables and equality. It was emphasized that students lack conceptual understanding of the specified concepts. They call for a deliberate effort on the part of the teacher to connect previous concepts to the current topics.

Major misconceptions are observed in their responses on number and number sense concepts. Most common misconceptions and errors that fall under number and number sense cover numbers, their properties, and operations. Here are some misconceptions about the number zero (0) from the PSTs.

> *"Zero is not part of the integers". (PST 432)*
>
> *"The mathematical statement, 0 – 1 = -1 is false because zero cannot be subtracted with a negative number."*
> *(PST 85)*
>
> *"Everything with zero exponent is equal to zero [20 = 0]". (PST 521)*

PST 432's idea of zero as not part of the set of integers correlates with the findings of Russel & Chernoff (2011) in one of the teacher participants who viewed zero as a starting point of numbers but not a number itself. Further, the limited and misconstrued understandings of computations involving zero from PST 85 and PST 521 were also reflected in their results. They expressed that PSTs lack knowledge about zero. The need for pre-service education programs to bring attention to developing a more complete and meaningful understanding of zero was suggested. PSTs also expressed some misconceptions about the operations of integers. Here are some of their statements:

> *"Negative one minus one equal zero (-1-1 = 0) because negative number minus another negative number is equal to positive number." (PST 21)*
>
> *"I think if -1 + -1 = 2 because negative [number] plus negative [number] will become positive [number]."*
> *(PST 53)*

The misconceptions on subtracting integers found in the present study, with PST 21, corroborates the findings of Rosyidah et al. (2021) in Indonesia that the highest portion (53%) of the PSTs performed concept errors in subtracting two negative numbers, also on subtracting two positive numbers. He added that students commit concept errors in adding integers, as resonated in the statement of PST 53. In Ghana, findings parallel the results revealed by Owusu et al. (2023) that 73.67% of preservice mathematics teachers committed common errors and misconceptions in adding and subtracting integers. As observed, teaching integers through rules or formulas led to their confusion rather than being helpful to them. The answers and explanations of PSTs confirmed this reality. Fuadiah et al. (2019) asserted that the way concepts on integers are taught in the classroom needs to improve.

Also, PSTs are confused about the concept of prime numbers. A common misconception is that the number 1 is prime when it is neither prime nor composite. Another common misconception is that all prime numbers are odd numbers. It is not true since the number 2 has only two factors, 1 and 2, and is also an even number. They narrated that:

> *"Prime numbers are odd numbers and 1 is prime because it is an odd number". (PST 265)*
>
> *"2 is a not prime number because it is even".*
> *(PST 511)*

On *probability and statistics,* major misconceptions are observed in their responses. PSTs were asked to determine the probability that a teacher selected randomly from a group of 70 is a male mathematics teacher. It was given that there were 30 general science teachers, composed of 10 males and 20 females. On the other hand, there were 40 mathematics teachers, ten males, and 30 females. Most PSTs who responded incorrectly expressed that one-third is the answer. They elaborated that it is ten over 30, as to the ratio of 10 male mathematics teachers over 30 females. PSTs should have considered the number of male mathematics teachers over the total number of mathematics teachers, which is 40, to derive the correct answer of 10 over 40 or one-fourth. Parallel findings were documented by Arican & Kuzu (2019) that most PSTs experienced difficulty in drawing inferences about populations based on samples, selecting and using appropriate statistical methods, and understanding and applying the basic concepts of statistics and probability. Hokor et al. (2022) added that PSTs had conceptual difficulties, interpretation difficulties, and procedural difficulties in probability.

Results specify that PSTs demonstrated little to no understanding of key concepts in *geometry* based on the major misconceptions are observed in their responses. PSTs were given statements on geometry and were asked to identify which was the truth. However, most PSTs with incorrect responses chose that a circle is a polygon and a ball is a circular object. These misconceptions suggest that PSTs needed to understand polygons and three-dimensional figures fully. The observations of Gueudet & Pepin (2018) corroborate the present results. Accordingly, PSTs had a fragmented understanding of geometric concepts and struggled to connect different aspects of geometry to understand the subject coherently. It also supports the findings of Unlu (2021) that PSTs had either insufficiently detailed or incorrect answers for the concepts of circle, circular region, and sphere.

Findings divulged that PSTs demonstrated little to no understanding of key *measurement* concepts. PSTs relied heavily on memorization or rote procedures without genuinely understanding the underlying concepts. PSTs were questioned about how long the motor could be kept running, with 20 gallons of fuel available when it takes 8 gallons of fuel for 2.5 hours. Most numbers of the PSTs answered 6 hours and 25 minutes. They got the correct result of 6.25 hours but got the wrong answer because 6.25 hours differ from 6 hours and 25 minutes. PSTs were to convert the 0.25 hours to 15 minutes. They should have recognized that time is in the sexagesimal number system.

> *"When we divide 20 by 8, the answer is 2.5 which is to be multiplied to the number of hours (2.5 hours). The result is 6.25 hours. Therefore, 20 gallons of fuel can run a motor for at least 6 hours and 25 minutes." (PST 90)*

The study's findings are similar to the results of Dincer & Osmanoglu (2018), wherein PSTs were found to have misconceptions and difficulty using appropriate units of measurement and converting to different units. Kilic et al. (2019) corroborated that PSTs had a limited understanding of measurement concepts and struggled with their differences. It is substantiated by Khalid & Embong (2019) as they disclosed that the leading cause of errors and misconceptions is superficial understanding, which was most probably due to teachers rushing to complete the extensive syllabus. Consequently, students resorted to memorizing rules because of surface understanding. They added that teaching practices on integers were found to lack multiple representations, creativity, cooperative learning, and active learning.

Most PSTs need help understanding and applying the concept of mathematics in a real-world context. Misconceptions signify that PSTs have persistent difficulties in mathematics (Phanphech et al., 2019). The difficulty is due to the conventional learning strategy, which cannot improve the student's ability (Jazuli et al., 2017). Evidently, conceptual understanding of mathematics may be partially understood, but with continuous search for its improvement, mathematical proficiency will come into its place (Hull et al., 2015; Mills, 2016). The results were also parallel with studies on global scope. Similar results on conceptual understanding in the Mathematics of PSTs were documented in the following countries: the United States of America (Aguilar & Telese, 2018), Ireland (Riodain et al., 2023), South Africa (Ndlovu et al., 2017), and Philippines (Cabras, 2022; Cananua-Labid, 2015; Ebio, 2022; Tubo, 2018). The findings on the conceptual understanding of the PSTs, and even their misconceptions, entail lapses in the pre-service teacher preparation program of the teacher education institutions. It is of great concern to the mathematics education community. Mathematics teachers in teacher education institutions need to initiate policies, programs, and strategies to mitigate this phenomenon.

Mathematical Mindset of PSTs

Table 3 presents the results of the conducted assessment. As gleaned from the table, it was divulged that, in general, PSTs have a *high mathematical mindset.* Findings suggest that the PSTs own a strong growth mindset in mathematics. They view challenges as opportunities to learn and grow and actively seek out new and difficult problems to solve. They believe they can constantly improve their mathematical abilities through hard work and dedication. When looking into the two dimensions, intelligence, and ability, both are high. It was disclosed that PSTs believe that mathematical intelligence and ability are growing and not fixed. They can learn mathematics if they practice and exert effort.

PSTs with a high mathematical mindset approach mathematics with a growth-oriented attitude. They tend to view mathematics as a learnable subject rather than an innate talent. The PSTs embrace challenges and mistakes as opportunities for growth and learning. They also value the importance of effort and hard work in developing mathematical abilities rather than relying solely on natural intelligence. However, it is essential to note that having a high mathematical mindset does not necessarily mean being highly skilled in all areas of mathematics, as mathematical ability can vary depending on the specific domain or task. For example, a pre-service teacher with a high mathematical mindset may excel at solving algebraic equations but need help with spatial reasoning tasks in geometry. Similarly, someone who excels in measurement may find statistics challenging.

PSTs' mathematical mindset was perceived to be among the many reasons they may struggle in mathematics (Fu & Kartal, 2023). With the result that PSTs had a high mathematical mindset, it is a manifestation that they positively approach mathematics as a dynamic and interconnected subject rather than a set of isolated skills and procedures. PSTs who approach mathematics with this mindset are more likely to see the connections between different concepts and recognize mathematical ideas' relevance in real-world situations. Developing a mathematical mindset requires intentional effort and practice. PSTs can benefit from experiences that allow them to explore mathematical concepts in multiple ways, make connections between ideas, and engage in productive struggle as they work to solve problems. With a strong growth mindset, they are more willing to embrace challenges as learning opportunities and persist in the face of difficulty or failure.

Table 3 Level of Mathematical Mindset of PSTs

Indicators	Mean	SD	QD
Mathematical Intelligence Self-Beliefs	3.93	0.64	High
I believe that mathematical intelligence is not fixed and can be changed.	4.02	0.73	High
With enough effort, I think I could significantly improve my intelligence level in Mathematics.	3.95	0.79	High
I believe that all people are born with mathematical intelligence.	3.94	0.74	High
I believe that everyone has the potential to become intelligent at Mathematics considerably over time.	3.90	0.77	High
Regardless of my current intelligence level in Mathematics, I think I have the capacity to change it quite a bit.	3.86	0.75	High
Mathematical Ability Self-Beliefs	3.59	0.77	High
I am confident in my ability to solve Mathematics problems.	3.67	0.92	High
I can always learn Mathematics and understand better with techniques and strategies.	3.64	0.89	High
The harder I work to learn Mathematics, the better I will be.	3.58	0.91	High
I believe that I have the ability to learn and improve in Mathematics.	3.54	0.90	High
I believe that I can improve my Mathematics ability with practice and effort.	3.51	0.88	High
Overall	3.76	0.63	High

Mabandos & Moneva (2020) disclosed that PSTs with growth mindset have a moderate level of anxiety. This implies that while they have a positive belief in their ability to grow and develop as teachers, they may still feel a certain degree of nervousness or apprehension about the challenges they may encounter in their teaching journey. This observation was noted on the informal talks with the PSTs before they took the test. The study's findings corroborate the earlier results of Mariano-Dolesh et al. (2022) that PSTs have a strong growth mindset regarding the time and effort needed to improve themselves. It demonstrates the PSTs' readiness to maximize their resources, learn from their mistakes, and accept challenges, considering failure a chance to learn.

The results were also parallel to Saefudin et al. (2023) as they unveiled that most of the junior high school students had the characteristics of a growth math mindset with a little bit of a fixed math mindset. Most students believe that mathematical abilities and intelligence can be changed, even though they find it difficult to face challenges and difficulties when learning mathematics. Fostering a positive mathematical mindset can be an influential factor in developing PSTs' conceptual understanding of mathematics. By cultivating interconnected conceptual beliefs and resilience in problem-solving, PSTs are better prepared to teach future students for deep mathematical comprehension. With growth mindset training, PSTs could achieve even stronger growth attitudes by reflecting on their beliefs and teaching practices.

School Climate of PSTs

Table 4 presents the school climate of PSTs and reveals that PSTs have *a high positive school climate.* Results mean that PSTs' school climate is supportive and conducive to learning with minor concerns. The school is safe and has a sense of community, inclusivity, respect, and support. When the five school climate indicators were examined, it was found that the dimension of interpersonal relationships received the highest average score among the indicators. In contrast, the dimension of social media received the lowest average score.

It could indicate that PSTs perceived the quality of interpersonal relationships to be relatively high. At the same time, they may have concerns or negative experiences related to social media use within the school community, such as Facebook, Twitter, and Instagram. Further, the statement suggests that, on average, respondents rated the interpersonal relationships dimension of school climate as the most positive aspect of the school environment. In contrast, the social media dimension received the lowest average score. It could indicate that students and staff members perceive the quality of interpersonal relationships to be relatively high. At the same time, they may have concerns or negative experiences related to social media use within the school community.

Table 4 Level of School Climate among PSTs

Indicators	Mean	SD	Qualitative Description
Interpersonal Relationship	4.13	0.75	*High Positive*
Safety	4.11	0.73	*High Positive*
Teaching and Learning	4.00	0.68	*High Positive*
Institutional Environment	3.98	0.70	*High Positive*
Social Media	3.93	0.68	*High Positive*
Overall	4.03	0.66	*High Positive*

Opportunities for PSTs to connect with other teachers are observable, both new and experienced, to share ideas and strategies. There is a presence of student-centered learning, where PSTs are encouraged to develop their teaching styles and approaches. A culture of continuous learning is visible, where PSTs are supported in their professional development and given opportunities to grow and improve their skills. Access to resources and support systems are available, such as mentors, coaches, and professional development programs. Similar results that teachers' perceptions of school climate were high and very positive resonated from Sun's (2019) study in Shanghai. Crankson et al. (2020) had similar findings to the present study. The outcomes indicated that PSTs have a high level of perception on their classroom environment. Subsequently, Colita & Genuba (2019), from the Philippines, revealed the level of school climate of the private schools was high.

Jayme & Dayon (2019), added that a higher education institution in Southern Philippines is welcoming, clean, smoke-free and warm. Also, Cardenas & Cerado (2016) divulged that the public schools in Koronadal City are safe, healthy, and pleasant learning environment. Each classroom demonstrates respect, accountability, and trust. The teachers are collegial and the administrators are kind. UNESCO (2014) highlighted that schools should be a space where children build academic and social-emotional leaning to co-exist with one another. The learning environment plays an important role on the students' cognitive, behavioral, and affective aspects (Amirul et al., 2013). Morales (2016) expressed that one of the critical causes of the achievement gap is the anti-intellectual school climate. Thus, having a highly positive school climate is a good manifestation that PSTs can thrive. Creating a positive school climate for PSTs is vital because it can impact their motivation, engagement, and, ultimately, their success as future educators. By providing a supportive and collaborative environment, PSTs can feel empowered to take risks, try new approaches, and develop their teaching style, leading to improved student outcomes. A supportive and positive school climate can foster a conducive learning environment for PSTs to develop mathematical skills.

Metacognition of PSTs

Table 5 presents the metacognition of PSTs. The result reveals that, overall, PSTs have a *high level of metacognition.* Results indicate that PSTs consistently demonstrate a high awareness of their learning processes or strategies and can apply them flexibly. They could identify their strengths and weaknesses as a learner and use that knowledge to improve their learning. They can work independently but may seek external guidance and support to deepen their understanding. In addition, their regulation of cognition indicators, including debugging strategies and planning, is higher than their knowledge of cognition indicators, composed of conditional, procedural, and declarative knowledge. It entails that PSTs are better at regulating their cognitive processes than knowing about them. PSTs may have better skills at managing and optimizing their cognitive processes, such as debugging strategies and planning, than understanding the underlying cognitive mechanisms. In other words, they may be more effective at using specific techniques and strategies to improve their cognitive performance than explaining how these techniques and strategies work.

Table 5 Level of Metacognition of PSTs

Metacognition Dimension	Mean	SD	Qualitative Description
IDebugging Strategies	4.11	0.67	*High*
Planning	3.98	0.66	*High*
Conditional Knowledge	3.98	0.65	*High*
Evaluation	3.93	0.65	*High*
Information Management Strategies	3.91	0.63	*High*
Procedural Knowledge	3.91	0.66	*High*
Comprehension Monitoring	3.90	0.61	*High*
Declarative Knowledge	3.82	0.59	*High*
Overall	3.94	0.58	*High*

PSTs with high metacognition entail awareness of their strengths and weaknesses as learners and future teachers. They can reflect on and understand their thinking, learning, and teaching strategies. They are more likely to be effective learners and teachers because they can better understand and control their thinking processes. They are more self-directed in their learning and teaching and better equipped to adapt to new situations and challenges. They can set specific learning goals and monitor their progress toward achieving them. Also, they can identify and use appropriate strategies to solve problems and overcome obstacles in their learning and teaching. Further, they can reflect on their own learning and teaching experiences and use that reflection to improve their future performance.

Other studies substantiate the results of the present study. Yorulmaz et al. (2021) found high pre-service primary school teachers' metacognitive awareness in Turkey. In the same country, Koc & Kuvac (2016) expressed that pre-service science teachers' metacognitive awareness levels were determined to be generally high based on the results. In Indonesia, a similar finding was captured by Fauzi & Sa'diyah (2019), which showed that the level of metacognitive awareness of pre-service biology teachers was good. However, in the Philippines, Andres (2022) presented that pre-service teachers have an average level of metacognition. In addition, Ozcakmak et al. (2021) found that PSTs metacognitive awareness are high, but their metacognitive skills are low. Kartika & Firmansyah (2019) disclosed similar result and they expressed the need for continuous enhancement of PSTs metacognitive skills.

Relationship of PSTs' Conceptual Understanding and Other Variables

Table 6 shows the results of the correlation between PSTs' conceptual understanding of mathematics and their mathematical mindset, school climate, and metacognition. It was tested at a 0.05 level of significance. It can be gleaned from the table that the relationship of conceptual understanding towards mathematical mindset, school climate, and metacognition came *positive*, based on the r values. It means that the constructs are moving in the same direction. When pre-service teachers' mathematical mindset increases, their conceptual understanding also increases. If their school climate decreases, their conceptual understanding also decreases. The same is true of the relationship between conceptual understanding and metacognition. In addition, null hypotheses 1, 2, and 3 which state that "there is no significant relationship between mathematical mindsets and conceptual understanding of mathematics, school climate and conceptual understanding, and metacognition and conceptual understanding" are rejected. The decision is due to the fact that they generated a p-value that is less than 0.05.

The rejection of hypothesis 1 signifies a *significant relationship* between mathematical mindset and conceptual understanding of mathematics. Consequently, the rejection of hypothesis 2 means that there is a significant relationship between school climate and conceptual understanding of mathematics. Subsequently, rejection of null hypothesis 3 suggests a significant relationship between metacognition and conceptual understanding of mathematics. The mathematical mindset has the highest degree of relationship with the conceptual understanding of mathematics, while school climate has the lowest degree of relationship with the conceptual understanding of mathematics. It means that PSTs with a positive mathematical mindset, such as believing in their abilities to improve their mathematical skills, are more likely to have a solid conceptual understanding of mathematics. On the other hand, as measured in this study, school climate appears to have less of a direct relationship with PSTs' conceptual understanding of mathematics.

It can be noted that specific indicators of planning and debugging strategies from metacognition and specific indicators of safety and interpersonal relationships from school climate received a low

Table 6 Correlation Results of PSTs' Conceptual Understanding and Other Variables

Variables	**Conceptual Understanding**	
	r	***p-value***
Mathematical Mindset	0.495	0.000
Mathematical Ability Self-Beliefs	0.504	0.000
Mathematical Intelligence Self-Beliefs	0.363	0.000
Metacognition	0.404	0.000
Declarative Knowledge	0.483	0.000
Information Management Strategies	0.406	0.000
Procedural Knowledge	0.385	0.000
Comprehension Monitoring	0.384	0.000
Evaluation	0.365	0.000
Conditional Knowledge	0.345	0.000
Planning	0.293	0.000
Debugging Strategies	0.271	0.000
School Climate	0.329	0.000
Social Media	0.338	0.000
Institutional Environment	0.331	0.000
Teaching and Learning	0.315	0.000
Safety	0.289	0.000
Interpersonal Relationship	0.265	0.000

correlation toward conceptual understanding in mathematics. While these factors and indicators may be necessary to promote overall learning and well-being, they may not directly relate to PSTs' ability to understand mathematical concepts. It is possible that other factors, such as mathematical ability, self-belief, and declarative knowledge with the highest degree of relationship, may play a more decisive role in influencing PSTs' conceptual understanding of mathematics. PSTs with a positive mathematical mindset, experience a positive school climate, and strong metacognitive skills are more likely to have a solid conceptual understanding of mathematics. The results are consistent with the idea that various factors beyond content knowledge, such as attitudes, beliefs, and learning strategies, influence the conceptual understanding of mathematics. It highlights the importance of creating a positive and supportive learning environment for students and promoting metacognitive skills and a growth mindset toward mathematics.

The significant relationship between mathematical mindset and conceptual understanding was also cited by Hachfeld et al. (2019). They emphasized that PSTs with a growth mindset were more likely to have a deeper conceptual understanding of mathematics. Bernardo from the Philippines had similar results that Filipino students' growth mindset was positively associated with learning in mathematics. Further, Waid (2018) disclosed that PSTs growth mindset was related to their assessment results and feedback. However, Lai et. al (2018) revealed a limited relationship exists between growth mindset and final grades, as a form of mathematics performance.

In terms of the significant relationship between school climate and conceptual understanding in mathematics, Gellor (2019) had similar results that school environment is significantly correlated to mathematics achievement, which indicates that PSTs possess sound understanding. Relatively, Greenway (2017) indicated a statistically significant, positive relationship between school climate and student achievement. Gustafsson & Nilsen (2016) confided that school climate items reflecting parental support were significantly related to student achievement. In addition, Colita & Genuba (2019) found that school climate and mathematical dispositions of students were significantly and positively correlated.

Moreover, Cano-Garcia et al. (2019) found that PSTs metacognitive abilities and their conceptual understanding of mathematics correlate; the higher the metacognitive abilities, the better their conceptual understanding of mathematical concepts. Similarly, Abdelrahman (2020) disclosed a significant relationship between students' academic achievement and motivation, where metacognitive awareness is the major contributor. Parallel results were documented in the Philippines by Limueco (2017). There was a significant relationship between conceptual understanding and all the components of metacognition except procedural knowledge. Also, Constantino et al. (2020) found a significant correlation.

Predictors of Conceptual Understanding of Mathematics

Table 7 shows the regression analysis of PSTs' conceptual understanding of mathematics. The null hypothesis is tested at 0.05 level of significance that no significant predictor exists among PSTs' mathematical mindset, school climate, and metacognition to their conceptual understanding of mathematics. Results revealed that the p-value of the variables is less than 0.05; thus, the null hypothesis is rejected. Thus, PSTs' mathematical mindset in terms of mathematical ability self-beliefs, school climate in terms of institutional environment, and metacognition in terms of declarative knowledge, planning, information management strategies, and conditional knowledge significantly predict their conceptual understanding of mathematics.

Results revealed that the p-value of the six observed variables is less than 0.05; thus, the null hypothesis is rejected. Thus, PSTs' mathematical ability self-beliefs from mathematical mindset; declarative knowledge, planning, information management strategies, conditional knowledge from metacognition; and the institutional environment from school climate are significant predictors of the conceptual understanding of mathematics. Moreover, a regression model is generated from Table 13 with an r-squared of 0.368. The resulting equation is *conceptual understanding = -35.595 + 8.828 * mathematical ability self-beliefs + 15.903 * declarative knowledge - 5.702 * planning + 6.673 *information management strategies – 5.390 * conditional knowledge – 2.715 * institutional environment.* The coefficients in the equation represent the degree to which each observed variable contributes to the dependent variable.

Findings suggest that for each unit increase in mathematical ability self-belief, declarative knowledge, and information management strategies, there is an expected increase of 8.828, 15.903, and 6.673 units in conceptual understanding of mathematics, respectively.

However, for each unit increase in planning, conditional knowledge, and institutional environment, there is an expected decrease of 5.702, 5.390, and 2.715 units in conceptual understanding of mathematics, respectively. Generally, the regression model proposes that mathematical mindset and metacognition are positively associated with the conceptual understanding of mathematics, while school climate is negatively associated. This finding highlights the importance of supporting PSTs' attitudes, beliefs, and skills in mathematics and mathematics education. It recommends that teacher education programs and schools should focus on developing PSTs' content knowledge in mathematics and fostering positive attitudes toward mathematics, creating supportive learning environments, and promoting metacognitive skills that can support ongoing learning and growth.

Table 7 Predictors of Conceptual Understanding of Mathematics

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	t	p-value
	B	*SE*	*Beta*		
Constant	-35.595	3.601		-9.885	.000
Mathematical Mindset					
Mathematical Ability Self-Beliefs	8.828	0.781	0.367	11.303	.000
Metacognition					
Declarative Knowledge	15.903	1.839	0.508	8.647	.000
Planning	-5.702	1.545	-0.204	-3.691	.000
Information Management Strategies	6.673	1.613	0.227	4.136	.000
Conditional Knowledge	-5.390	1.775	-0.188	-3.037	.002
School Climate					
Institutional Environment	-2.715	1.118	-0.110	-2.428	.015

Note: r = 0.607, adjusted r-squared = 0.368, F-ratio = 79.338, p-value = 0.000

Results from other authors corroborate with the results of the present study. In the Philippines, Mariano-Dolesh et al. (2022) also found that in an online environment, PSTs' mindset predicts the level of their conceptual understanding in problem-solving. Moreover, Flores-Gonzalez et al. (2021) disclosed that PSTs' mathematical mindset significantly predicted their conceptual understanding of mathematical concepts. Relatively, Sachs (2017) expressed that growth mindset influenced students' mathematics performance. Daly et al. (2019) cited that mathematical mindset increases motivation and that this change reflects that students were attempting to understand and solve mathematical problems. Moreover, Pyper (2018) pointed that students with growth mindset will likely perform better than their classmates with a fixed mentality.

On school climate and conceptual understanding, similar results were cited. Berkowitz et al. (2017) documented that school climate predicts conceptual understanding, in a form of academic achievement. Amirul et al. (2013) articulated that the learning environment impacts the teaching and learning process and can affect their cognitive, behavioral, and affective aspects. Colita & Genuba (2019) added that school climate influenced students' mathematical dispositions. For metacognition and conceptual understanding, Cakir & Guven (2019) found that PSTs metacognition and motivation predicted their academic achievement. When PSTs determine specific learning strategies for themselves and plan accordingly, when they monitor whether these strategies are helpful, and when they assess their learning; they can learn effectively.

Evaluation of Best-Fit Structural Model

Table 8 summarizes the fit indices of the five structural models in this study. The table displays the computed standard values of structural models 1 to 4 that did not satisfy the criteria of a best-fit model. Hence, this result shows that these models do not fit PSTs' conceptual understanding of mathematics. For Structural Models 1,2 and 4, the models did not have a good fit on any fit indices presented. However, for Structural Model 3, the model had a good fit on indices NFI, TLI, and CFI. These are baseline comparison indices; however, Model 3 lacks good fit indices in the other baseline to be considered a best-fit model.

Table 8 Goodness of Fit Indices of the Five Structural Models

Standard Indices	Standard Value	Model 1 Value	Model 2 Value	Model 3 Value	Model 4 Value	Model 5 Value
CMIN/DF	<2.00	8.028	7.834	6.940	8.461	1.600
p-value	>0.05	0.000	0.000	0.000	0.000	0.071
NFI	>0.95	0.933	0.944	0.965	0.944	0.996
TLI	>0.95	0.932	0.943	0.961	0.940	0.997
CFI	>0.95	0.941	0.951	0.970	0.950	0.999
GFI	>0.95	0.858	0.875	0.930	0.893	0.993
RMSEA	<0.05	0.092	0.091	0.085	0.095	0.027

Legend: CMIN/DF (Chi-square Minimum/Degrees of Freedom)
NFI (Normed Fit Index)
GFI (Goodness of Fit Index)
TLI (Tucker-Lewis Index)
RMSEA (Root Mean Square Error of Approximation)
CFI (Comparative Fit Index)

On the other hand, the fit indices values of Structural Model 5, in Figure 10, satisfied the prescribed standard values. Therefore, it is clear that the final model depicts the conceptual understanding of the mathematics of PSTs concerning school climate and metacognition. The best-fit model of conceptual understanding in mathematics comprises school climate with three observed variables and metacognition with three observed variables. These are procedural knowledge, comprehension monitoring, and evaluation for metacognition. Further, the school climate comprises teaching and learning, institutional environment, and interpersonal relationship.

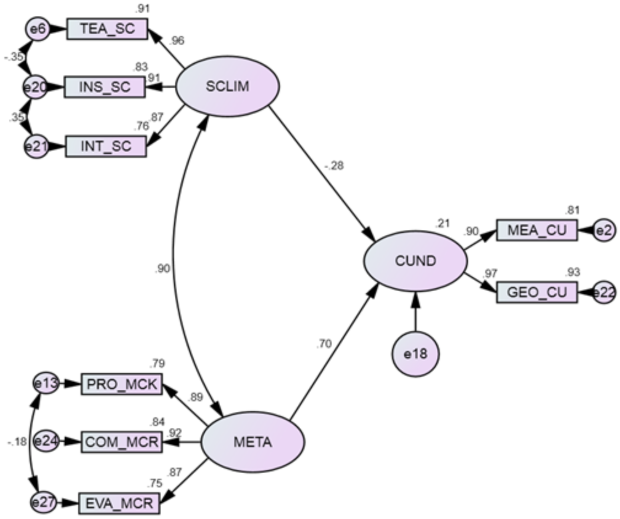

Figure 6 Structural model 5 on PSTs' Conceptual Understanding of Mathematics

The generated model extends Bandura's (1986) social cognitive theory. He posited that learning happens in a social context with a dynamic and reciprocal interaction of the person, environment, and behavior. In the present model generated, his theory confirms that conceptual understanding happens in a social context with a dynamic and reciprocal interaction of PSTs, school climate, and metacognition. In addition, the generated model presents a clearer view of which factor is more influential than the other. Lamorte (2022) expressed that Bandura's (1986) social cognitive theory is unclear as to which factors are more influential. In the present model, it is evident that metacognition is the most influential factor.

Vygotsky's (1978) sociocultural theory also supports the resulting model. He conceived that learning is constructed socially and stressed the fundamental role of social interaction in the development of cognition. With the interplay of metacognition and school climate, it is confirmed that conceptual understanding is constructed with teaching and learning, institutional environment, interpersonal relationship, procedural knowledge, comprehension monitoring, and evaluation. Dewey (1938) experiential learning theory reinforced the generated model. He argues that education and learning are social and interactive processes; thus, the school is a social institution. The school climate factor in the generated model depicts the importance of teaching and learning, institutional environment, and interpersonal relationship.

The generated model paved the way for the theorized socio-metacognitive conceptual understanding model for PSTs (SCUMPT). The model, in *Figure 7,* posits that PSTs' conceptual understanding of mathematics is influenced by the continuous reciprocal interaction of their metacognitive awareness and skills in a supportive learning environment. Specifically, the generated SCUMPT model suggests the following:

1. School climate and metacognition are interrelated factors that can work together to support PSTs' conceptual understanding of mathematics.
2. The more supportive the learning environment for developing PST's metacognition, the higher their conceptual understanding of mathematics.
3. Positive school climate can enhance students' metacognitive skills, improving their conceptual understanding of mathematics.
4. Cultivating a positive school climate and promoting strong metacognitive skills, educators can help students develop the skills and knowledge they need to succeed in mathematics and other academic subjects.

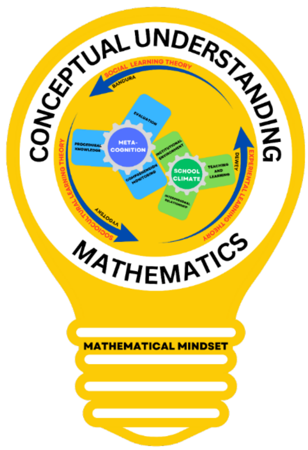

Figure 7 A Socio-Metacognitive Conceptual Understanding Model for PSTs (SCUMPT)

Suggestions

Based on the findings, the following conclusions are given:

1. The PSTs demonstrate little to no understanding of key mathematical concepts. They struggle to apply basic mathematical procedures and algorithms accurately. They rely heavily on memorization or rote procedures and need to understand the underlying concepts. Major misconceptions are observed in their responses.

2. The PSTs own a strong growth mindset in mathematics. They view challenges as opportunities to learn and grow and actively seek out new and difficult problems to solve. They believe they can continually improve their mathematical abilities through hard work and dedication.

3. The school climate is supportive and conducive for learning with minor concerns. The school has a sense of community, inclusivity, and support. PSTs feel safe and respected, and there is a positive and engaging learning environment.

4. The PSTs possess high metacognition. They consistently demonstrate a high level of awareness of their own learning processes or strategies and can apply them flexibly. They are able to identify all of their strengths and weaknesses as a learner and use that knowledge to improve their learning. They can work independently but may seek external guidance and support to deepen their understanding.

5. The higher the mathematical mindset, the better the conceptual understanding of mathematics of PSTs. An increase in school climate entails an improvement in their conceptual understanding. Moreover, the higher the metacognition, the more sound the understanding of mathematics.

6. Mathematical mindset, school climate, and metacognition influence PSTs' conceptual understanding of mathematics.

7. A socio-metacognitive conceptual understanding model for PSTs (SCUMPT) posits that PSTs' conceptual understanding of mathematics is influenced by the continuous reciprocal interaction of their metacognitive awareness and skills in a supportive learning environment.

Given the findings and conclusions of the study, the following recommendations are made:

1. PSTs may enhance their metacognitive skills to better understand mathematical concepts and procedures.

2. Mathematics teachers may teach the subject area focused on conceptual understanding, not limited to procedural knowledge, in a conducive learning environment. They may continue pursuing professional development, such as taking post-graduate degrees in mathematics education.

3. Teacher education institutions may conduct mathematics education curriculum audits to emphasize the teaching of conceptual understanding of mathematics, as it is neither a set of algorithms nor rote memorization.

4. The Department of Education may develop policies and programs to enhance mathematics teachers' competence in teaching mathematics for conceptual understanding.

5. Mathematics education researchers in the Philippines may conduct another similar study considering basic education learners to augment the country's poor performance in international, national, and even local benchmarks in Mathematics.

6. International teacher education programs may focus on integrating metacognitive strategies into mathematics teaching methods to help future educators improve both their own and their students' conceptual understanding.

7. Governments, education departments, and policy-makers across various countries, including international organizations like UNESCO or OECD, may develop and promote policies that enhance mathematics teachers' competence.

8. Researchers globally are encouraged to conduct similar studies in different educational contexts, particularly targeting basic education learners. International academic communities can support cross-country research initiatives, fostering data-sharing and comparative analyses to create more effective strategies for improving mathematics education on a global scale.

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