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Mathematical literacy of prospective mathematics teacher based on cognitive style

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Abstract

Mathematical literacy has become a crucial competency that prospective mathematics teachers must master, especially in the context of globalization. However, a significant challenge is the low mathematical literacy skills, particularly in communication, reasoning, and mathematical modeling. This study aims to analyze the mathematical literacy skills of prospective mathematics teachers based on their cognitive styles, namely field-independent (FI) and field-dependent (FD). A descriptive qualitative approach was used with four students selected based on cognitive style tests and mathematical literacy tests. The instruments used included PISA-based mathematical literacy tests, the Group Embedded Figures Test (GEFT), semi-structured interviews, and observation sheets. The results indicated that students with the FI cognitive style exhibited better communication, mathematization, representation, and reasoning skills, especially in numerical-based problems. In contrast, students with the FD cognitive style faced difficulties in mathematics, representation, and using symbols and diagrams, particularly in data-based and visual problems. Cognitive style plays a significant role in shaping students' mathematical literacy skills and should be considered in teacher education programs.

Keywords: cognitive style; field dependent; field independent; mathematical literacy; pre-service teachers,

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Introduction

In the era of globalization, mathematical literacy has become one of the main competencies that students, especially prospective mathematics teachers, must master. Mathematical literacy includes the ability to understand mathematical concepts and formulate, use, and interpret mathematics in various real-life contexts (Santia, 2023). It aligns with the Program for International Student Assessment (PISA) framework, which emphasizes the importance of mathematical literacy in solving real-world problems (Almarashdi & Jarrah, 2022; Lestari et al., 2021). Mathematical literacy includes several important indicators, such as mathematical communication skills, modeling, reasoning, and data-based decision-making. For example, mathematical communication skills involve understanding the language of mathematics and communicating mathematical ideas clearly, which is a marker of successful mathematical literacy in learning (Dewi & Maulida, 2023; Santia, 2023).

However, mathematical literacy among prospective mathematics teacher students is still challenging. Various studies show their low achievement in mathematical literacy indicators such as communication, reasoning, and mathematical modeling (Lestari et al., 2021; Purnaningtyas & Safa'atullah, 2023). In addition, research shows that obstacles in mathematical literacy often stem from students' lack of confidence in their mathematical abilities, known as self-efficacy, which has a significant role in shaping learning outcomes (Memnun et al., 2012; Nisa & Arliani, 2023). Students with low self-efficacy tend to experience difficulties dealing with complex mathematical tasks, ultimately affecting their overall mathematical literacy skills (Kurniawati & Mahmudi, 2019).

On the other hand, mathematical literacy also depends on students' ability to apply mathematical reasoning to solve real-world problems. Mathematical reasoning includes making logical arguments, evaluating solutions, and modeling real-life situations using mathematical concepts. Research shows that students who engage in tasks that demand mathematical reasoning tend to develop higher mathematical literacy (Lestari et al., 2021; Norhidayah, 2023). Within the PISA framework, indicators such as modeling and applying mathematics to real-life situations are considered key elements in mathematical literacy (Almarashdi & Jarrah, 2022; Lestari et al., 2021). However, studies in Indonesia show that students often struggle to use mathematical models to solve complex problems, indicating a need for teaching approaches centered on developing these skills (Setiawan et al., 2020; Sobirin et al., 2023).

In addition to reasoning, the influence of cognitive style on students' ability to solve mathematical tasks is also seen in their ability to use effective mathematical representations. For example, students with the field-independent (FI) style are known to be more likely to use diverse visual and symbolic representations, while students with the field-dependent (FD) style often rely only on simpler verbal or numerical representations (Bintoro et al., 2022; Sutama et al., 2021). It is relevant to the finding that technology integration in learning, such as using mobile-based digital teaching materials, can help students with various cognitive styles improve their mathematical communication and representation skills (Dewi & Maulida, 2023). Thus, technology-based learning approaches have the potential to bridge the mathematical literacy gap influenced by differences in cognitive styles (Chen & Macredie, 2002; Lee & Wang, 2020).

In addition to psychological factors, students' cognitive styles play a significant role in determining their success in understanding and applying mathematical literacy. The concept of cognitive style proposed by Witkin, namely field-dependent (FD) and field-independent (FI), indicates a fundamental difference in the way individuals process information (Febrina et al., 2022; Guillot & Collet, 2004). Research shows that students with FI cognitive style tend to excel in tasks that require analytical thinking, problem-solving, and mathematical reasoning, compared to students with FD cognitive style who rely more on contextual clues (Lee & Wang, 2020; Nozari & Siamian, 2015). In addition, the FI style is associated with cognitive flexibility and more varied mathematical representation abilities, which are important elements in improving mathematical literacy (Kusuma et al., 2021; Sobirin et al., 2023).

Previous research has identified the relationship between cognitive styles and mathematical literacy skills. However, a gap exists in understanding how specific cognitive styles affect student teachers' ability to model real-world problems, communicate mathematically, and apply mathematical concepts effectively (Bintoro et al., 2022; Sobirin et al., 2023). Most previous studies focused on secondary school students, while studies on prospective mathematics teachers as agents of educational transformation are still limited (Sutama et al., 2021; Tambunan, 2021). In addition, integrating educational innovations such as project-based learning and collaboration to accommodate various cognitive styles has not been widely explored in this context (Batubara, 2023; Sari et al., 2022).

This study offers a new contribution by exploring the mathematical literacy skills of prospective mathematics teachers in terms of their cognitive style. The uniqueness of this study lies in the qualitative analysis approach to understand the interaction between cognitive style and mathematical literacy indicators, such as communication, reasoning, and problem-solving. This approach also highlights the importance of supporting factors, such as self-efficacy, cognitive flexibility, and courage in making mathematical decisions, as an integral part of developing mathematical literacy (Kusuma et al., 2021; Nisa & Arliani, 2023).

Based on the above explanation and the importance of interaction between cognitive style and mathematical literacy indicators, this study aims to analyze the mathematical literacy ability of prospective mathematics teachers based on cognitive style, namely Field Independent (FI) and Field Dependent (FD). This research is expected to significantly contribute to the field of mathematics education, especially in developing teaching strategies that are adaptive to students' cognitive styles. By understanding the relationship between cognitive style and mathematical literacy, the results of this study are expected to provide a strong basis for developing a more inclusive and effective mathematics teacher education curriculum.

Methods

The approach used in this research is a descriptive qualitative approach, which aims to describe in depth the mathematical literacy abilities of prospective mathematics teachers based on their cognitive styles. This approach allowed for a holistic exploration of phenomena in real contexts, making it suitable for understanding complex individual differences (Creswell & J. David

Creswell, 2019). The main focus of this study was to explore the strategies, constraints, and patterns of mathematical problem-solving in terms of students' cognitive styles.

The research subjects were 13 mathematics education students selected through a purposive sampling technique. The inclusion criteria included students who had completed the mathematical literacy course and previously took the cognitive style test. Due to time constraints and the desire to conduct an in-depth analysis, the researchers selected four students as research subjects, consisting of 2 students classified as Field Dependent (FD) and two students as Field Independent (FI), who had completed the mathematical literacy course and previously taken the cognitive style test. These four subjects were chosen based on their performance in solving mathematical literacy questions, which were almost identical. As suggested in qualitative research, a limited number of subjects was chosen to allow an in-depth analysis of each individual (Miles et al., 2014). Based on the Group Embedded Figures Test (GEFT) results, students were grouped into two main categories: field-dependent (FD) and field-independent (FI), according to their cognitive style characteristics (Chen & Macredie, 2002; Zhang, 2004).

This study used three main instruments: (1) a Mathematical Literacy Test, which is designed to measure students ' ability to model, analyze, and communicate mathematical solutions to real-world problems. The questions in the test were designed based on mathematical literacy indicators from the PISA framework (OECD, 2018), which include mathematical communication, reasoning, and problem-solving. (2) Semi-structured Interview Guidelines were developed to explore students' understanding of problem-solving strategies, obstacles, and the relationship between cognitive style and mathematical literacy skills. The semi-structured format was chosen to provide flexibility in exploring the subject's perspectives, which aligns with the principles of qualitative research (Blandford, 2019). (3) An observation sheet was used to record students ' problem-solving strategies during the mathematical literacy test. Direct observation provided additional data to triangulate the test and interview results (Flick, 2018).

Data collection occurred in three stages: (1) Identification of Cognitive Style using the GEFT test to classify students' cognitive style as FD or FI. The GEFT has been proven to be a valid and reliable tool for assessing individual cognitive styles in various educational contexts (Zhang, 2004). (2) Mathematical Literacy Test Administration, where students complete a contextual-based mathematical literacy test. Researchers made direct observations during the test to record patterns and strategies used in solving problems. (3) In-depth Interviews were conducted individually to explore the test results and observations. The interview process was recorded and transcribed for further analysis. The interviews focused on students' thinking patterns, obstacles, and strategies they used to solve mathematical literacy problems (Brooks & King, 2017).

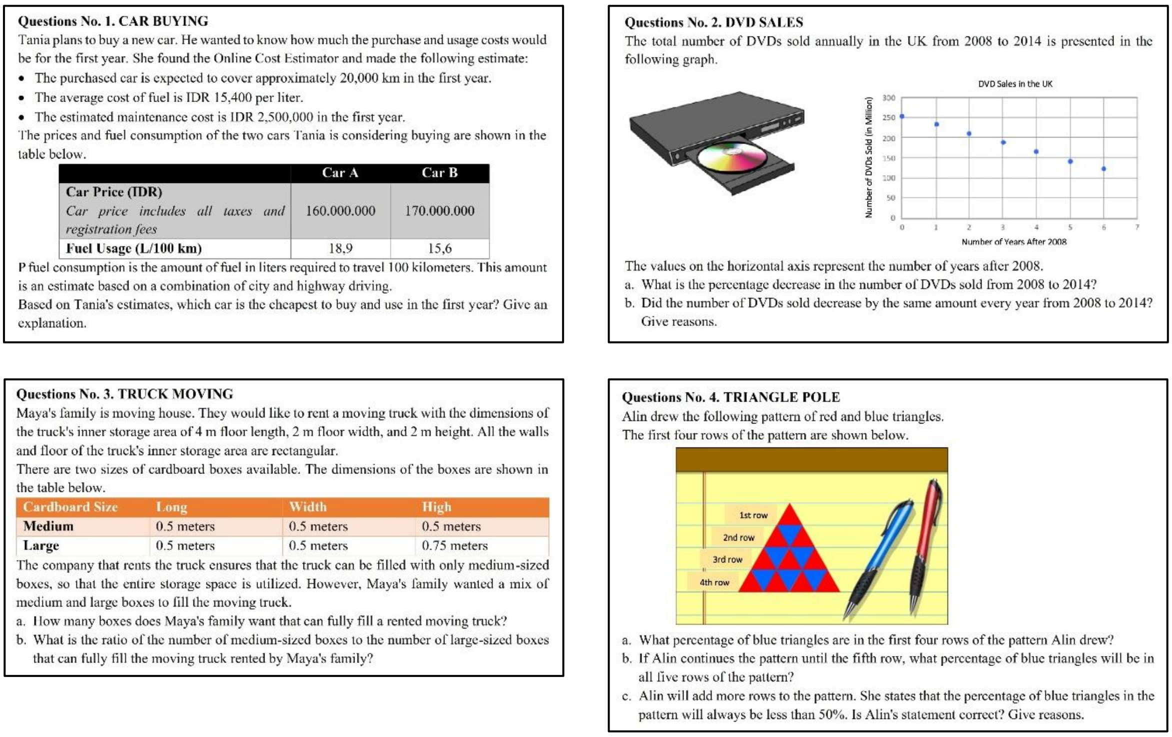
Data were analyzed using thematic analysis techniques (Braun & Clarke, 2019), which involved the following steps: (1) Data reduction. Data from interview transcripts, test results, and observation notes were simplified by focusing on relevant themes, such as problem-solving strategies, mathematical problem-solving patterns, and obstacles faced. (2) Data Categorization. Data were grouped based on themes reflecting the differences between students with FD and FI cognitive styles. The main themes included mathematical modeling skills, communication strategies, and the level of flexibility in mathematical reasoning. (3) Data Presentation. The analysis results were presented as narrative descriptions supported by interview quotes and observation results. This presentation aimed to provide a clear and in-depth picture of the relationship between cognitive style and students' mathematical literacy skills.

Data validity was ensured through source triangulation, comparing data from test results, interviews, and direct observation (Flick, 2018). In addition, member-checking techniques were applied by asking subjects to confirm the results of their data interpretation and ensure data validity and accuracy (Lincoln & Guba, 1985).

Results

This research was conducted at the Mathematics Education Study Program (Madiun City Campus), Universitas Katolik Widya Mandala Surabaya, Indonesia, in the even semester of the 2023/2024 academic year. The research subjects consisted of 13 students, with six students in class 2023 and 7 students in class 2022. The subjects of this study were subjected to a cognitive style test using the Group Embedded Figures Test (GEFT), which resulted in 7 students with Field Dependent (FD) style and six students with Field Independent (FI) style. Cognitive style grouping is based on the results of GEFT scores. According to Gordon & Wyant (1994), if $0 \leq$ GEFT score ≤ 11, then the subject has a Field Dependent (FD) style. Meanwhile, if a $12 \leq$ GEFT score ≤ 18, then the subject field-independent dent (FI) style. The study included a PISA-based mathematical literacy test and interviews to confirm the test results, conducted on subjects selected using stratified random sampling based on the results of the mathematical literacy test. The mathematical literacy test consists of four questions based on the Program for International Student Assessment (PISA) category (Figure 1), namely question 1. Change and Relationship, question 2. Uncertainty and Data, question 3. Space and Shape, and question 4. Quantity. Mathematical literacy test questions are taken from some of the 2022 PISA questions with necessary adjustments. The subject's mathematical literacy skills were measured through four main indicators: (1) communication, which assesses the clarity and structure of the answer delivery; (2) mathematization and representation, which measures the ability to transform real-world problems into mathematical form; (3) reasoning and argumentation, which evaluates the logic and accuracy of the reasoning in supporting the answer; and (4) use of symbols and diagrams, which assesses the ability to interpret and utilize visual information.

This study involved four research subjects who were taken based on the results of the Group Embedded Figures Test (GEFT) and the mathematical literacy test by looking at the similarity of the results of the mathematical literacy test. The four research subjects, namely two subjects with Field Independent (FI) cognitive style coded SFI1 from students of the Class of 2022 and SFI2 from students of the Class of 2023, and two subjects with Field Dependent (FD) cognitive style coded SFD1 from students of the Class of 2022 and SFD2 from students of the Class of 2023.



Questions No. 1. CAR BUYING

Tania plans to buy a new car. He wanted to know how much the purchase and usage costs would be for the first year. She found the Online Cost Estimator and made the following estimate:

- The purchased car is expected to cover approximately 20,000 km in the first year.
- The average cost of fuel is IDR 15,400 per liter.
- The estimated maintenance cost is IDR 2,500,000 in the first year.

The prices and fuel consumption of the two cars Tania is considering buying are shown in the table below.

	Car A	Car B
Car Price (IDR) *Car price includes all taxes and registration fees*	160.000.000	170.000.000
Fuel Usage (L/100 km)	18,9	15,6

P fuel consumption is the amount of fuel in liters required to travel 100 kilometers. This amount is an estimate based on a combination of city and highway driving.

Based on Tania's estimates, which car is the cheapest to buy and use in the first year? Give an explanation.

Questions No. 2. DVD SALES

The total number of DVDs sold annually in the UK from 2008 to 2014 is presented in the following graph.

The values on the horizontal axis represent the number of years after 2008.

a. What is the percentage decrease in the number of DVDs sold from 2008 to 2014?

b. Did the number of DVDs sold decrease by the same amount every year from 2008 to 2014? Give reasons.

Questions No. 3. TRUCK MOVING

Maya's family is moving house. They would like to rent a moving truck with the dimensions of the truck's inner storage area of 4 m floor length, 2 m floor width, and 2 m height. All the walls and floor of the truck's inner storage area are rectangular.

There are two sizes of cardboard boxes available. The dimensions of the boxes are shown in the table below.

Cardboard Size	Long	Width	High
Medium	0.5 meters	0.5 meters	0.5 meters
Large	0.5 meters	0.5 meters	0.75 meters

The company that rents the truck ensures that the truck can be filled with only medium-sized boxes, so that the entire storage space is utilized. However, Maya's family wanted a mix of medium and large boxes to fill the moving truck.

a. How many boxes does Maya's family want that can fully fill a rented moving truck?

b. What is the ratio of the number of medium-sized boxes to the number of large-sized boxes that can fully fill the moving truck rented by Maya's family?

Questions No. 4. TRIANGLE POLE

Alin drew the following pattern of red and blue triangles.

The first four rows of the pattern are shown below.

a. What percentage of blue triangles are in the first four rows of the pattern Alin drew?

b. If Alin continues the pattern until the fifth row, what percentage of blue triangles will be in all five rows of the pattern?

c. Alin will add more rows to the pattern. She states that the percentage of blue triangles in the pattern will always be less than 50%. Is Alin's statement correct? Give reasons.

Figure 1. Mathematical literacy problem

Subjects with field independent (FI) cognitive style

Mathematical literacy on communication indicator

In mathematical literacy questions number 1 (Change and Relationship), number 2 (Uncertainty and Data), and number 4 (Quantity), both SFI1 and SFI2 subjects were able to explain their answers clearly and logically (See Figure 2). Subject SFI2 was more detailed than SFI1, although still concise. SFI1's answer was coherent and correct, while SFI2's answer was detailed and logical. However, on mathematical literacy question number 3 (Space and Shape), both subjects gave clear but imprecise answers (See Figure 3). This shows that FI subjects have strengths in structuring and conveying ideas in a structured manner, although they sometimes struggle with types of problems with complex visualizations. This is shown in Table 1 of the interview results on FI subjects.

Table 1. FI subject interview results on mathematical literacy communication indicator

Subject SFI1	Subject SFI2
"When I read the questions, I usually focus on the relationship between the numbers and the clues. Explaining the answer is not too difficult for me, especially if the question information is clear. However, for problem number 3, I was confused about the steps because I didn't really understand the visualization of the shape."	*"I usually explain my answers in detail so that no steps are missed. However, in problem number 3, I only wrote things that I felt were relevant because I was not sure of the answer."*

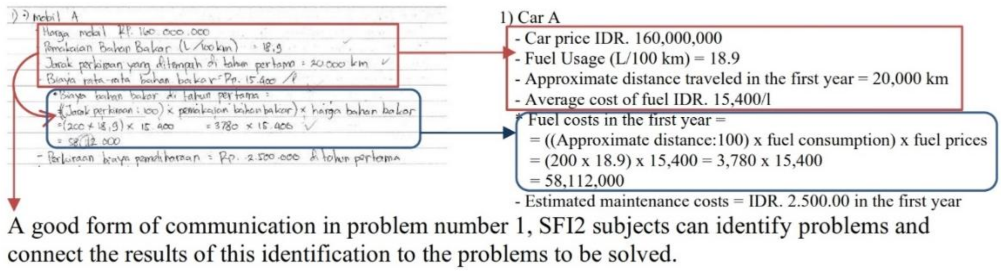


Figure 2. Examples of snippets of SFI2 Subject's answers that show good communication

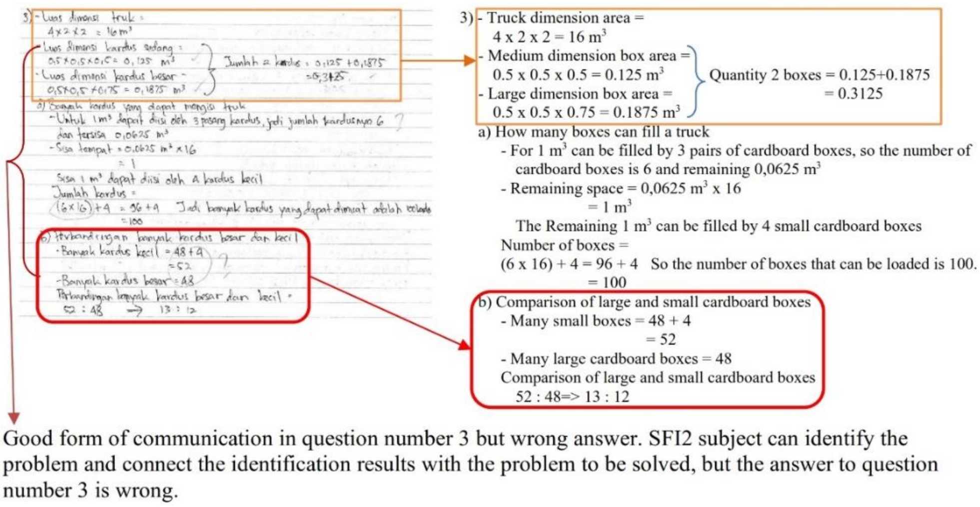


Figure 3. An example of a snippet of Subject SFI2's answer that shows good communication, but the answer to this problem is wrong.

Mathematical literacy on mathematization and representation indicators

Based on the results of the mathematical literacy test work in all questions, SFI1 and SFI2 can transform real-world problems into mathematical form well. Both subjects wrote the steps of the solution coherently, including processing inter-conceptual relationships. In problem number 2 (Uncertainty and Data) and problem number 4 (Quantity), SFI1 was able to write mathematical relationships correctly (See Figure 4). SFI2 managed to write inter-conceptual relationships well in almost all problems. However, in problem number 3 (Space and Shape), there were errors in understanding spatial relationships, resulting in inappropriate answers. Table 2 interview results on FI subject.

Table 2. FI subject interview results on mathematical literacy mathematization and representation indicators

Subject SFI1	Subject SFI2
"I usually write the question information into numbers or formulas. If the problem involves visuals, I try to understand the context first, but I can't always convert it into the right mathematical form."	*"My first step was to write down the numbers from the problem into mathematical form. Usually, I create an equation to help me find the solution, unless the problem has a diagram."*

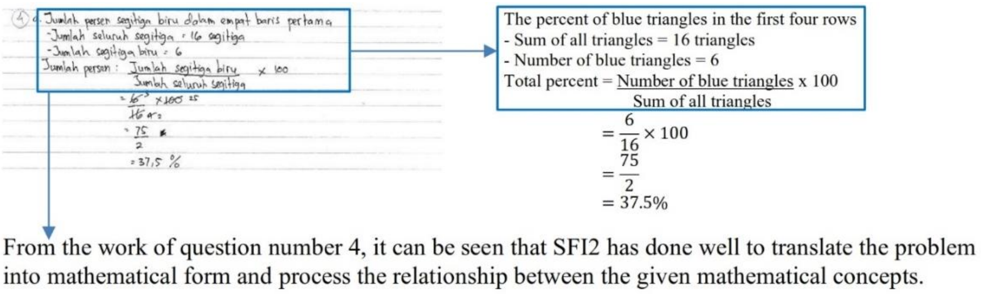


Figure 4. Examples of snippets of Subject SFI2's answers that show good Mathematization and Representation

Mathematical literacy on reasoning and argumentation indicators

SFI1 and SFI2 subjects provided logical reasons that supported their answers, including identifying the weaknesses of other answer options (See Figure 5). For example, in question number 2 (Uncertainty and Data), both subjects were able to explain in detail the answer options chosen by providing strong arguments and mentioning logical reasons. Table 3 interview results on FI subject.

Table 3. FI subject interview results on mathematical literacy reasoning and argumentation indicator

Subject SFI1	Subject SFI2
"I try to give logical reasons for each answer. If I got it wrong, it was usually because I didn't understand the clues well enough, especially in question 2 which involved diagrams."	*"I tried to give a convincing reason, although sometimes I was not sure whether I had interpreted the information in question 2 in the diagram correctly."*

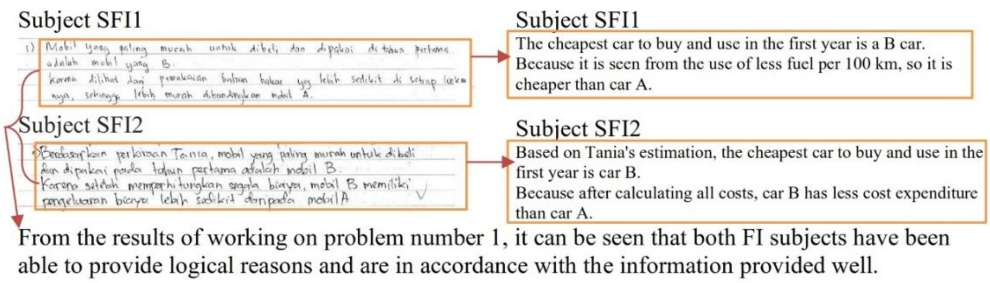


Figure 5. Examples of snippets of Subject FI answers that show good Reasoning and Argumentation

Mathematical literacy on symbol and diagram use indicators

FI subjects were better at translating symbols and diagrams in problem number 1 (Change and Relationship) and number 4 (Quantity). However, these two subjects faced difficulties in problem number 2 (Uncertainty and Data) and number 3 (Space and Shape), especially in understanding and processing complex visual information (See Figure 6). In number 3 (Space and Shape), SFI1 misinterpreted the diagram, although the initial steps looked logical, while SFI2 failed to connect the diagram with the correct mathematical solution. Table 4 interview results on FI subjects.

Table 4. FI subject interview results on mathematical literacy indicators for the use of symbols and diagrams

Subject SFI1	Subject SFI2
"Symbols and diagrams help me understand the problem, but if the diagram form is too complex in problem number 2, I get confused, as in the cardboard box in the truck problem number 3."	*"I often have difficulty if the problem contains complex diagrams such as problem number 2. For example, in problem number 3, I am not sure how to use the size of the cardboard box in the truck problem."*

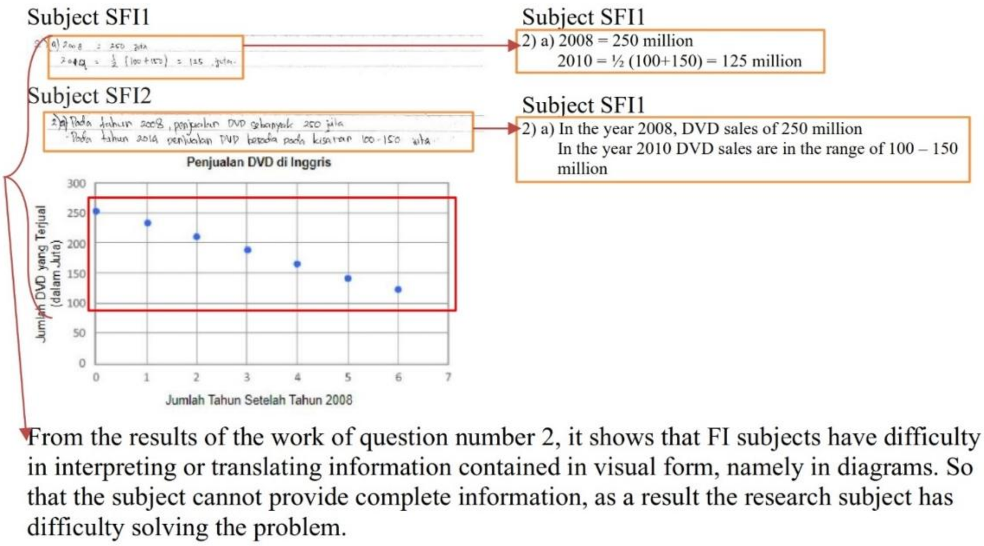


Figure 6. Examples of snippets of FI Subjects' answers showing poor use of symbols and diagrams

Of the four indicators of mathematical literacy questions, both SFI1 and SFI2 subjects showed superior abilities in the indicators of Communication, Mathematization and Representation, and Reasoning and Argumentation compared to the indicators of Symbol and Diagram Use. Table 5 interview results of FI subjects in the final session.

Table 5. Interview results of FI subject in the final session

Subject SFI1	Subject SFI2
"I find it easier to work on problems that contain numbers or relationships between numbers than problems that involve diagrams. Diagrams can be confusing, especially if no information is immediately apparent."	*"I tried to read the questions carefully, especially the parts that required calculations. For problems that use diagrams, I focus more on the numbers in them, but I often have doubts about the results."*

Subjects with field dependent (FD) cognitive style

Mathematical literacy on communication indicator

SFD1 and SFD2 were able to convey answers clearly but simply. In problem number 1 (Change and Relationship), the answers of both subjects were more structured than other problems (See Figure 7). However, in problem number 2 (Uncertainty and Data), number 3 (Space and Shape), and number 4 (Quantity), the answers tended to be short and did not contain all the steps of problem solving (See Figure 8). This is shown in Table 6 of the interview results on the FD subject.

Table 6. FD subject interview results on mathematical literacy communication indicator

Subject SFD1	Subject SFD2
"I answered according to what I understood. If the question seems easy, I can explain it more clearly, but if there are diagrams or data that are confusing, I usually answer simply."	*"I usually just answer briefly and don't explain my steps too much, especially if the question is difficult."*

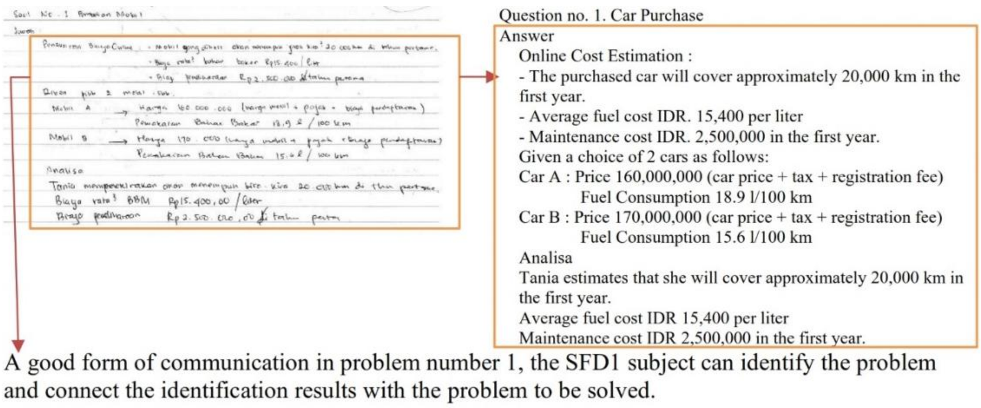


Figure 7. Examples of snippets of SFD1 Subject's answers that show good communication

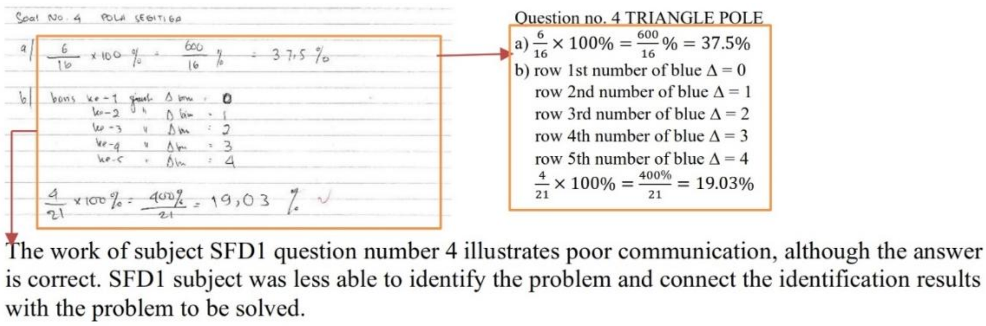


Figure 8. An example of a snippet of Subject SFD1's answer that shows poor communication, but the answer to this question is correct.

Mathematical literacy on mathematization and representation indicators

SFD1 could mathematize the problem better than SFD2, but both had limitations in processing mathematical inter-concept relationships. For example, in problem number 4 (Quantity), SFD2 was unable to process the inter-conceptual relationships correctly, resulting in errors in the answer (See Figure 9), while SFD1 was able to write the symbols correctly but incompletely. In problem number 2 (Uncertainty and Data), SFD1 failed to write the mathematical inter-conceptual relationships completely. This is shown in Table 7 of the interview results on the FD subject.

Table 7. FD subject interview results on mathematical literacy mathematization and representation indicators

Subject SFD1	Subject SFD2
"I often have difficulty converting problems into mathematical form. I usually try to write down the numbers I find in the problem, but often don't know how to proceed."	*"I am often confused about how to start if the question is long or uses diagrams. I just try to answer with the formulas I know."*

The results of the SFD2 subject's work on question number 4 illustrate a lack of ability to translate problems into mathematical form and process relationships between given mathematical concepts.

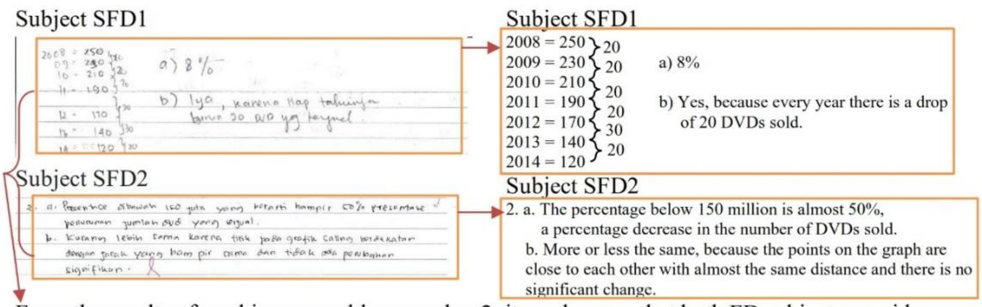
Figure 9. Examples of snippets of SFD2 Subject's answers that show poor Mathematization and Representation.

Mathematical literacy on reasoning and argumentation indicators

Both SFD1 and SFD2 subjects gave logical but not strong reasons to support their answers. In problem number 2 (Uncertainty and Data), SFD1 could not capture important information which caused their argumentation to be weak. Likewise, the reasoning given by SFD2 did not support the answer to question number 2 (Uncertainty and Data) (See Figure 10). In problem number 4 (Quantity), SFD1's argument is weak and lacks support for the reasons given. This is shown in Table 8 of the interview results on subject FD.

Table 8. FD subject interview results on mathematical literacy reasoning and argumentation indicator

Subject SFD1	Subject SFD2
"I know my reasons may not always be strong, but I answer based on what I think makes the most sense. Sometimes I'm not sure if my answer is right."	*"The reasons I use are often just based on guesses or things that I think make sense."*



From the results of working on problem number 2, it can be seen that both FD subjects provide reasons that are less logical and less in accordance with the information provided.

Figure 10. Examples of snippets of FD Subject's answers that show poor Reasoning and Argumentation

Mathematical literacy on symbol and diagram use indicators

Both FD subjects showed significant difficulties in diagram-based problems, such as problem number 2 (Uncertainty and Data) and number 3 (Space and Shape). In number 3 (Space and Shape), SFD1 was unable to translate the dimensions of the cardboard into correct mathematical steps. SFD2 failed to understand the visual information, leading to inaccurate answers (See Figure 11). Both subjects had difficulty understanding the visual information and translating it into appropriate mathematical steps. This is shown in Table 9 of the interview results on subject FD.

Table 9. FD subject interview results on mathematical literacy indicators for the use of symbols and diagrams

Subject SFD1	Subject SFD2
"The diagram of question 2 often confuses me, especially if the information is not immediately obvious."	*"I find it difficult to understand the diagram in question number 2. I usually only focus on the numbers that are visible."*

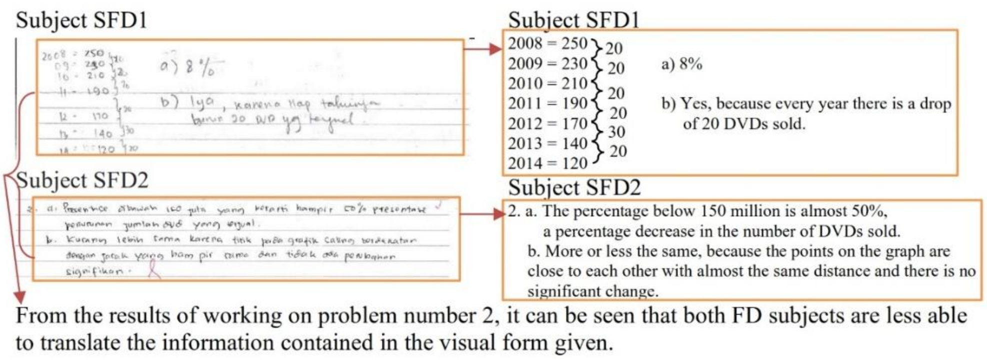


Figure 11. Examples of snippets of FD Subjects' answers showing poor use of symbols and diagrams

Of the four indicators of mathematical literacy, both SFD1 and SFD2 subjects showed more limited abilities in most indicators, especially in mathematization and representation and the use of symbols and diagrams. Table 10 FD subject interview results in the final session.

Table 10. Interview results of FD subject in the final session

Subject SFI1	Subject SFI2
"I tend to answer questions with what I think of first. If there is a diagram, I often get confused by the information in it."	*"For problems that require symbols or complicated calculations, I often feel hesitant because I am not sure of the steps I have made. Diagrams make me even more confused, especially if the size doesn't match the question information."*

Interview findings

Relationship between cognitive style and mathematical literacy

From the interview results, it was found that there were profound differences between Field Independent (FI) and Field Dependent (FD) subjects in the way they understood and solved mathematical literacy-based problems. These interviews not only confirmed the test results, but also provided insights into the strategies, thinking patterns and challenges the subjects faced.

Mathematical communication

FI subjects (SFI1 and SFI2) showed better mathematical communication skills than FD subjects (SFD1 and SFD2). In the interview, FI subjects explained that they were used to analysing the question information in a structured manner before providing answers. SFI2, for example, said:

> "I usually explain the answers in detail so that all the steps are clear. But when it's a visual-based question like a diagram, I just write down what I think is relevant."

This quote is supported by observation data, where SFI2 tends to record the steps of the solution in detail, even though there are errors in diagram-based problems. In contrast, SFD1 recognised his limitations in providing in-depth explanations:

> "I answered according to what I understood. If the question seemed easy, I could explain it more clearly. But if there are complicated diagrams or data, I answer briefly."

Observations of SFD1 showed a less structured answer pattern, especially on visual-based problems, such as Space and Shape. This data is consistent with the test results which show that their answers tend to be short and lack explanations of the solution steps.

Mathematisation and representation

Mathematisation, the ability to transform real-world problems into mathematical models, is one of the main strengths of FI subjects. In the interview, SFI1 explained:

> "I usually write the question information into numbers or formulas. If there is a picture, I try to understand the context first, although it doesn't always work."

The test results showed that SFI1 was able to make accurate mathematical models on number-based problems, such as Quantity and Change and Relationship. However, on visual-based problems such as Space and Shape, there were errors in understanding spatial relationships. Instead, SFD2 stated:

> "I am often confused about how to start if the question is too long or uses diagrams. I just try to answer with the formula I know."

This statement is consistent with the observation, where SFD2 often only wrote down parts of the information without integrating it into a complete mathematical model. In the Uncertainty and Data problem, for example, SFD2 failed to process the relationship between data, resulting in an inaccurate answer.

Reasoning and argumentation

FI subjects also excelled in providing logical reasons for their answers. SFI2 explained:

> "I always try to give convincing reasons for every answer. If I get it wrong, it's usually because I didn't understand the instructions in the question."

Data from the test shows that FI subjects are able to provide logical arguments on data-based problems such as Uncertainty and Data. They not only chose the correct answer, but also mentioned the weaknesses of the other answer choices, which shows a higher level of understanding.

In contrast, FD subjects, like SFD1, recognised their limitations:

> "I answer based on what I think makes sense. Sometimes I'm not sure if my answer is right."

Observations showed that the reasons given by SFD1 and SFD2 often did not strongly support their answers. In the Quantity problem, for example, their arguments tended to be speculative and not based on clear problem information.

Use of symbols and diagrams

This indicator was the main challenge for both groups. FI subjects showed better results than FD, but still faced difficulties in interpreting visual information. SFI1 stated:

> "Symbols and diagrams help me understand the problem, but if the diagram is too complex, I often get confused, like in problem number 3."

The test results showed that FI subjects were able to understand mathematical symbols well on number-based problems, but made significant errors on visual-based problems such as Space and Shape.

Meanwhile, FD subjects, like SFD2, showed more significant limitations. SFD2 explained:

> "I often struggle when the questions contain complicated diagrams. I usually just focus on the numbers that are visible."

Observations showed that FD subjects tended to ignore complex visual elements, so their answers were not relevant to the context of the problem.

Triangulation of data

These interview results were strengthened by triangulation with test and observation data. FI subjects showed analytical thinking patterns, as seen from their ability to compose structured answers to test questions and problem solving strategies observed during problem solving. FD subjects, on the other hand, tend to give less structured answers and show dependence on the context of the problem, which is also evident in their test results and observations. This triangulation reinforces the validity of the findings that cognitive style has a significant effect on mathematical literacy patterns, with FI subjects excelling in most indicators, but still facing challenges in visual interpretation. FD subjects require additional support to develop analytical and mathematical representation skills.

Discussion

Relationship between cognitive style and mathematical literacy

The results showed a significant relationship between cognitive style and mathematical literacy skills. Students with the Field Independent (FI) style consistently excelled in several indicators of mathematical literacy, such as communication, mathematization, and argumentation. FI subjects, such as SFI1 and SFI2, demonstrated the ability to process information analytically, enabling them to solve problems with clear and logical steps. For example, they can write answers coherently on number and data relationship-based problems such as Change, Relationship, and Quantity, provide detailed explanations, and identify relevant mathematical relationships. It is in line with the characteristics of FI, who tend to be able to separate the main information from the context, as stated by Chen and Macredie (2002), Ford et al. (2002), Witkin et al. (1977) and supported by the research of Kusuma et al. (2021).

In contrast, students with field-dependent (FD) styles such as SFD1 and SFD2 show more limited abilities, especially in complex analysis problems. FD subjects tend to rely more on the context of the problem, so they often struggle to identify important information underlying the problem. For example, in the uncertainty and data problem, FD subjects failed to translate the visual data in the diagram into correct mathematical steps, unlike FI subjects, who managed to process the information imperfectly. This limitation suggests that FD subjects need support in building abstract and analytical thinking skills, as Guillot and Collet (2004) expressed.

Mathematization and representation skills are also strongly influenced by cognitive style. FI subjects were more flexible in transforming information into mathematical form and processing inter-conceptual relationships, especially in number or formula-based problems. In contrast, FD subjects showed difficulty representing information, leading to errors in processing mathematical relationships. It can be attributed to Chen and Macredie's (2002) research, which states that FD students rely more on explicit directions and often face challenges in solving tasks with less apparent structures.

However, there are aspects where FI and FD cognitive styles show similar difficulties, namely on indicators of the use of symbols and diagrams, especially visual-based problems such as Space and Shape. This error occurred because the problem demanded a more complex interpretation of the dimensions of space, which was a challenge for both groups. FI subjects were better at identifying symbols and diagrams but struggled to transform visual information into mathematical calculations. On the other hand, FD subjects showed more significant limitations in understanding diagrams and integrating them into problem-solving. These findings suggest the need for strengthening spatial visualization skills for both groups, as proposed by Setiawan et al. (2020).

Other factors that influenced this relationship were each group's confidence level and learning strategy approach. FI subjects, as seen in the SFI1 and SFI2 interviews, were more confident in explaining and defending their answers with logical reasoning. In contrast, FD subjects tended to give short and straightforward answers, reflecting their lack of confidence in the steps taken. It confirms the importance of pedagogical interventions that improve technical skills and build students' confidence in working on mathematical problems (Memnun et al., 2012; Nisa & Arliani, 2023).

These results showed that cognitive style contributed significantly to students' mathematical literacy patterns and outcomes. FI students showed excellence in almost all indicators, but challenges in mathematical visualization remained an obstacle. In contrast, FD students need more support in building analytical skills and mathematical representation. Therefore, learning approaches that strengthen abstraction, argumentation, and visualization skills are essential to improve mathematical literacy in both groups.

Analysis based on mathematical literacy indicators

Communication indicator

Mathematical communication is one of the fundamental aspects of mathematical literacy that involves clarity in conveying ideas, solution steps, and final results. Field Independent (FI) subjects, namely SFI1 and SFI2, showed excellence in this indicator. On number and data-based problems such as Change, Relationship, and Quantity, they could explain their answers in a detailed and structured manner, with steps that were easy to understand. SFI2, for example, provided a more detailed explanation than SFI1, although still concise. This ability aligns with the characteristics of FIs, who tend to analyze problems thoroughly and convey information in a structured manner (Chen & Macredie, 2002; Ford et al., 2002).

In contrast, Field Dependent (FD) subjects, namely SFD1 and SFD2, showed limitations in the communication indicator. They could convey their answers quite clearly on relatively simple problems, such as Change and Relationship. However, on more complex problems, such as Space and Shape or Uncertainty and Data, their answers tended to be short, less structured, and often did not include the solution steps. These limitations indicate that FD subjects rely more on the context of the problem and are less able to describe their thought processes explicitly. It supports the finding (Guillot & Collet, 2004) that FD students struggle to convey information independently without clear support or direction.

Mathematization and representation indicators

Mathematization ability, i.e., transforming real-world problems into mathematical form, is the main strength of FI subjects. In problems such as Quantity and Change and Relationship, SFI1 and SFI2 can transform information from the problem into relevant mathematical equations, connect concepts logically, and solve them accurately. For example, in the quantity problem, they successfully used numerical information to model the relationship of the variables and find the correct solution.

However, FD subjects showed difficulty in this indicator. SFD1 could transform information better than SFD2, but often only at the horizontal mathematization level (identifying data from the problem without fully solving the problem). For example, in the space and shape problem, SFD1 successfully symbolized some elements of the problem but failed to integrate them to solve the problem. SFD2 was even more limited, often only writing down partial information without clear logical connections. It supports the findings (Setiawan et al., 2020) that FD students often have difficulty integrating information in the vertical mathematization process.

Reasoning and argumentation indicators

The reasons and arguments reflect logic and accuracy in supporting the answer. FI subjects again showed excellence in this indicator. SFI1 and SFI2 were able to provide logical reasons for each of their answers, often by adding explanations as to why other answer choices were considered inappropriate. On data-based problems such as Uncertainty and Data, they not only chose the correct answer but also mentioned the weaknesses of the other options, showing a deeper level of understanding.

On the other hand, FD subjects often gave illogical reasons and weak argumentation. SFD1 was sometimes able to explain its steps, but the reasons given did not always support the answer strongly. SFD2 more often gave answers without clear reasons, especially for highly complex problems, such as uncertainty and data. This weakness shows that FD subjects have difficulty building logic-based arguments, which challenges mathematical literacy (Tambunan, 2021).

Symbol and diagram use indicators

This indicator was a big challenge for both groups, although FI subjects showed slightly better results than FD. Regarding Change and Relationship, and Quantity, SFI1 and SFI2 understood and utilized mathematical symbols and diagrams to answer the questions. However, in visual-based problems such as space and shape, both had difficulty translating information from diagrams into the correct mathematical form. For example, in the cardboard and truck problem, they misunderstood the dimensions of the space and made errors in calculations.

FD subjects showed greater limitations on this indicator. SFD1 and SFD2 often could not translate visual information, causing them to have difficulty solving problems such as Space and Shape, Uncertainty, and Data. In diagram-based problems, they often focused on the visible numbers without understanding the relationship between the diagram's elements. This limitation supports the finding (Chen & Macredie, 2002) that FD students often struggle with tasks that require the interpretation of symbols and complex visualizations.

These results indicate that mathematical literacy indicators are important in identifying strengths and weaknesses based on cognitive style. FI subjects excelled in communication, mathematization, and argumentation indicators but still needed strengthening in visual interpretation. FD subjects showed significant challenges on all indicators, especially in mathematization and symbol use. Visual technology-based learning approaches, such as geometric simulations and diagram-based software, may help improve these skills in both groups.

Conclusion

The mathematical literacy skills of prospective mathematics teachers showed a close relationship with field-independent (FI) and field-dependent (FD) cognitive styles. Students with FI cognitive style have advantages in mathematical communication, mathematization, representation, and logical reasoning, especially on numerical-based problems such as Change and Relationship, Uncertainty and Data, and Quantity. However, they face challenges in visual-based problems such as Space and Shape, especially in using symbols and diagrams effectively. On the other hand, students with FD cognitive style showed good communication skills on numerical-based problems such as Change and Relationship. However, they had difficulty in mathematization, representation, use of symbols and diagrams, and logical reasoning on more complex problems, such as Uncertainty and Data, Space and Shape, and Quantity. It shows their limitations in processing visual information and solving data-based problems.

The main challenge for both groups was visual-based problems, which required complex interpretation of symbols and diagrams. These findings emphasize the importance of strengthening spatial visualization skills for students with FI and FD cognitive styles. In addition, the results of this study suggest that visual technology-based learning approaches, such as geometry simulation and diagram-based software, may be a solution to this challenge. By understanding these cognitive style differences, the mathematics teacher education curriculum can be adaptively designed to meet the needs of both groups. It will help improve mathematical literacy skills holistically so that prospective mathematics teachers can be more effective in solving real-world problems and meeting the demands of modern education.

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Conflicts of Interest

Authors have no competing interests. In addition, the writers have addressed ethical concerns like plagiarism, misconduct, data fabrication and falsification, double publishing and submission, and redundancy.

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