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Unravelling Affective Mathematical Disposition: Its Role in Strengthening Numeracy Among Pre-Service Mathematics Teachers

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Abstract: This study investigates the relationship between affective mathematical disposition (MD) and numeracy among pre-service mathematics teachers in Indonesia. The research examines explicitly how different dimensions of MD influence students' numeracy skills. A total of 237 participants took part in a semester-long numeracy enrichment program, followed by a numeracy assessment and an MD questionnaire based on Beyers' seven affective dimensions. Using multiple linear regression analysis, the findings indicate that MD significantly affects numeracy ($p = 0.018$), with an adjusted R-squared value of 0.571, indicating that 57.1% of the variance in numeracy scores can be explained by MD. Notably, the dimensions "Nature in Mathematics" ($\beta = 0.584$, $p = 0.033$) and "Mathematics Self-Concept" ($\beta = 0.612$, $p = 0.016$) exhibit significant positive influences on numeracy. Highlighting the role of conceptual understanding and self-perception in mathematical learning. These results align with the program's design, which emphasized conceptual understanding and reflective self-assessment—elements directly tied to both dimensions. However, other dimensions, including "Usefulness," "Worthwhileness," "Sensibleness," "Attitude," and "Math Anxiety," did not show significant effects. This may be due to participants' shared perceptions as mathematics teacher candidates, resulting in low variability on those dimensions, or due to possible mediation effects (e.g., motivation) that were not examined in this study. The findings suggest that interventions aiming to strengthen numeracy should focus on enhancing students' understanding of mathematical structures and fostering a strong self-concept as mathematics learners. This study contributes to mathematics education by highlighting the specific affective dimensions that most directly relate to numeracy, providing a nuanced perspective for teacher educators seeking to balance cognitive and affective development in their curriculum.

Keywords: mathematical disposition, affective domain, numeracy, pre-service mathematics teachers, mathematics education.

▪ INTRODUCTION

Mathematical disposition (MD) broadly encompasses key components such as emotions, beliefs, and actions that reflect a willingness to engage with and apply mathematical concepts (Almerino, Jr. et al., 2019; Kamid et al., 2021). Beyers classifies MD into three categories: cognitive, affective, and conative mental functions (Beyers, 2011), which provides a framework for analyzing students' dispositions towards mathematics. The essence of MD, which is closely related to students' confidence, interest, and perceptions when confronting mathematical problems, underscores the vital role that MD plays in students' engagement with mathematics learning.

Numerous global studies have demonstrated that mathematical disposition (MD) directly correlates with enhanced confidence and learning motivation (Crow & Kastello, 2016; Norton, 2019), mathematical reasoning (Agyei et al., 2021), as well as academic achievement in mathematics (Hwang & Choi, 2020). During the pandemic, MD was shown to have a positive impact on online learning (Soesanto & Dirgantoro, 2021). These findings underscore that MD significantly influences students as they navigate the

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challenges and complexities of mathematical problems, whether in online or face-to-face learning contexts.

Indonesia recognizes the pivotal role of MD in cultivating a positive attitude toward mathematics, enhancing critical thinking, and fostering independent learning. Numerous studies support this recognition. A correlational study, for instance, has demonstrated a positive relationship between MD and independent learning, suggesting that a higher level of mathematical disposition correlates with greater independence in learning (Yulia et al., 2024). Within the broader context of STEM education, which is increasingly prioritized in Indonesia's current curriculum, the development of a positive disposition toward mathematics, alongside other subjects such as science and technology, is emphasized as crucial for advancing critical thinking and problem-solving skills (Sintema & Marbán, 2020). Over the past decade, a range of studies have focused on interventions and assessments related to MD across various levels of the education system (Bahar et al., 2023; Watson, 2015). These findings collectively underscore Indonesia's recognition of the importance of mathematical disposition in fostering a positive orientation toward mathematics.

In the Indonesian context, numeracy is not only a key component of student learning but also a core professional competence for mathematics teachers. Unlike students or teachers of other subjects, pre-service mathematics teachers are expected to model mathematically informed thinking, apply flexible strategies, and interpret quantitative information across contexts. According to the Indonesian Teacher Competency Standards (Permendiknas No. 16/2007), numeracy is embedded in pedagogical and professional competence, highlighting its foundational role in planning, teaching, and assessing mathematical ideas. Thus, strengthening numeracy among future teachers is a strategic imperative for sustainable mathematics education.

However, the critical importance of MD for the sustainability of mathematics education in Indonesia faces substantial challenges. While international studies have shown that mathematical disposition (MD) positively influences learning motivation (Crow & Kastello, 2016), mathematical reasoning (Awofala et al., 2022), and achievement (Hwang & Choi, 2020), the affective domain of MD, and especially its role in supporting numeracy, remains understudied. Most research explores MD globally or holistically, without disaggregating its components or situating them within specific educational programs (e.g., enrichment, professional training). In particular, few studies have investigated how affective MD dimensions, such as beliefs about the nature of mathematics or self-concept, contribute to numeracy development in pre-service mathematics teachers. This is especially critical in Indonesia, where challenges in numeracy persist due to procedural learning traditions, low exposure to real-world problems, and regional disparities in educational access (Ng et al., 2023; Wahyudin et al., 2024). Given this backdrop, exploring which affective dispositions matter most for numeracy can help optimize teacher education programs to develop both cognitive and non-cognitive strengths.

From an educational perspective, the prevalent use of traditional teaching methods that prioritize memorization over problem-solving (Nortvedt & Wiese, 2020), along with a deficiency in Higher-Order Thinking Skills (HOTS) problems (Nurfauziyah et al., 2024), which are vital for fostering deeper comprehension, may hinder the development of positive mathematical dispositions. Moreover, environmental factors such as inadequate infrastructure, including insufficient access to technology and educational materials (Ng et al., 2023), further complicate efforts to nurture interest and positive perceptions in mathematics learning. Socio-economic status also plays a pivotal role in shaping MD. Students from lower socio-economic backgrounds often have reduced access to quality educational resources, such as textbooks, technology, and qualified teachers, thereby limiting their capacity to develop a robust MD (Williams et al., 2016). Additionally, parental influence is a significant determinant of an individual's perception of mathematics; parents with a negative attitude toward the subject can adversely affect their children's disposition towards it (Moore & Lang, 2023). Addressing these challenges necessitates a multifaceted approach, including policy reforms, comprehensive teacher training programs, initiatives to enhance parental involvement, and the strategic allocation of resources to support inclusive and effective mathematics education in Indonesia.

In the context of higher education, universities are indeed increasingly focusing on MD, which refers to the attitudes, beliefs, and behaviours that influence an individual's ability to engage with and learn mathematics. According to several previous studies, universities assess their students' mathematical disposition using various methods, often combining quantitative and qualitative approaches. Quantitatively, some studies suggest the use of periodic surveys to measure MD, particularly in areas such as efficacy and epistemological beliefs (Hwang & Choi, 2020). Qualitatively, interviews are conducted to complement quantitative findings and offer a more nuanced understanding of students' dispositions (Larkin & Jorgensen, 2016; Thacker, 2021). In terms of pedagogy, several universities have implemented project-based learning (PjBL) approaches, where group projects are assigned to enhance students' productive disposition towards mathematics significantly (McGinnis et al., 2002; Rozgonjuk et al., 2020). This approach is efficient as it involves students in real-world problem-solving, thereby fostering deeper engagement with mathematical concepts. By embedding mathematical concepts within real-world contexts and utilizing case studies, universities can effectively cultivate a positive disposition towards mathematics among their students (Agyei et al., 2021).

According to the context of mathematics education, it is imperative to address not only the disposition aspects, which include attitudes, beliefs, perceptions, and emotions, but also to explore content-related dimensions. A content area that has recently emerged as a top priority in mathematics education is numeracy (Forgasz & Hall, 2019), also widely recognized as mathematical literacy. Numeracy refers to an individual's ability to think mathematically and to formulate, apply, and interpret mathematics for solving problems across various real-world contexts (OECD, 2023). It encompasses the concepts, procedures, facts, and tools necessary to describe, explain, and predict phenomena, thereby enabling individuals to understand the role of mathematics in the world. Moreover, numeracy skills are intrinsically linked to the components of mathematical knowledge, disposition, ability, and practices within the learning process (Gittens, 2015). Drawing from these theoretical perspectives, it can be synthesized that mathematical disposition also contributes to influencing numeracy.

Recently, numeracy has garnered significant attention from educators globally, recognized as a critical skill that warrants deliberate emphasis. Numerous studies underscore that numeracy extends beyond mere arithmetic operations, encompassing problem-solving, critical thinking, and analytical capabilities (Nortvedt & Wiese, 2020).

Furthermore, numeracy is increasingly promoted as a foundational skill for STEM education, providing the essential groundwork for understanding scientific concepts, technological innovations, engineering principles, and mathematical theories (Bennison & Geiger, 2020). Consequently, numeracy education must be inclusive, ensuring that all students, irrespective of their backgrounds or abilities, have equitable access to high-quality mathematics education.

The proficiency in numeracy varies across different countries, influenced by several factors, including cultural norms, educational policies, and institutional frameworks (Jorgensen, 2010; Leuze & Helbig, 2015). These variables significantly shape how nations address numeracy. For example, in the United Kingdom, numeracy is a fundamental component of the National Curriculum for Mathematics. In contrast, several European countries, such as Finland and Sweden, employ hands-on learning activities to render numeracy more engaging and practical (Hemmi & Ryve, 2014; Star et al., 2022). Meanwhile, countries like Denmark and the Netherlands utilize digital tools to enhance numeracy education, making it more interactive and accessible (Rohatgi et al., 2020). Certainly, sharpening numeracy skills also requires the involvement of parents and the enhancement of teacher competencies to achieve optimal results. Many European countries foster strong parent-teacher associations to engage parents in their children's numeracy education, offering workshops on how to support their children's learning at home. Additionally, teachers undergo professional development programs to improve their numeracy teaching skills (Dowker, 2021; Fraser & Honeyford, 2013).

The implementation of numeracy education in Indonesia has become a key focus of government education policy, particularly through the Merdeka Belajar Kampus Merdeka (MBKM) program. This program, initiated by the Ministry of Education and Culture, aims to enhance the competencies of higher education students by providing opportunities for experiential learning beyond the classroom (Pasira, 2023). Numerous studies have highlighted the significant role of the MBKM initiative in advancing numeracy skills within mathematics education in Indonesia. A prominent example of this initiative is the Kampus Mengajar (Teaching Campus) sub-program, which enables university students from higher education institutions to actively participate in the educational process in various schools, with a particular focus on disadvantaged, frontier, and outermost regions (Cahyani & Mohammad, 2023). These students play a pivotal role in strengthening students' literacy and numeracy skills, assisting teachers in integrating technology into their teaching practices, and supporting school administrative functions.

For a mathematics teacher, numeracy is an essential asset that supports meaningful mathematics instruction. Findings from several studies affirm that when teachers demonstrate proficiency in numeracy, it instills confidence in students (McMinn et al., 2020). Teachers serve as role models for their students. By exemplifying strong numeracy skills, they not only encourage students to value mathematics but also to recognize its relevance in everyday life, thereby cultivating a positive attitude towards the subject (Kargar et al., 2010). Thus, a mathematics teacher's numeracy proficiency is indispensable for effective pedagogy, enhancing students' confidence, improving their problem-solving capabilities, and contributing to the development of a meaningful and contextualized mathematics learning environment.

The dependence on lecture-based methods limits opportunities for creative engagement (Hollister et al., 2022). To address this, developed models like Challenge-

Based Learning (CBL), which integrates problem-based, project-based, and contextual learning, are needed (McGinnis et al., 2002). The CBL is collaborative and hands-on, encouraging students to learn with classmates, teachers, and experts in their societies and around their surroundings to ask excellent questions, improve more profound subject knowledge, accept and tackle challenges, and undertake and share their experiences. CBL's three-phase syntax (Engage, Investigate, Act) strengthens students to solve real-world problems, boosting their creativity (Jailani et al., 2020). Creative thinking skills are important for generating new ideas and gauging the effectiveness of existing solutions in solving complex problems.

Ethnoscience bridges indigenous knowledge and scientific inquiry, cultivating learning with cultural relevance (Chen et al., 2020). The science learning based on the local wisdom provides a more contextual and meaningful knowledge discourse, so that it can foster creativity to solve students' real-world problems. For instance, Pulo Village's gold and silver craftsmanship is a generational livelihood that provides a tangible context for teaching temperature, heat, and expansion topics often perceived as challenging (Bakker et al., 2021). By embedding such local wisdom into CBL, students can delve into scientific concepts while preserving cultural heritage. Furthermore, typical knowledge of society, such as Pulo gold-craft ethnoscience, is also important for developing the learners' character.

The Challenge-Based Learning (CBL) approach has widely cultivated problem-solving and collaborative skills in science learning (Borba et al., 2016). However, its integration with ethnoscience, especially local wisdom such as Pulo gold-craft, remains unexplored. Most existing CBL research predominantly emphasises generic STEM challenges or Western-centric contexts, overlooking culturally rooted frameworks that could enhance relevance and engagement for diverse learners. Meanwhile, typical knowledge of local society is also vital in developing the students' character. Thus, this study addresses the gap by embedding Pulo gold-craft ethnoscience into CBL, investigating how localized knowledge uniquely improves creative thinking skills in science students.

Filling this research void, incorporating local culture aspects into a structured pedagogical approach like CBL demonstrates significant potential for advancing creative competencies. Focusing on junior high school students at SMPN 2 Tempeh, this research investigates the impact of Pulo gold-craft-integrated CBL on improving creative thinking skills. The results aim to provide actionable insights for educators, bridging the difference between abstract scientific concepts and culturally relevant real-world implementation. This work seeks to reinforce the quality of science education at the middle school level by positioning ethnoscience as a transformative method for preserving Indigenous heritage in innovative education.

In the context of mathematics learning in Indonesia, studies focusing on numeracy have predominantly emphasized its relationship with academic achievement in mathematics and problem-solving abilities (Gittens, 2015). However, numeracy skills are intrinsically tied to the components of disposition, ability, and practices within the learning process. This study therefore aims to investigate the influence of affective MD on numeracy, focusing on its seven dimensions as proposed by Beyers (2011): Nature in Mathematics, Usefulness, Worthwhileness, Sensibleness, Mathematics Self-Concept, Attitude, and Math Anxiety. Each of these dimensions carries potential explanatory power. For example, beliefs about the interrelatedness of mathematical concepts ("Nature in Mathematics") may enhance pattern recognition and flexible strategy use, while a strong "Mathematics Self-Concept" may boost persistence and problem-solving confidence. On the other hand, perceptions of usefulness or worthiness may not always translate into performance unless supported by conceptual clarity or confidence.

▪ METHOD

Participant

The research involved pre-service mathematics teachers (N = 237) aged 19-20 years, with a percentage of 20.68% male (N = 49) and 79.32% female (N = 188). In this context, all participants were gathered by using a purposive sampling technique, which was the first-year (freshmen) students from one private university in Tangerang who were involved in a numeracy enrichment program. Furthermore, the demographics of the participants are distributed across several regions in Indonesia, as presented in Table 1.

Table 1. Participants' demography

No	Domicile (Islands)	N	Percentage (%)
1	Molucca & Papua	8	3.38
2	Bali	6	2.53
3	Java	49	20.68
4	Kalimantan	14	5.91
5	Nusa Tenggara	21	8.86
6	Sumatera	117	49.37
7	Sulawesi	22	9.27
	Total	237	100

All participants engaged in a numeracy enrichment program that was conducted over one semester, comprising a total of 12 sessions, each with a duration of 90 minutes. During the final enrichment session, participants were administered a test consisting of 30 multiple-choice numeracy questions. To provide a comprehensive perspective, the researcher will elaborate in detail on the numeracy enrichment program. This program was mandatory for all first-year students, who were assigned to 12 classrooms, each comprising approximately 20 participants. Each class was facilitated by two tutors, resulting in a total of 24 tutors involved in the program. Prior to the first session, all tutors received a briefing from the researcher concerning the instructional content, which aligned with key areas of content knowledge based on PISA mathematics framework, namely: (1) Numbers, (2) Algebra, (3) Geometry, (4) Measurement, (5) Statistics and Probability. Tutors were provided with a guidebook that served as a reference for delivering and presenting the enrichment material. Each 90-minute session consisted of instruction and relevant problem-solving exercises. Teaching media included PowerPoint presentations and various digital platforms aimed at enhancing student engagement, such as Mentimeter, Quizizz, and Wordwall. The program aimed to strengthen both numeracy and affective mathematical dispositions. Its content was aligned with the PISA mathematics framework, emphasizing real-world contexts, reasoning, and flexible problem solving. Instructional strategies included problem-based learning, small group collaboration, and contextual discussions using four contexts, which also referred to the PISA framework, such as: (1) personal, (2) occupational, (3) societal, and (4) scientific.

Instruments

We used a numeracy test as the first instrument, consisting of 30 multiple-choice items. The development of this instrument was designed regarding the PISA mathematics framework (https://pisa2022-maths.oecd.org/), as outlined in Table 2. To ensure the validity of the content and wording, the researcher organized a Focus Group Discussion (FGD) by inviting two experts in the field of mathematics education to engage in brainstorming sessions aimed at evaluating the alignment of the mathematical problems with the aspects of Content Knowledge and Context, as delineated in the PISA mathematics framework, which were categorized according to content domains (e.g., quantity, space, change and relationships, uncertainty and data) and context domains (personal, occupational, societal, scientific). The feedback provided by both experts was considered in the process of revising and refining the mathematics questions. Moreover, each item was scored dichotomously (1 = correct, 0 = incorrect), and total scores ranged from 0 to 30. The reliability of the test, calculated using Cronbach's Alpha, was 0.84, indicating high internal consistency.

Table 2. PISA mathematics framework

Content Knowledge (CK)	Context	Math Problem (Sample)
Quantity Uncertainty and Data Change and Relationships Space and Shapes	Personal Occupational Societal Scientific	CK: Quantity Context: Personal Ina is currently undergoing a program to maintain her dietary regimen. Every day, she must meet a vitamin C intake of no less than 200 mg, but not exceeding 250 mg. She subsequently seeks data regarding the vitamin C content of several of her favourite fruits, as illustrated in the provided table. If she can only consume a maximum of 500 g of fruits in one day, the amount she needs to consume in one day to meet her vitamin C intake requirements is ...

Buah	Berat	Kandungan Vitamin C
	200 gr	124 mg
	1 kg	310 mg
	0,5 kg	140 mg
	100 gr	9 mg

	A. 200 g papaya, 200 g orange, dan 100 g avocado B. 200 g orange dan 300 g mango C. 200 g papaya, 200 g orange, dan 100 g mango D. 300 g orange, 100 g mango, dan 100 g avocado E. 200 g papaya, 200 g mango, dan 100 g avocado

Another instrument is the MD questionnaire for the affective domain, which comprises seven dimensions: (1) nature in mathematics: beliefs about the interconnectedness and logical structure of mathematics, (2) usefulness: perceived relevance of mathematics to real-life and other disciplines, (3) worthwhileness: belief that learning mathematics is valuable and important, (4) sensibleness: belief that mathematics makes sense and is learnable, (5) mathematics self-concept: confidence in one's ability to learn and perform mathematics, (6) attitude: emotional response toward mathematics tasks, and (7) math anxiety: being worry about engaging in mathematics. These seven dimensions refer to the study conducted by Beyers (Beyers, 2011) and have been developed into 33 items. This questionnaire was constructed using Confirmatory Factor Analysis (CFA), applying maximum likelihood as the extraction method, and also utilizing Varimax rotation to optimally distinguish among the dimensions, resulting in a Cronbach's Alpha value of 0.911 (Soesanto & Dirgantoro, 2023). The questionnaire was administered in digital form via Microsoft Forms at the end of the enrichment program, with a completion duration of 30 minutes. The completion of the study was conducted promptly to enhance participant monitoring and to mitigate the risk of respondents failing to complete the survey.

Data Analysis

As a data analysis technique, the researcher employed multiple linear regression to examine the significance of the influence of MD on numeracy. Furthermore, multiple linear regression also provides statistical output in the form of ANOVA test values and t-tests that can address the research questions. The ANOVA test is conducted to review the effect of MD as a whole variable on numeracy, while the t-test is performed to assess the influence of the seven dimensions of MD individually on numeracy, as depicted in Figure 1. From this analysis, it will be possible to map which dimensions have the strongest and weakest significance regarding numeracy.

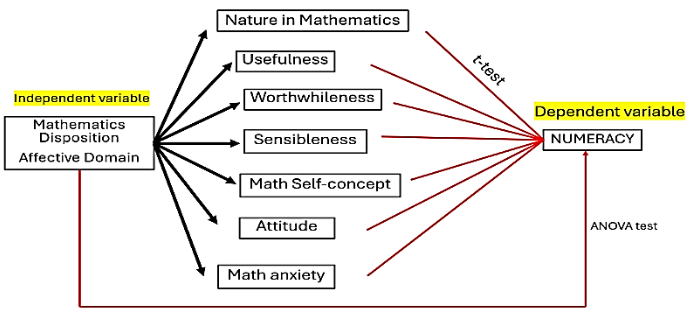

Figure 1. Variables mapping (multiple linear regression)

▪ RESULT AND DISSCUSSION

In this section, the findings related to two research questions will be presented: (1) Does MD have a significant effect on students' numeracy, and (2) which dimensions of MD have significant or non-significant effects? The ANOVA test on multiple linear regression yielded a significance value of Sig. = 0.018 (< 0.05), indicating a significant effect of MD on numeracy. The regression model explained 57.1% of the variance in numeracy scores (adjusted $R^2 = 0.571$), with the overall model being statistically significant by the F value = 12.36, $p < 0.001$. These results indicate that although other factors may contribute to numeracy, affective components especially specific dimensions play a meaningful role. Furthermore, the dimensions within the affective domain of MD that have a significant effect on numeracy will be discussed. The statistical hypothesis applicable for this testing is:

H0: The variable has a significant effect on numeracy.
H1: The variable does not have a significant effect on numeracy.

The null hypothesis (H0) is accepted if the significance value (Sig.) is less than 0.05, and it is rejected if the Sig. is greater than 0.05. Table 3 provides information regarding the significance values across the seven dimensions of the affective domain.

Table 3. Statistics results for the seven dimensions of affective MD towards numeracy

Variable	Dimension	B coefficient	β	Standard Error	Sig. value	Note
X1	Nature in Mathematics	1.87	0.584	0.86	0.033	Significant
X2	Usefulness	0.72	0.079	0.65	0.267	Not Significant
X3	Worthwhileness	0.56	0.054	0.71	0.433	Not Significant
X4	Sensibleness	0.48	0.167	0.63	0.282	Not Significant
X5	Mathematics Self-Concept	2.09	0.612	0.86	0.016	Significant
X6	Attitude	0.95	0.103	0.75	0.197	Not Significant
X7	Math Anxiety	0.43	0.036	0.88	0.627	Not Significant

Among the seven affective dimensions, only Mathematics Self-Concept and Nature in Mathematics showed statistically significant predictive effects. Between the two, Mathematics Self-Concept had the highest standardized beta coefficient ($\beta = 0.612$), suggesting that students' confidence in their mathematical abilities is the strongest predictor of their numeracy performance. Meanwhile, Nature in Mathematics ($\beta = 0.584$) also contributed meaningfully, indicating the importance of seeing mathematics as a connected and logical discipline. These findings appear to reflect the design and focus of the numeracy enrichment program, which placed strong emphasis on building conceptual understanding and encouraging reflective self-assessment. Activities involved rich problem contexts and opportunities for metacognitive dialogue, which are likely to reinforce both conceptual awareness and mathematical self-concept. On the other hand, dimensions like Usefulness, Worthiness, and Sensibleness may not have been explicitly emphasized, or their effects may be indirect or pre-established due to the participants' shared background as mathematics majors.

In the dimension "Nature Mathematics," the belief is in mathematical characteristics that fundamentally encompass various interrelated concepts. As indicated in Table 3, a significant effect is evident, suggesting that an enhanced understanding of the nature of mathematics positively correlates with the improvement of numeracy skills. The dimension "Usefulness" highlights the application of mathematics across various aspects of life and its interconnections with other disciplines. Within this dimension, it is observed that the perception of mathematics as beneficial for life is not sufficiently robust to serve as a predictor of numeracy. The dimension "Worthwhileness" pertains to the alignment of mathematics learning with educational objectives, resulting in students' ability to perform tasks optimally. The findings suggest that this dimension does not exert a significant effect on numeracy. The dimension "Sensibleness" underscores mathematical ideas that can be comprehended, thereby influencing the belief that mathematics is relevant to future professions and fostering a sense of comfort when engaging with mathematical content. The perception regarding the understanding that mathematics holds relevance to future professions is not strong enough to affect numeracy. The dimension "Mathematics Self-Concept" emphasizes the beliefs that students hold about themselves as learners of mathematics. This dimension significantly influences numeracy, indicating that a higher self-concept in mathematics correlates with improved numeracy skills. The dimension "Attitude" examines the emotional responses of students to mathematical activities, as reflected in self-confidence and the perception of understanding mathematical material. This dimension also does not significantly influence numeracy. Finally, the dimension "Math Anxiety" focuses on the anxiety experienced by students when learning mathematics. It appears that an individual's level of anxiety towards mathematics does not have a significant effect on numeracy. The non-significance of Math Anxiety is also noteworthy. One explanation could be that students who have progressed into advanced teacher preparation programs may already possess coping mechanisms or have lower anxiety levels compared to the general population. Alternatively, the influence of anxiety on numeracy may be mediated by motivational variables (e.g., goal orientation or resilience), which were not assessed in this study. This invites further research into mediation or moderation effects. Although the model's explanatory power is moderate (57.1%), the implications are clear. Educational programs targeting numeracy development in pre-service teachers should prioritize affective elements that build confidence and foster deep conceptual appreciation of mathematics. These elements appear more directly linked to performance than general attitudes or emotional responses.

The results of the regression analysis indicate that the dimension of "Nature in Mathematics" has a significant influence on numeracy. This finding suggests that a deep understanding of the fundamental characteristics of mathematics, including the interconnections between concepts, positively contributes to the enhancement of numeracy skills. Several studies further support this finding. Research conducted by Foster emphasizes that a comprehensive understanding of the nature and structure of mathematics can enhance students' numeracy skills (Foster et al., 2021). Additionally, research by Valley demonstrates that students who understand the relationships between mathematical concepts show significant improvement in their numeracy skills (Valley, 2019). This is attributed to their ability to transfer knowledge from one concept to another, enabling them to recognize patterns and underlying structures in various mathematical operations. When students comprehend the interconnections between concepts, they do not merely memorize procedures but are also capable of applying that understanding in diverse contexts, including solving more complex mathematical problems. Thus, an understanding of the relationships between mathematical concepts can provide a stronger cognitive foundation, ultimately enhancing their numeracy skills.

This is also in line with other findings that state that a deep understanding of the nature of mathematics plays a crucial role in the development of numeracy skills (Geiger & Schmid, 2024). This study reveals that students who possess a strong conceptual understanding of the nature of mathematics are better able to recognize the relationships between various numerical representations, such as decimals, fractions, and percentages. This understanding enables them to perform calculations more flexibly and to develop more efficient strategies for solving mathematical problems. Furthermore, students with a profound understanding of the nature of mathematics tend to be more confident when facing numerical tasks that require analytical thinking and problem-solving.

Furthermore, a solid understanding of the nature and structure of mathematics aids students in solving numerical problems more effectively (Semenets et al., 2024). By comprehensively understanding the nature of mathematics, students can develop a stronger numerical intuition, enabling them to estimate calculation outcomes, identify errors in the computation process, and apply alternative strategies in addressing various mathematical problems (Reyes-Rodriguez et al., 2016). Thus, it can be asserted that there has been a significant enhancement in their numeracy skills.

In contrast, the dimensions of "Usefulness, Worthwhileness, Sensibleness, Attitude, and Math Anxiety" do not show a significant effect on numeracy. This result indicates that although students are aware of the benefits and relevance of mathematics in daily life and possess a positive attitude towards it, this awareness does not directly enhance their numeracy skills. A study emphasizes that students' perceptions of the usefulness of mathematics do not have a significant correlation with their numeracy abilities (Bautista & Dones, 2025). One of the primary reasons for this finding is that, despite students' understanding of the practical benefits of mathematics in everyday life, this awareness does not necessarily result in enhanced numeracy skills. Many students consider mathematics to be practical, yet they still encounter difficulties in applying mathematical concepts in calculations or problem-solving. This suggests that cognitive factors, such as conceptual understanding and mathematical thinking skills, play a more significant role in enhancing numeracy abilities than mere perceptions of the usefulness of mathematics.

Moreover, a positive attitude towards mathematics is not always correlated with an improvement in numeracy skills. Appropriate support is still necessary to stimulate the development of a positive attitude towards mathematics (Hwang & Son, 2021). A positive attitude towards mathematics can reflect students' interest and motivation in learning; however, it does not necessarily guarantee a deeper understanding of numerical concepts. Many students possess a positive attitude towards mathematics because they enjoy the learning process or have had pleasant learning experiences, yet they still encounter difficulties in developing their numeracy skills. In other words, although a positive attitude can enhance engagement in learning, other factors such as teaching methods, the learning strategies employed, and the quality of students' understanding of the material play a more significant role in the improvement of their numeracy skills.

In the context of mathematical anxiety, there is a unique finding that mathematical anxiety does not have a significant direct impact on academic achievement, including students' numeracy skills (Zhang et al., 2019). Mathematical anxiety is often associated with lower academic performance; however, in the context of numeracy, its effects are not always direct. Several studies highlight that motivation plays a key role in determining mathematical achievement significantly (Hutajulu et al., 2019). Some students may experience anxiety when facing complex mathematical tasks, yet they can still demonstrate good numeracy skills when given sufficient time or in a supportive environment. Additionally, there are students with low anxiety who still encounter difficulties in numeracy due to a lack of conceptual understanding. Regarding the relevance of mathematics to daily life, a study indicates that the perception of the relevance of mathematics to everyday life does not have a significant relationship with numeracy skills (Forgasz & Hall, 2019). Many students understand that mathematics has applications in real life, yet they still struggle to apply their numeracy skills outside of academic contexts. For instance, a student may recognize the importance of mathematics in personal finance or science. However, if they do not possess a strong numeracy foundation, this awareness will not automatically enhance their skills in calculation or data analysis.

Regarding the finding that a positive attitude towards mathematics does not have a significant impact on students' numerical abilities, this is also supported by previous research. This indicates that although students feel comfortable and enthusiastic about learning mathematics, improvements in numeracy are more dependent on consistent practice, a deep understanding of concepts, and experience in applying mathematics in various situations (Norton, 2019). Thus, a positive attitude towards mathematics can serve as a supportive factor in the learning process, but it is not the primary factor determining students' numeracy achievement.

The dimension of "Mathematics Self-Concept" was found to have a significant effect on numeracy, indicating that the higher an individual's self-concept as a mathematics learner, the better their numeracy skills. Several studies have also confirmed that a positive mathematics self-concept correlates with improved numeracy skills (Van der Beek et al., 2017). Students with a positive self-concept tend to be more confident in solving mathematical problems of varying levels of complexity, more persistent in facing difficulties, and more open to diverse problem-solving strategies (Alves et al., 2016). Moreover, a robust self-concept facilitates students in cultivating an optimistic disposition towards the study of mathematics, which subsequently enhances their engagement in numerical practice and the exploration of more advanced mathematical concepts (Sahin et al., 2016). This, in turn, exerts a positive influence on their numeracy skills.

Students with a high mathematical self-concept demonstrate better performance in numerical tasks (Warren et al., 2020). Students who believe in their mathematical abilities are more likely to employ more effective cognitive strategies, such as reflective thinking, connecting previously learned concepts, and applying more systematic problem-solving strategies. Conversely, students with low self-concept tend to avoid mathematical challenges and become frustrated more quickly when faced with complex problems, which can hinder the development of their numeracy skills. Thus, a positive self-concept not only plays a role in enhancing learning motivation but also contributes to the effectiveness of the learning strategies employed by students in formulating, employing, and applying mathematical ideas.

Lastly, the other study found that a positive self-concept in mathematics significantly impacts students' numeracy skills (Fan et al., 2019). This study demonstrates that students who possess a positive perception of their mathematical abilities are more likely to engage in more intensive and consistent practice. They tend to view mathematical challenges as opportunities for learning rather than obstacles. Consequently, they gain more experience in solving mathematical problems of varying difficulty levels and develop a deeper understanding of mathematical structures. The intensity and consistency of practice support the enhancement of students' numeracy skills. The findings of this research highlight that a positive mathematical self-concept is not merely a psychological factor linked to self-confidence; it also has a direct impact on numeracy skills, the implementation of advanced mathematical strategies, and the ability to exhibit resilience when faced with mathematical challenges.

▪ CONCLUSION

This study explored the relationship between affective mathematical disposition (MD) and numeracy among pre-service mathematics teachers in Indonesia. The results confirm that MD, as a multidimensional affective construct, significantly contributes to numeracy, accounting for 57.1% of the variance in numeracy scores. However, only two of the seven dimensions, Mathematics Self-Concept and Nature in Mathematics, were found to be statistically significant predictors. These findings underscore the importance of students' beliefs about their mathematical abilities and their conceptual understanding of mathematics in developing numeracy. Educational programs that foster confidence and emphasize conceptual relationships may more effectively enhance numeracy performance among future mathematics teachers. In contrast, dimensions such as usefulness or attitude, while important in broader learning contexts, may not directly translate into numeracy gains without complementary cognitive engagement or motivational support.

Theoretically, this study supports the growing recognition of affective factors as integral components in mathematical thinking and teaching preparation. Practically, it suggests that teacher education programs should integrate affective-reflective components, particularly those aimed at strengthening mathematical self-concept and conceptual awareness, alongside content-based numeracy instruction. Future research may explore whether other variables (e.g., motivation, metacognition) mediate the influence of non-significant affective dimensions or test potential interaction effects among affective traits. Longitudinal designs may also help determine whether improvements in MD over time predict sustained numeracy development.

These results emphasize the need for mathematics education programs to focus on strengthening students' understanding of mathematical interconnections and fostering a strong self-concept. For the remaining dimensions, the enrichment program has succeeded in elevating students' perceptions in these areas to a relatively uniform level, thus reducing variability and weakening their statistical association with numeracy outcomes. This is reflected in the types of mathematical problems presented to the students throughout the program. Aligned with the program's emphasis on numeracy, the problems were designed to enable students to recognize strong connections with real-world contexts. They were encouraged to formulate, employ, and apply various mathematical ideas to solve everyday problems. This focus likely explains why other aspects were not as significant as the two aforementioned dimensions. Strategies such as integrating problem-based learning, conceptual discussions, and confidence-building activities can be instrumental in improving numeracy. Future research could explore additional cognitive and pedagogical factors that influence numeracy, as well as interventions designed to enhance mathematical disposition in broader educational contexts. Overall, this study provides valuable insights for educators and policymakers in designing effective mathematics curricula that support both conceptual mastery and affective development in numeracy educatio

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