

Investigating Number Sense in Teacher Education: Evidence from Indonesian Prospective Teachers' Understanding of Fractions and Decimals

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ABSTRACT

Despite its essential place, the concept of numbers is challenging for children and adults. However, few studies have examined prospective teachers' number sense, specifically regarding fractions and decimals, leaving a research gap. Thus, this study aimed to investigate prospective teachers' performance in fraction and decimal number sense through a written test and interview with prospective teachers from two universities in Indonesia. The results showed that prospective teachers' number sense was considered poor, relying predominantly on rule-based strategies. The least successful components were benchmark and estimation skills, as well as the understanding of operations, while the strongest were the ability to recognize and manipulate numbers by size and order. This finding underscores the need to improve Indonesian teacher education programs. Curriculum modification and teaching interventions can be implemented to support prospective teachers' number sense. While context-specific, the findings may inform future research and curriculum development in similar educational settings across ASEAN.

Keywords: Decimals, fractions, number sense, prospective teachers

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Introduction

The concept of numbers is fundamental in mathematics, other subjects, and daily life. However, many researchers have noted that these concepts have been perceived as difficult and perplexing by children and adults worldwide (Kusuma & Retnawati, 2019; Yapici & Altay, 2017). Number sense comprehension has become an issue in Indonesia, where students have struggled to achieve satisfactory mathematics outcomes for years. For example, Indonesia has consistently performed poorly in international assessments (Fenanlampir et al., 2019) such as TIMSS and PISA, reflecting a persistent gap in students' mathematical understanding, including number sense.

Challenges in Number Sense Comprehension

Research across various countries has examined the comprehension of numbers among children and adults. Studies have revealed that students in Indonesia (Wulandari et al., 2021) and Taiwan (Yang, 2019) possess a weak understanding of numbers. Notably, challenges in number sense are not limited to students. Some studies found that prospective teachers also demonstrate limited comprehension of numbers (Can, 2020; Er & Artut, 2021; Yang & Jan, 2019). This issue requires serious attention, as prospective teachers are expected to support students' mathematical abilities.

The Role of Teachers in Developing Number Sense

Teachers play a significant role in developing students' number sense. A study by Novitasari et al. (2024) suggests that teachers may be unaware of the significance of number sense, which restricts their ability to promote it effectively.

In Indonesia, teacher education programs often emphasize procedural over conceptual knowledge (Jupri et al., 2024). Thus, prospective teachers may show poor number sense in the classroom. Given the discrepancies between the expected and actual capabilities of the teachers, further investigation into their number sense is needed to identify gaps and arrange preliminary support.

Purpose of the Research

Several studies have explored students' number sense, yet few have examined prospective teachers' comprehension (Er & Artut, 2021; Yang & Jan, 2019), specifically in fractions and decimals, topics recognized as perplexing yet fundamental in mathematics. Earlier studies involving prospective teachers in Turkey (Can, 2020; Er & Artut, 2021) and Taiwan (Yang & Jan, 2019) have confirmed that many prospective teachers exhibit inflexibility and tend to rely heavily on procedural approaches. However, limited attention has been given to how future educators in Indonesia conceptualize number sense, leaving a significant research gap. Thus, this study aims to investigate the number sense of prospective teachers in Indonesia, exploring their strategies and challenges related to fractions and decimals. The results are expected to provide recommendations for improving teacher education programs, mathematics instruction, and number-sense foundation.

Theoretical Framework

Number Sense (NS)

Number sense refers to individuals' comprehension of numbers and operations, along with the flexibility to reason and acquire efficient strategies for dealing with numbers and operations (McIntosh et al., 1992; Yang & Jan, 2019). As the development of number sense progresses, many experts have put forward the psychological and theoretical groundwork for its elements (Bulut & Kuzu, 2023). McIntosh et al. (1992) proposed a framework of number sense elements, which has been adapted by some researchers in their studies (Er & Artut, 2021), specifically knowledge of numbers, knowledge of operations, and knowledge of number and operation applications in a computational setting. Furthermore, according to Yang and Jan (2019), number sense components include (1) understanding numbers and their representations, (2) comprehension of operations and their properties, and (3) the ability to flexibly employ that concept in solving mathematical situations.

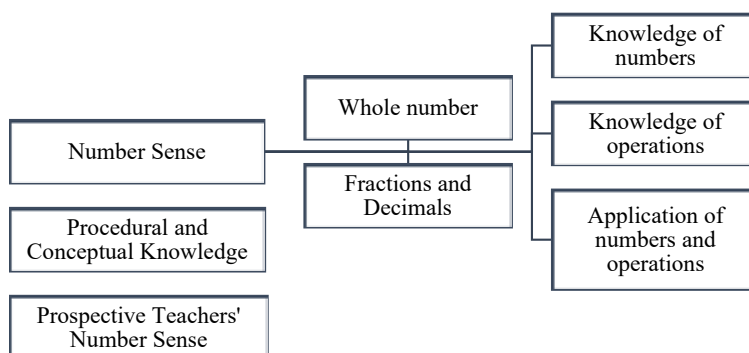
Conceptual and Procedural Knowledge

Conceptual knowledge means understanding concepts, principles, and their relationships (Braithwaite & Sprague, 2021; Rittle-Johnson & Siegler, 2022). Conceptual knowledge enables individuals to think flexibly and adaptively, facilitating the transfer of understanding across diverse contexts. Meanwhile, procedural knowledge is the ability to perform structured algorithms in solving problems (Braithwaite & Sprague, 2021; Rittle-Johnson & Siegler, 2022). This knowledge emphasizes the importance of memorizing rules taught in the classroom (Barumbun & Kharisma, 2022; Hakim & Yasmadi, 2021). Thus, students relying solely on procedural knowledge may struggle to fit the rules into unfamiliar problems.

Mastering number sense requires both conceptual and procedural understanding, which together support a deep understanding of mathematics. Thus, these theories form the foundation for investigating prospective teachers' number sense, particularly their reasoning and strategies for dealing with fraction and decimal tasks.

Figure 1

Theoretical Framework



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Figure 1 illustrates the underlying theories in this study, specifically the components of number sense and the conceptual and procedural knowledge. The theory of number sense components guides the construction of the written test. In contrast, the conceptual and procedural knowledge theory directs the analysis of participants' strategies, flexibility, and reasoning, indicating their reliance on conceptual and procedural knowledge.

Research Questions

This study aimed to investigate prospective teachers' number sense. Specifically, this study sought to answer the following questions.

1. How is prospective teachers' performance on number sense across its components?
2. What strategies and challenges do prospective teachers encounter with fraction and decimal problems?

Participants

The participants of this study were 250 fifth-semester college students majoring in Mathematics Education and Primary Education at

UIN Siber Syekh Nurjati Cirebon and UIN K.H. Abdurrahman Wahid Pekalongan, Indonesia. The samples were selected purposively to align with the objectives of this study. According to Akkaş and Meydan (2024), purposive sampling is a technique for selecting informants by considering their capacity to illustrate a particular topic or phenomenon.

The participants have learned advanced mathematics in both senior high school and undergraduate programs. Thus, the participants are theoretically expected to have a solid understanding of numbers. Moreover, the participants are scheduled to have school internships the following semester, making this study valuable in helping them prepare for their understanding of numbers. The demographic profile of the participants is presented in Table 1.

The 250 participants were asked to solve the Fraction Decimal Number Sense Test (FD-NST); thereafter, 13 participants were selected for interviews to confirm their approaches and reasoning. The inclusion criteria for the interviewees are those who have completed the FD-NST, have the most incorrect answers, and show the most strategy variability. They are expected to represent all participants, as their strategies encompass a variety of responses,

Table 1

The Demographic Profile of the Participants (n=250)

University	Semester	Major	Number of participants
UIN Siber Syekh Nurjati Cirebon	5	Mathematics Education	85
		Primary Education	42
UIN K.H. Abdurrahman Wahid Pekalongan	5	Mathematics Education	80
		Primary Education	43

ensuring diverse strategy representation. The interviewee's criteria exclude participants who leave some FD-NST blank and those who consistently respond to the problems correctly and similarly using formal algorithms only, as this study aims to describe varied reasoning and strategies.

Methodology

Research Design

This study employed a mixed-methods approach to gain a clear understanding of prospective teachers' number sense. The quantitative data provides general trends and performance levels of number sense, while the qualitative data explores the strategies and reasoning (Er & Artut, 2021). The combination of both methods contributes to a sound interpretation of the results, as the data confirm each other (Creswell & Clark, 2018).

Instruments

The test item construction process began with gathering and reviewing relevant references related to the Fraction Decimal Number Sense Test (FD-NST). The framework employed in this study is presented in Table 2.

Table 2

Number Sense Framework

Number Sense Components	Items
Understanding the meaning, size, and orderliness of numbers.	2, 3, 4, 5
Understanding multiple representations of numbers.	1, 6
Using a system of benchmarks and the strategies of estimation	8, 10
Understanding the meaning and effect of the operations	7, 9
Understanding equivalent expressions	11, 12

To contribute to the content validity of the FD-NST, a draft of fifteen multiple-choice questions was consulted with five mathematics education experts. After the revision and refinement, three test items were discarded due to issues with content and language. The results of expert judgments were then tested using Aiken's Validity Index (AVI). Based on the Aiken coefficient table (Aiken, 1985), with five experts and five judgment scales, the test item is considered valid if the Aiken coefficient value (AVI) is greater than or equal to 0.80. Moreover, the FD-NST was pilot-tested with 30 college students to examine its validity (using the Pearson product-moment correlation) and reliability (as measured by Cronbach's Alpha). If the results exceed the value of the *r* table (.36, with $n = 30$ and a 5% significance value), then the items meet the criteria for validity and reliability. The results of AVI from the expert judgments, as well as the validity and reliability results from the pilot test, are presented in Table 3.

As Table 3 shows, the AVI meets the valid criteria. The pilot test results also show that all the items are valid and reliable. Thus, the FD-NST is suitable for examining prospective teachers' number sense.

Table 3

Validity and Reliability of FD-NST

Item	Expert validation			Pilot Test	
	AVI	Category	Validity	Category	Reliability
1	0.80		0.428		
2	0.85		0.498		
3	0.90		0.459		
4	0.85		0.693		
5	0.85		0.663		
6	0.95	Valid	0.699	Valid	0.719 Reliable
7	0.90		0.578		
8	0.80		0.495		
9	0.80		0.383		
10	0.95		0.635		
11	0.95		0.412		
12	0.95		0.577		

Table 4

Categorization of Number Sense Answers

Correct Answer	
Number Sense Based (NSB)	Performing one or more number sense components
Rule-Based (RB)	Applying formal algorithms
Wrong Reasoning (WR)	Answering correctly, but employing the wrong reasoning
No Explanation (NE)	Answering correctly without any explanations
Incorrect Answer	
Rule-Based (IRB)	Using a formal procedure but performing mistakes
Wrong Reasoning (IWR)	Presenting wrong reasoning
No Explanation (INE)	Answering incorrectly without any explanations.

Data Collection

This study employed a written test and a follow-up interview to investigate participants' number sense. As suggested by Ay (2017), a written test and an interview are employed to obtain an in-depth description of the participants' strategies. The participants were asked to complete and write down their strategies in the FD-NST. After the written test, 13 participants were interviewed to confirm their approaches and reasoning in solving the FD-NST, and to reflect on their

experiences regarding how their teachers taught fractions and decimals.

Data Analysis

To address the first research question, prospective teachers' responses to the FD-NST were analyzed quantitatively based on the number sense components presented in Table 2. Participants' answers were grouped into the categories shown in Table 4 to identify the strategies applied. Number-sense-based reasoning indicates

correct conceptual knowledge, while rule-based reasoning refers to procedural knowledge. Moreover, based on the FD-NST and interview results, the strategies employed by all types of participants were documented and described qualitatively to address the second research question.

Ethical Considerations

All stages of the research process followed the study ethics rules issued by UIN K.H. Abdurrahman Wahid Pekalongan and UIN Siber Sykeh Nurjati Cirebon. Before collecting the data, the researchers explained the study’s aim and procedures to all participants. The participants agreed to take part in this study voluntarily. Any personal identifiers were omitted to guarantee participants’ confidentiality.

Findings and Discussion

Prospective Teachers’ Performance Built Upon Number Sense Components

Overall, the average success rate for each number sense component was low. Table 5 shows the number of participants who answered

correctly and incorrectly within the number sense components. As shown in Table 5, the participants primarily employed rule-based strategies for both correct and incorrect answers. They performed the least successfully in the benchmark and estimation skills, and the meaning and effect of operations, with only 53% and 57% success rates, respectively. Conversely, the highest-performing component was the number size and orderliness, with an average success rate of 74%, indicating participants’ familiarity with numerical comparison problems.

This finding indicates a substantial gap in participants’ flexible thinking and conceptual fluency (Üredi, 2022). Some participants lacked number sense and struggled with the FD-NST even though the topics tested were basic concepts taught since primary school. With this condition, the participants may struggle to support their future students’ reasoning. It implies a crucial need for teacher education programs to balance the conceptual and procedural knowledge courses, including reasoning, estimating, and thinking flexibly.

The interview results revealed that their teachers prioritized formal algorithms over conceptual understanding in solving mathematical

Table 5

Summary of Written Test Result for Each NS Component

NS Components	Respondents (n=250)								
	Correct Answer				Incorrect Answer				
	RB	NSB	WR	NE	Total	IRB	IWR	INE	Total
1	39%	20%	2%	13%	74%	7%	10%	9%	26%
2	33%	22%	0%	10%	65%	13%	12%	11%	35%
3	35%	9%	0%	9%	53%	23%	11%	12%	47%
4	38%	11%	0%	8%	57%	24%	11%	9%	43%
5	45%	10%	0%	10%	65%	20%	6%	9%	35%
Average	39%	14%	1%	9%	62%	16%	12%	10%	38%

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problems, starting from primary school. This finding was expressed in the interview process, when the researchers confirmed the procedural methods they applied in solving the estimation problem. The following are the sample responses from participants 1 and 2 (P1 and P2).

P1: *Saya hanya tahu cara itu Bu, dari dulu di SD dan SMP hanya diajarkan cara menyamakan penyebut pada soal penjumlahan pecahan*

(I only know that method, Ma'am. In primary and middle school, I was only taught to find a common denominator in the addition of fractions.)

P2: *Kami hanya tahu cara itu. Kami tidak pernah dibiasakan mengestimasi hasil. Saat mengerjakan soal, guru kami hanya menyuruh kami mengerjakan soal sesuai contoh yang dituliskan di papan tulis.*

(We only know that method. We did not get used to estimating results. To solve problems, our teachers only asked us to follow the examples written on the blackboard.)

Based on the sample responses above, the interviewees stated that their primary and middle school teachers did not familiarize students with the estimation strategies and support students' reasoning. Their proclivity for applying formal algorithms likely restricted their flexible thinking and number sense exploration when solving mathematical problems (Novitasari et al., 2024; Üredi, 2022).

Strategies and Challenges Associated with Fractions and Decimals

Investigating how prospective teachers solve the FD-NST provides an in-depth understanding of their number sense and the strategies they apply. This section elaborates on various strategies and challenges demonstrated by the participants in each number sense component.

Knowledge of the Size and Orderliness of Numbers

Question:

Arrange the following decimal numbers in ascending order.

2.35 ; 2.078 ; 2.136 ; 2.4

a. 2.4 ; 2.35 ; 2.078 ; 2.136

b. 2.078 ; 2.136 ; 2.35 ; 2.4

c. 2.136 ; 2.078 ; 2.35 ; 2.4

To solve this problem, some participants were aware of the digits right after the decimal point, noticing that 0 is the smallest, followed by 1, 3, 4. Thus, the correct arrangement is 2.078, 2.136, 2.35, 2.4. Another correct procedure was multiplying all decimals by 1000 to convert them to whole numbers, making it easier to compare their relative sizes.

However, some wrong reasoning was noted. Some participants converted the decimals into whole numbers by multiplying them by different powers of ten, depending on the decimal digits (e.g., 10, 100, or 1000). Thus, they argued that the correct arrangement was 2.4, 2.35, 2.078, and 2.136. Furthermore, other participants applied

the fraction or whole-number rules. Those who employed the fraction rule (or shorter-is-larger rule) considered that more extended decimal numbers have a smaller magnitude, just as fractions with a longer denominator have a smaller value (Lai & Wong, 2017, p. 97), such as $2.136 = 2\frac{1}{136}$. Meanwhile, the whole-number or longer-is-larger rule assumes that the more decimal digits, the greater the magnitude of decimal numbers (Lai & Wong, 2017, p. 97). The participants argued that 2.136 is greater than 2.4 since 136 is greater than 4. This whole number bias suggests a limited understanding of the place value concept.

Knowledge of Various Representations of Numbers

Question:

Which decimal number is equal to $26\frac{1}{40}$?

- a. 26.40 b. 26.25 c. 26.025

The participants presented two procedures to obtain the correct answer 26.025. Some applied the long division strategy to convert $\frac{1}{40}$ into a decimal number, while the others showed their number sense by associating $\frac{1}{40}$ with $\frac{1}{4}$ as an anchor point. Recognizing that $\frac{1}{4}$ equals 0.25 allows them to reason that $\frac{1}{40}$ equals 0.025.

On the other hand, some participants incorrectly answered 26.40 and 26.25. Those who chose 26.25 considered that $\frac{1}{40}$ it equals 00.25 instead of 0.025. Others incorrectly assumed that equals 0.40, as they misinterpreted the number behind the decimal point as representing the fraction’s denominator. This erroneous belief leads participants to incorrectly apply the “shorter-is-larger” rule to decimal numbers, as smaller denominators represent a greater value in

fractions (Lai & Wong, 2017, p. 97). As Üredi (2022) reported, these errors confirm participants’ difficulties with decimal-fraction conversion and the concept of place value.

Knowledge of the Meaning and Effect of Operations

Question:

Without calculating the exact answer,

which one is the best estimate for $3\frac{5}{7} \cdot \frac{15}{16}$?

- a. Greater than $3\frac{5}{7}$
- b. Less than $3\frac{5}{7}$
- c. Equal to $3\frac{5}{7}$

In this problem, some participants did the multiplication to obtain the exact answer, that is $3\frac{5}{7} \cdot \frac{15}{16} = \frac{25}{7} \cdot \frac{15}{16} = \frac{416}{105} = 3.96$. The others noticed the number sense idea that dividing a number by a fraction less than one increases the dividend.

Conversely, some participants mistakenly believed that division always results in smaller numbers. In comparison, multiplication always results in greater numbers, regardless of the operand sizes, indicating a weak conceptual understanding of operation rules. As revealed by Lee and Boyadzhiev (2020), some participants preserved the properties of operations in whole numbers to make sense of fractions. They noticed that it is less than 1 and assumed that the division result decreases the dividend. This issue confirms what Lortie-Forgues et al. (2015) asserted: some fallacies in fractions and decimal numbers include the puzzlement of multiplication and division involving less-than-one numbers, as well as the confusion in connecting the properties of operations in rational numbers.

Knowledge of Reference Points and Estimation Skills

Question:

Without calculating the exact answer, which one is the best estimate for $\frac{10}{11} + \frac{6}{7}$?

- a. 1 b. 2 c. $\frac{16}{18}$

In this problem, some participants noticed that if both operands are close to 1, then the sum must be close to 2 as it is similar to $1+1$. Meanwhile, others calculated the exact sum $\frac{10}{11} + \frac{6}{7}$ instead of using benchmarks to estimate the result. This finding supports the report by Lortie-Forgues et al. (2015) that participants did not make estimations using a point of reference.

Incorrect responses revealed that some participants regarded the fractions as separated whole numbers. Consequently, they added the numerators and denominators separately, resulting in the answer $\frac{16}{18}$. Moreover, an unexpected error occurred, with the incorrect assumption that if the value of the operands is less than one, then the result of the addition is also less than one. This result signifies a conceptual gap in understanding how operations behave with fractional values.

Knowledge of Equivalent Expressions

Question:

Which option is correct to make the statement below a true one:

$$3 \times 5\frac{1}{2} \dots 15 + \frac{1}{2}$$

- a. >
b. <
c. =

The participants responded correctly by converting both sides into decimal or improper fraction forms. Some discovered $16.5 > 15.5$, while others got $\frac{33}{2} > \frac{31}{2}$ it after converting both sides. In contrast, most of those who picked the answer (=) argued that both sides resulted in $15\frac{1}{2}$. They did not reflect the distributive property, which $(3 \times 5\frac{1}{2})$ equals $3 \times (5 + \frac{1}{2})$. Moreover, some unexpectedly showed a fallacy in converting a mixed number into a common fraction $15\frac{1}{2} = \frac{15}{2}$, which led to an inaccurate comparison.

The proofs from participants' responses on each number sense component indicate that prior understanding of whole numbers hindered their knowledge-building of fractions and decimals (Roell et al., 2019). They often overgeneralized whole number rules and properties to fractions and decimals, leading to misconceptions (Lin & Powell, 2021; Lortie-Forgues et al., 2015; Ren & Gunderson, 2019). For instance, they add the numerator and denominator separately when adding fractions and assume that division always reduces while multiplication always increases the operands. Moreover, the findings indicate that a weak understanding of place value can lead to significant errors in fraction-decimal tasks (Joung & Kim, 2022), particularly in tasks involving ordering and converting fractions and decimals. It implies that the concept of place value and the relative size of fractions and decimals needs crucial attention in the classroom.

Furthermore, these findings confirm the study by Rittle-Johnson and Siegler (2022), which suggests that conceptual and procedural knowledge must support each other to develop a thorough mathematical understanding. Participants' tendency to apply formal algorithms and their inflexibility in reasoning about numbers indicate a disproportionate relationship between conceptual and procedural knowledge. Students'

unsatisfactory number sense facilities are attributed to excessive exposure to rule-based algorithms and inadequate teachers' proficiency (Er & Artut, 2021; Palabıyık & Tertemiz, 2024). Therefore, paying more attention to learners' reasoning and sense-making during the class is essential.

Implications

Theoretically, this study contributes to the understanding of the correlation between number sense and conceptual-procedural knowledge. The prospective teachers' low number sense indicates the dominance of procedural instruction, restricting the development of flexible and meaningful number sense. Therefore, this study highlights the importance of supporting prospective teachers' conceptual understanding of number sense, including fractions and decimals.

Practically, this study underscores the need to improve Indonesian teacher education programs. While context-specific, the findings may inform future research and curriculum developments in similar educational settings across ASEAN. This study suggests that mathematics and primary teacher education programs should incorporate number sense into their curricula. Some practical strategies, such as modules that merge number sense with conceptual understanding, can be implemented. Several teaching interventions, such as number talks, open-ended problem-solving, estimation strategies, and visual aids, should be incorporated to enhance sense-making strategies and flexible reasoning. Moreover, the courses should provide cognitive conflicts to prevent incorrect reasoning about numbers. These suggestions align with ASEAN curriculum frameworks that prioritize

learner-centered education, problem-based curricula, and the development of 21st-century skills (SEAMEO, 2018).

Conclusion

This study aims to investigate prospective teachers' number sense, explore their strategies and challenges associated with fractions and decimals, and provide recommendations to support their number sense. The FD-NST investigates prospective teachers' number sense involving fractions and decimals to address the objectives.

The results reveal that prospective teachers' number sense is considered low. The participants succeeded the most in the size and orderliness of numbers, with an average of 74% of respondents answering correctly. Meanwhile, they performed the least successfully in the benchmark and estimation skills component, and the meaning and effect of operations, with only 53% and 57% success rates, respectively.

Most participants apply formal algorithms to solve the FD-NST. One cause is the overexposure to formal algorithms without meaningful conceptual understanding. The habit of applying rule-based strategies becomes so ingrained in their minds that it hinders the development of number sense and flexible thinking. Thus, integrating number sense into undergraduate programs through curriculum modification and teaching interventions is necessary.

This study focuses on fractions and decimals, involving participants from only two universities in Indonesia. As such, the results may not be fully generalizable to broader populations or other number domains. Further

studies on number sense, with a broader range of topics and participants, are highly anticipated. Additionally, we encourage longitudinal studies on interventions to enhance prospective teachers' number sense.



Statements and Declarations

1. Funding details.

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2. Disclosure statement.

The authors declare no competing interests.

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4. Ethical Approval

The research does not require any ethical approval from any institution.

5. Declaration of Generative AI in Scientific Writing

The authors confirm that there is no use of generative AI in writing this article

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