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Exploring Students' Mathematical Literacy Through Learning Styles and School Environment

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ABSTRACT

This study aims to analyze students' mathematical literacy skills in relation to their learning styles (visual, auditory, and kinesthetic) and their school learning environment. A mixed-methods approach was employed, using mathematical literacy tests, student response analysis, and in-depth interviews. The results show that visual learners excel in numerical representation and written communication but struggle with formal symbolism without visual support. Auditory learners understand procedures well through verbal explanations but have difficulty constructing arguments and alternative strategies. Kinesthetic learners perform well on contextual problems through practical activities but are weak in visual representation and formal reasoning. A non-varied and unresponsive learning environment hampers the development of mathematical literacy. These findings emphasize that a mismatch between learning styles and instructional approaches negatively affects literacy achievement, particularly in reasoning, argumentation, and representation. Therefore, fostering a learning environment that accommodates diverse learning styles is essential for enhancing students' overall mathematical literacy.

Keywords: *mathematical literacy, learning styles, learning environment, visual, auditory, kinesthetic*

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1. Introduction

Education is an essential part that equips students with the skills to face various challenges they will encounter throughout their lives (Amaliya & Fathurohman, 2022). The Law of the Republic of Indonesia Number 20 of 2003 on the National Education System states that education aims to develop students into individuals who are faithful and devoted to the One and

Only God, possess noble character, are healthy, knowledgeable, capable, creative, independent, and become democratic and responsible citizens.

One of the fields of study taught in schools is mathematics. Mathematics has been introduced to students from early childhood education to higher education. The aim of mathematics learning is for students to develop strong mathematical abilities, the capacity to think and act critically, the ability to think creatively and accurately, an objective attitude, open-mindedness, curiosity, and an interest in mathematics (Utomo et al., 2020). Mathematics has an abstract nature consisting of facts, operations, relationships, and concepts. Therefore, a good understanding of concepts is essential for learning mathematics. Understanding a mathematical concept means understanding other related concepts. In other words, grasping a new concept requires understanding the previous ones (Fauziah et al., 2019). Abstract concepts are often associated with mathematics and have strong and structured relationships. Therefore, the best way to teach mathematics to students is by relating mathematical material to everyday problems (Salsabilla & Hidayati, 2021). To solve everyday problems, it is not enough to have calculation skills; it also requires the ability to think logically, critically, and analytically. This mathematical ability is referred to as mathematical literacy skills (Simamora & Tilaar, 2021).

Sitopu et al. (2024) emphasizes that strong mathematical skills are a valuable asset for individuals in the job market. These skills not only help with solving tasks involving numbers and data, but also enhance one's ability to think strategically and make informed decisions.

Mathematical literacy skills help students apply mathematical concepts in various real-life situations (Lestari & Prayitno, 2025). These skills are not limited to numerical calculations but also include the ability to analyze situations, make rational judgments, and solve complex problems (Utomo et al. 2020). Mathematical literacy contains mathematical concepts, mathematical procedures, mathematical reasoning, and mathematical facts used to predict and explain related phenomena that emphasize process, content, and context competencies (Fernanda et al., 2024). In solving mathematics problems, there are students who are highly skilled, those who are average, and those who struggle. This is due to the fact that a person can only solve problems effectively if they have the ability to understand the problem (Issabilillah, et al., 2024). Thus, mathematical literacy is not merely about memorizing formulas but rather the ability to use mathematics effectively and relevantly in various aspects of life.

Mathematical literacy goes beyond simply understanding mathematical concepts; it also encompasses fundamental skills and independence in applying mathematical thinking, developing deep understanding, and solving problems effectively (Umbara & Suryadi, 2019). This demonstrates that mathematical literacy is not only about answering questions or understanding formulas, but also about critical and analytical thinking skills when faced with complex situations.

Mathematical literacy skills depend on mathematical knowledge and can vary across contexts. When students complete tasks derived from real-life situations, they acquire new mathematical knowledge by processing information in ways that, in turn, strengthen their mathematical understanding. Therefore, there is an interdependence between mathematical literacy and mathematical knowledge, where strengthening one component contributes to the development of the other (Kolar & Hodnik, 2021).

Based on the research results, it is important to develop a Mathematics Learning Model Based on Realistic Mathematics Education and Literacy (MLMB-RMEL) to improve students' mathematical literacy (Rusdi et al., 2020). In reality, students' mathematical literacy skills are still low. Based on the results of the PISA (Programme for International Student Assessment) study on mathematical literacy, from Indonesia's participation starting in 2000 up to 2022, there has been no significant improvement in quality, as reflected in the scores obtained throughout

2000–2022. The purpose of Indonesian students' participation in PISA is to evaluate their mathematics and reading abilities from an early stage (Putrawangsa & Hasanah, 2022).

PISA is a survey or research conducted every three years on students aged 15. The test is designed by the OECD (Organisation for Economic Co-operation and Development) with the aim of assessing the abilities of students who have completed their basic education in terms of reading skills, mathematical skills, and scientific understanding. In 2022, Indonesia was one of the participating countries in the PISA survey, among a total of 81 participating nations (OECD, 2023). The 2022 PISA results show that Indonesian students' international ranking improved by about 5–6 positions compared to 2018. However, the average scores of Indonesian students were still below the global average: reading literacy scored 359 compared to the world average of 469, mathematics scored 366 compared to the world average of 358, and science scored 383 compared to the world average of 384 with the latter two subjects showing a decline compared to 2018. These results are in line with several other studies in Indonesia which show that many students still have difficulty solving PISA problems (Edo & Tasik, 2022; Khusnah et al., 2022; Ilmi & Abdussakir, 2024; Wulandari & Jailani, 2018).

Instructional factors, personal factors, and environmental factors influence students' mathematical literacy learning outcomes. One personal factor that has a significant impact is students' learning style (Amaliya & Fathurohman, 2022). Each student has a different learning style, which needs to be matched with a differentiated learning approach to make learning effective. Learning style influences students' ability to receive and process information according to their capacity (Alhafiz, 2022). Productive learning can be achieved through the application of an appropriate learning style (Imamuddin et al., 2019).

The importance of aligning learning styles between teachers and students becomes evident because learning materials will not feel difficult if the teacher's teaching approach matches the student's learning style. Conversely, if the approach is not aligned, students tend to perceive the material as difficult (Heryyanti et al., 2021). Therefore, teachers need to understand students' learning styles and deliver the material in accordance with those styles. This can make it easier for students to grasp the material and improve their learning outcomes (Edimuslim et al., 2019).

After identifying students' learning styles, the next step is to correlate them with learning environment factors. According to Ramadania et al., (2022), the learning environment influences the success of the teaching and learning process. In line with the findings of Azma (2019), the quality of the learning environment is directly proportional to the quality of the output produced. The learning environment is classified into the family environment, school environment, and community environment. Based on the research of Hermawan et al. (2020), the family environment contributes 13.05%, the school environment contributes 17.96%, and the community environment contributes 12.09% to students' learning outcomes.

The school learning environment also plays an important role in supporting students' mathematical literacy (Hidayat et al., 2023). A conducive learning environment, both in terms of physical facilities and social interactions in the classroom, can enhance students' motivation and engagement in the learning process. Conversely, an unsupportive learning environment can hinder the development of students' mathematical literacy skills.

The diversity of learning styles and students' learning environment conditions are considered to have an interrelated influence on students' mathematical literacy skills. Students with a kinesthetic learning style need to be supported by a learning environment that provides learning models involving physical activities and teaching aids, while students with a visual learning style need to be supported by a learning environment that offers visual learning media such as videos, graphics, and images.

2. Method

The research method used in this study is the Mixed Method with a Sequential Explanatory Design, in which quantitative data collection and analysis are conducted first, followed by qualitative data collection and analysis to deepen the findings of the quantitative research (Hendrayadi et al., 2023). The quantitative approach is used to measure students' mathematical literacy skills and analyze the relationship between their learning styles and these skills, while the qualitative approach is used to explore in greater depth the factors influencing this relationship through interviews.

This study was conducted at SMP Amal Bakti Manislor during the even semester of the 2024/2025 academic year. The population in this study consisted of all eighth-grade students at the school, totaling 40 students. The sample for quantitative data collection was selected using the stratified random sampling technique, in which the population was divided into strata based on learning style categories (visual, auditory, and kinesthetic), and then randomly selected from each stratum to ensure proportional representation of students' learning style diversity. The total sample taken was 36 students, determined based on the Krejcie and Morgan (1970) table for a population of 40. Meanwhile, for qualitative data collection, subjects were purposively selected based on the identified learning styles from the quantitative data, namely students representing specific learning styles.

The quantitative data collection technique was carried out through administering a mathematical literacy test and distributing a student learning style questionnaire. The mathematical literacy test was developed based on the 2015 PISA indicators (OECD, 2015) which include the aspects of communication, mathematization, representation, reasoning and argument, problem-solving strategies, and symbolic, formal, and technical language and operations. Meanwhile, a VAK model–based learning style questionnaire was used to identify students' learning style types. Qualitative data were collected through in-depth interviews with selected students to gain deeper insights into how their learning styles and school learning environments relate to their mathematical literacy achievement. To present the test results, students were given a score for each of their answers to every question. The category in mathematical literacy can be seen in Table 1 and following formula was used to calculate the students' mathematical literacy level:

$$X = \frac{Soc}{Ims} \times 100 \qquad (1)$$

Description:
X = students' mathematical literacy score
Soc = students' obtained score
Ims = ideal maximum score

Table 1. Mathematical Literacy Skills Test Score Range

Range of Mathematical Literacy Skills Test Scores	Category
Score ≥ 80	High
$60 \leq$ Score < 80	Medium
Score < 60	Low

After obtaining the results of students' mathematical literacy skills and learning styles, interviews were conducted to gain deeper insights into how their learning styles and school learning environments affect their understanding of mathematics. Mathematical literacy skills were measured based on the results of the Mathematical Literacy Skills Test, with scores determined according to the mathematical literacy skill indicators.

3. Results and Discussion

3.1 Results

Based on the research conducted from February 10 to 14, 2025, at SMP Amal Bakti Manislor, located at Jl. Wisaprana No. 48, Manislor Village, Jalaksana Subdistrict, Kuningan Regency, West Java, SMP Amal Bakti Manislor is a private school that has shown better progress compared to other private schools in Kuningan Regency.

Based on the calculation of mathematical literacy scores, the average score of the mathematical literacy test for eighth-grade students at SMP Amal Bakti Manislor in solving mathematical literacy test questions was 61.3, as presented in the appendix. Table 2 presents the categories of mathematical literacy test results for the eighth-grade students of SMP Amal Bakti Manislor.

Table 2. Percentage of Mathematical Literacy Results

Category	Number	Percentage
High	20	55%
Medium	11	31%
Low	5	14%
Total	36	100%

Based on Table 2 of students' mathematical literacy test results, the highest percentage was in the low mathematical literacy category, at 55%. Meanwhile, the lowest percentage was in the high mathematical literacy category, at 14%. These student learning style results can be presented in the form of a bar chart.

Table 3. Descriptive Statistics of the Mathematical Literacy Test

Statistic	Statistical Score
Maximum Score	87
Minimum Score	39
Score Range	48
Mean Score	61,3
Median	58
Mode	56
Standard Deviation	12

Based on Table 3, the average score of the mathematical literacy test for eighth-grade students at SMP Amal Bakti Manislor is 61.3. The scores obtained by the students show a fairly wide variation, ranging from 39 to 87, while the ideal score that can be achieved is 100. With a score range of 48, these results indicate that students' mathematical literacy skills in solving test questions are still in the medium category. This significant variation in scores reflects differences in students' levels of understanding and mathematical literacy skills. Some students were able to achieve scores close to the ideal, while others still experienced difficulties in solving the problems optimally. Therefore, more effective teaching strategies that align with students' needs are required to improve their mathematical literacy skills to a higher level.

Based on the mathematical literacy test results of 40 eighth-grade students at SMP Amal Bakti Manislor with visual, auditory, and kinesthetic learning styles, the outcomes varied. However, overall, each variation was clearly distinguishable, leading the researcher to select one student from each learning style group who met the criteria as subjects.

The following is an analysis based on the explanations provided by the research subjects according to their answers to the mathematical literacy test:

1. Visual Research Subject

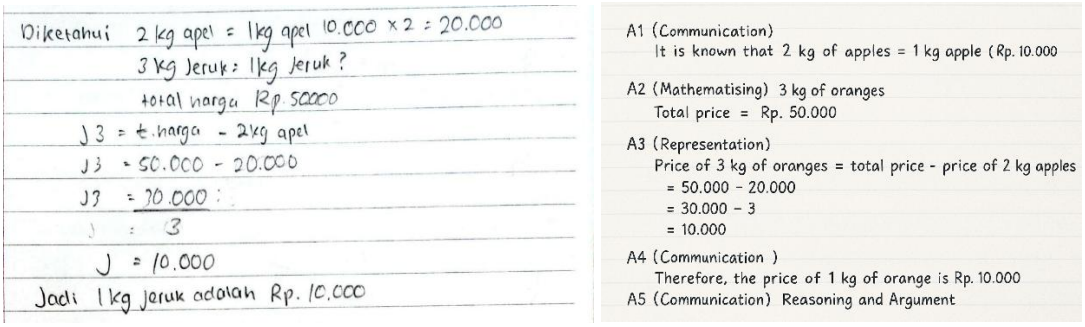


Figure 1. Answer of Visual Subject Number 1

Figure 1 shows the subject demonstrates good mathematical literacy skills. They solve the problems systematically, use basic operations correctly, and are able to convert problem information into numerical form. Their visual learning style appears to support their ability to understand numerical representations and organize problem-solving steps in a structured manner. Although the symbols used are still informal and the arguments are not explicitly written, the problem-solving strategy remains logical and effective, reflecting the visual learner's tendency to rely on concrete and structured representations for understanding.

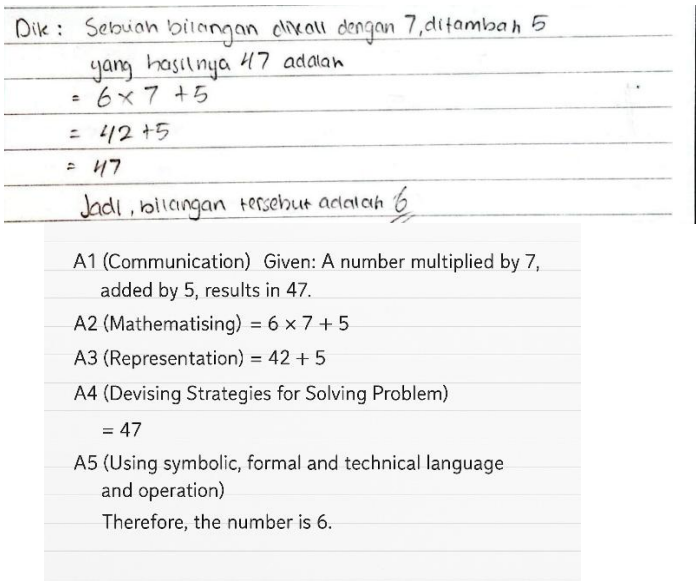


Figure 2. Answer of Visual Subject Number 2

Figure 2 shows the subject successfully arrived at the correct answer through a trial-and-error strategy. Although having a visual learning style, the subject did not model the problem in the form of equations or use formal symbols that typically support visual understanding. This indicates that the potential of their learning style has not been fully utilized in the problem-solving process. The reasoning demonstrated is still limited, as the subject did not provide logical arguments or justification that their answer is the only correct one. The absence of systematic visual representation and the lack of structure in explaining the answer appear to be obstacles to their mathematical literacy performance.

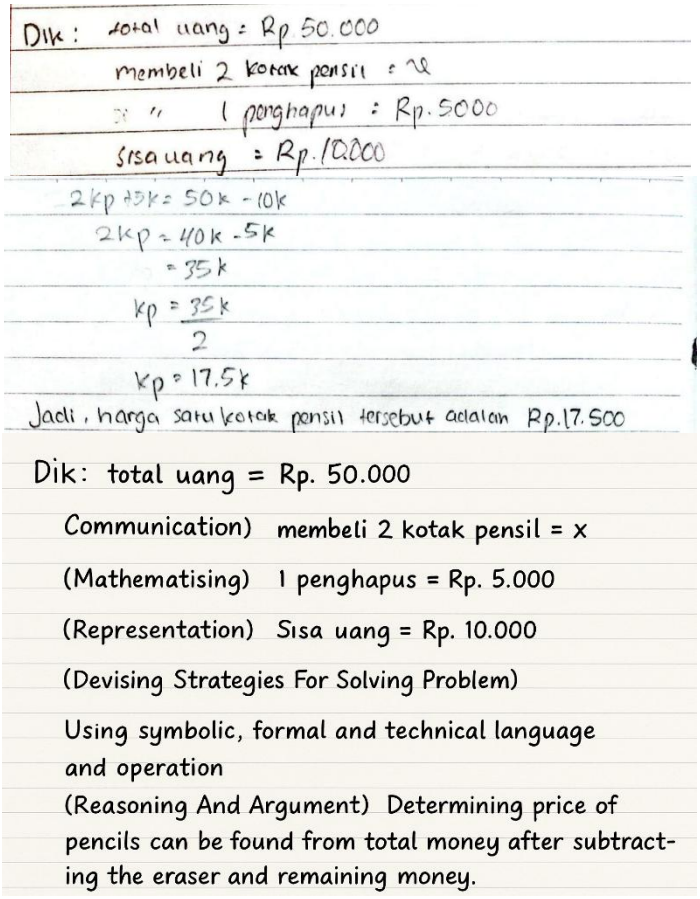


Figure *3*. Answer of Visual Subject Number *3*

From Figure 3 , the subject is able to understand the context of the problem and solve it using appropriate basic operations. Their visual learning style supports their ability to arrange calculation steps logically and in a structured manner. They use informal but consistent notation, reflecting a tendency to represent information concretely in a visual form. However, formal symbolism and the construction of mathematical arguments still need improvement, as the subject has not fully utilized the power of visualization to develop deeper generalizations or abstract reasoning.

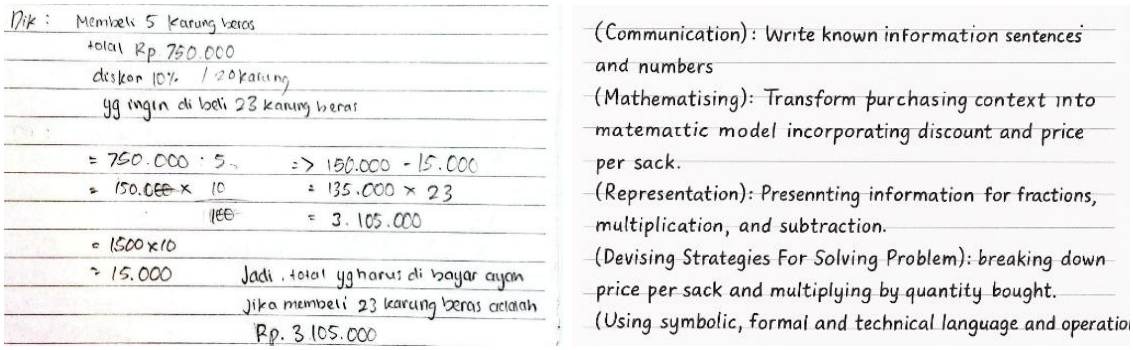


Figure 4. Answer of Visual Subject Number 4

The subject understands the problem and solves it systematically, starting from determining the price before and after the discount to calculating the total cost (see Figure 4). Their visual learning style appears to support their ability to represent information numerically in a clear and orderly manner. They demonstrate a good understanding of the sequence of calculation steps. However, the use of algebraic symbols is minimal and not accompanied by explicit

arguments, indicating that the subject has yet to fully develop formal symbolism and more abstract mathematical reasoning, despite having strong visualization potential.

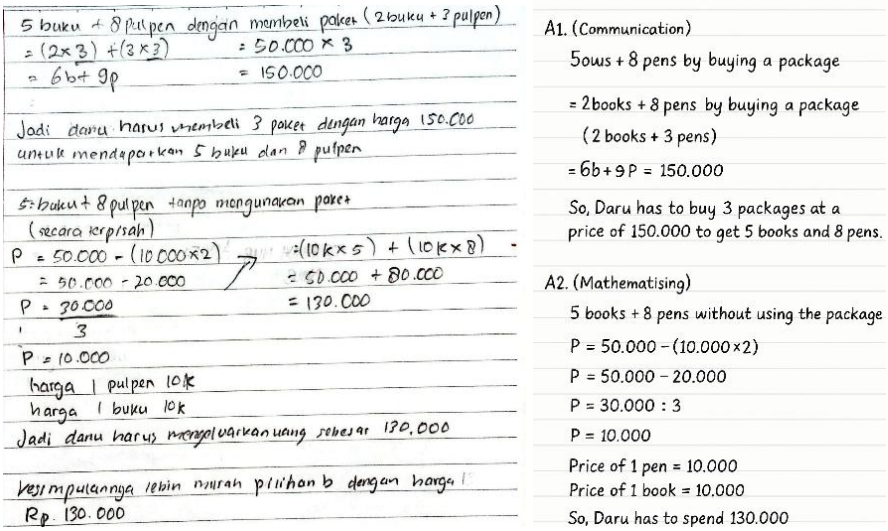


Figure 5. Answer of Visual Subject Number 5

Figure 5 shows the subject demonstrates fairly comprehensive mathematical literacy. Their visual learning style appears to support their ability to systematically compare two alternative solutions. They use structured arithmetic calculations and conclude the more economical choice based on the price difference. Numerical representations are clearly organized, and their arguments are supported by concrete calculation evidence. Although the symbols used are still informal, the orderly visual presentation indicates that the subject relies on their visualization strengths to understand and logically evaluate mathematical information.

Based on the analysis of the answers and the interview results, it can be concluded that the visual learner still faces some challenges in certain aspects of mathematical literacy. In the communication aspect, the subject is able to explain the problem-solving steps sequentially but is not yet accustomed to writing reasons or arguments explicitly. This is because the subject is more comfortable explaining orally, as reflected in the interview and classroom observations.

In the mathematization aspect, although the subject can convert contextual problems into numerical calculations, they have not used formal symbolic models. The subject finds the process confusing and less practical, thus prefers informal notation. Meanwhile, in terms of representation, the subject only uses numbers without utilizing tables or diagrams. This aligns with their admission that they feel they understand the problem well enough without visual forms, indicating limitations in using various types of representations.

After in-depth interviews regarding the student's learning style and school learning environment, it can be concluded that the visual subject has fairly good mathematical literacy skills, especially in communication, mathematization, problem-solving strategies, and the use of basic operations. However, there are still deficiencies in the use of formal symbols, algebraic modeling, alternative representations, and the delivery of mathematical arguments. The main obstacles influencing these abilities come from the school learning environment, including overly procedural teaching methods, lack of varied teaching strategies, limited openness in teacher-student relationships, insufficient learning aids, and a minimal culture of reflective thinking in the classroom. The curriculum, which should encourage contextual and exploratory approaches, has not yet been fully optimally implemented in practice.

2. Auditory Research Subject

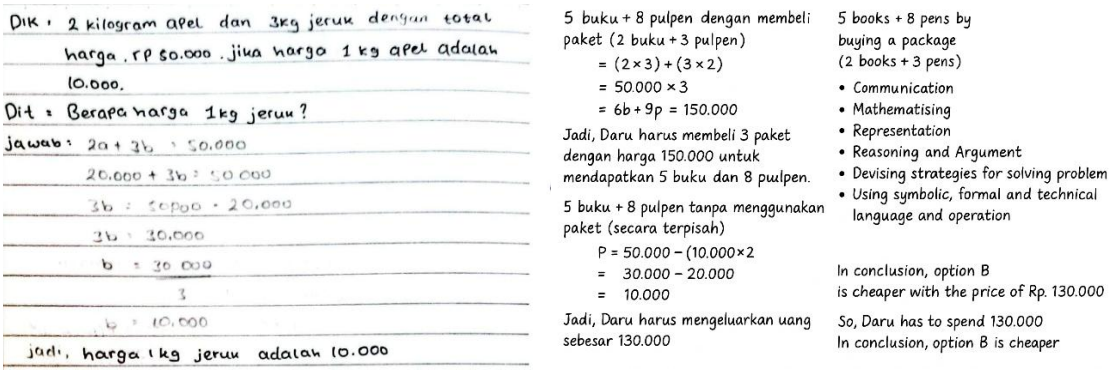
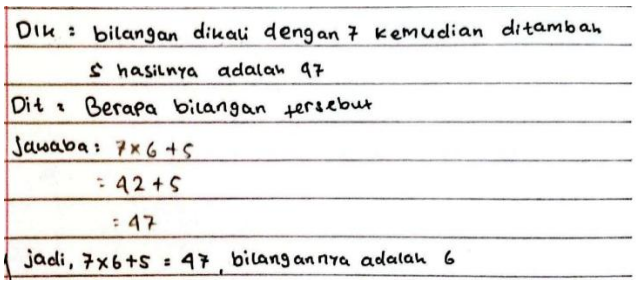


Figure 6. Answer of Auditory Subject Number 1

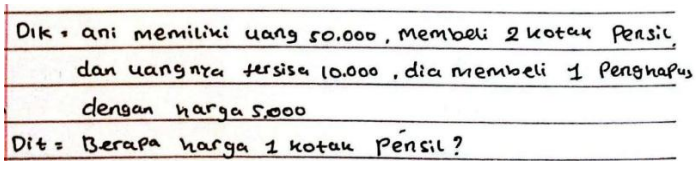
In the first question, the subject was able to effectively communicate the information from the problem into a mathematical equation. The subject accurately wrote the equation 2a + 3b = 50,000 and substituted the value a = 10,000, demonstrating good mathematization skills (see Figure 6). The symbolic representation is clear, using algebraic form to model the situation. The problem-solving strategy employed, namely substitution and solving a linear equation with one variable, was carried out correctly. Their auditory learning style appears to support their ability to understand verbal instructions and information presented in the problem, allowing them to process the information in a logical and sequential manner. The subject also showed accurate symbolic and technical operation skills in calculating the value of b and presented logical reasoning with the correct conclusion: the price of 1 kg of oranges is Rp10,000.

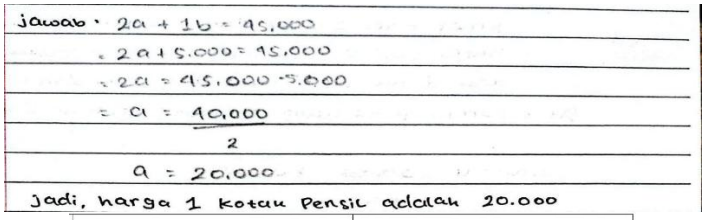


Diketahui : Bilangan dikali dengan 7 kemudian ditambah 5 hasilnya adalah 47	Given: A number is multiplied by 7 and then added by 5, the result is 47.
Ditanya: Berapa bilangan tersebut?	**Question:** What is the number?
Jawab: 7 × 6 + 5 = 42 + 5 = 47	**Answer** 7 × 6 + 5 = 42 + 5 = 47
Jadi, 7 × 6 + 5 = 47, bilangan itu adalah 6	**Therefore,** 7 × 6 + 5 = 47, the number is 6
Communication	Diketahui ... Ditanya ... → siswa mampu mengekspresikan soal dalam bentuk baha-
Mathematising	'bilangan dikali 7 kemudian ditambah 5'
Representation	Menggunakan simbol 7 × 6 + 5 = 47
Devising Strategies For Solving Problem	Strategi trial and error → substitusi bilangan
Using symbolic, formal and technical language and operation	Mengunnakan simbol operasi (×, +, =). Persamaan benar (7 × 6 + 5 = 47)

Figure 7. Answer of Auditory Subject Number 2

In the second question, the subject was able to understand the problem and formulate a mathematical model in the form of the equation 7x + 5 = 47 (see Figure 7). This demonstrates good communication and understanding of the problem context. Their auditory learning style appears to support comprehension through verbal information, enabling the subject to process the problem's instructions in a structured way mentally before expressing them symbolically. The subject then solved the equation using a simple algebraic method involving subtraction and division, arriving at the answer x = 6. The mathematization process was carried out correctly, the symbolic representation was accurate, and the symbolic operations and calculations were organized sequentially. Their reasoning was logical, although not yet accompanied by explicit written explanations, which is a common characteristic of students with an auditory learning style.

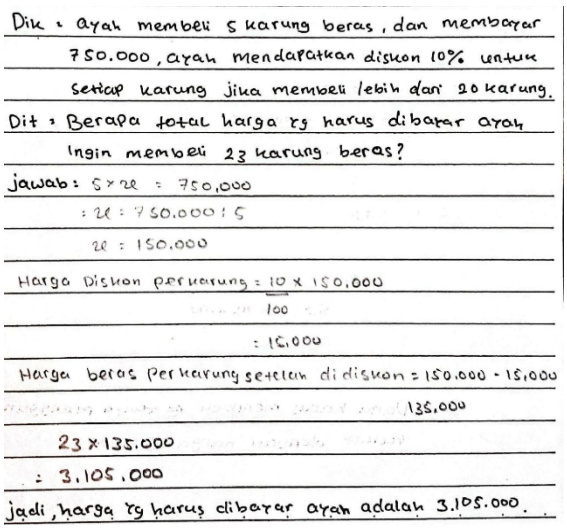




Translation	Analisis
Given: Ani has 50.000. She buys 2 boxes of pencils, and she still has 10.000 left. She also buys 1 eraser at the price of 5.000.	[Communication] Siswa menuliskan "Diketahui ... Ditanya ..." menurut komunikasi matematis jelas.
Berapa harga 1 kotak pensil?	[Mathematising] Situasi cerita diubah ke model matematika: $2a + b = 45.000$
$2a + 1b = 45.000$ $2a + 5.000 = 45.000$ $2a = 45.000 - 5.000$ $2a = 40.000$ $a = 20.000$	Reprenstation] Representasi dengan persamaan simbol (2a + 5.000 = 45.000)
Devising Strategies For Solving Problem: Strategi aljabar (eliminasi pengnappus $b = 5.000$, lalu hitung harga	[Devising Strategies For Solving Problem] Strategi aljabar (eliminasi penghapus $b = 5.000$, lalu hitung harga a)
And Argument | consomantion	Reasoning And Argument

Figure 8. Answer of Auditory Subject Number 3

In the third question, the subject successfully understood the information that Ani had Rp50,000, bought 2 pencil boxes, one eraser priced at Rp5,000, and still had Rp10,000 remaining (see Figure 8). This auditory learner was able to convert the verbal information in the problem into an appropriate mathematical model, namely the equation 2x + 5,000 + 10,000 = 50,000. This demonstrates good communication and mathematization skills, supported by their ability to listen to and process verbal information. The problem-solving strategy involved setting up and simplifying the equation until the value x = 20,000 was obtained. The symbolic representation used was clear, and the mathematical operations were carried out accurately. The subject also showed logical, sequential reasoning and correctly concluded that the price of one pencil box is Rp20,000.



English Translation	Coding Analisis (In-
Given: Father buys 5 sacks of rice and pays 750.000, He gets a 10% discount for each sack if he buys more than 20 sacks. Question: How much does Father have to pay if he wants to buy 23 sacks of rice?	**Communication** Siswa menuliskan "Diketanui ... Ditanya ..." → Komunikaitsai matematis jelas **Mathematizing** Situasi cerita diubah ke model matematika 5x = 750.000, lalu menghitung harga 1 karung, kemudian menerapkan diskon **Representation** Representasi simbolik dengan persamaan (23 x 135.000, 23 x 135.000) **Reasoning And Argument**
$5 \times x = 750.000$ $x = 750.000 + 5$ $x = 150.000$ Discount per sack = 10% x 150.000 = 15.000 Price per sack after discount = 135.000 – 15.000 = 3.105.000 Therefore, the total price Father has to pay is 3.105.000.	

Figure 9. Answer of Auditory Subject Number 4

In the fourth question, the subject dealt with calculations involving the purchase of rice in large quantities and the application of a discount (see Figure 9). Their auditory learning style appeared to support understanding of the verbal information in the problem, enabling them to correctly calculate the total price for 5 sacks of rice and proceed to calculate for 23 sacks,

considering a 10% discount for purchases over 20 sacks. The subject communicatively wrote down their thought process in a sequential manner, reflecting their tendency to process and organize information verbally before writing it down.

The mathematization process was evident when the subject assumed the discount applied to all 23 sacks. However, there was a small error in the discount calculation step, specifically when converting the price from Rp150,000 to Rp135,000, which could have been explained in more detail to clarify the discount process. Nevertheless, the representation, problem-solving strategy, and use of mathematical symbols were accurate. Their reasoning was quite good, as demonstrated by the correct final answer of Rp3,105,000, which aligns with the context of the problem.

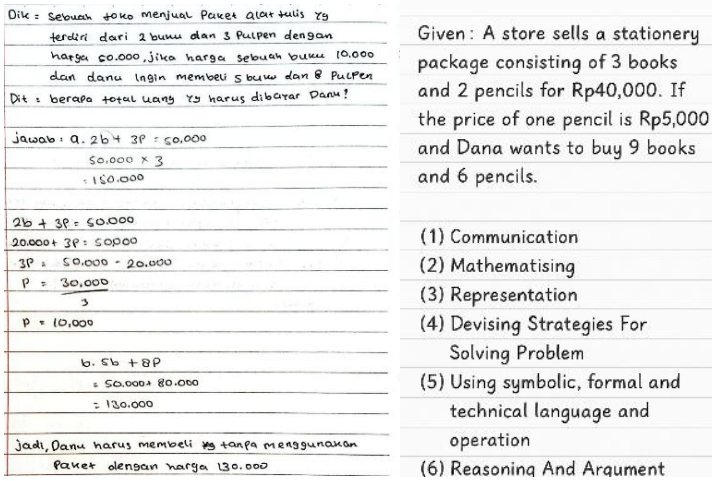


Figure 10. Answer of Auditory Subject Number 5

In the fifth question, the subject only calculated the total purchase of books and pens individually without comparing it to the option of buying a package (see Figure 10). The subject modeled the mathematics based on the information that 2 books and 3 pens cost Rp50,000, then used a substitution strategy to determine that the price of one pen is Rp10,000. Their auditory learning style was evident in their ability to understand and process verbal information sequentially, as well as clearly communicate the problem-solving steps. Communication and mathematization skills at this stage were quite good, with appropriate use of the substitution strategy. However, their reasoning and argumentation were incomplete because the subject did not compare the package option, which was the core of the question. They should have also considered cost efficiency by calculating the package price. As a result, the conclusion provided did not fully answer the problem's request to choose the most economical purchase option.

Based on the interview, it can be concluded that although the subject showed good ability in following verbally taught procedures, their dominant auditory learning style hindered the development of critical thinking skills, written communication, and independent understanding of mathematical concepts. Learning that focused more on imitating the teacher's verbal instructions and lacked practice in explaining arguments or choosing strategies flexibly caused difficulties in solving complex problems and building more abstract symbolic understanding. Therefore, it is important for classroom learning to provide more opportunities for exploration, discussion, and independent practice to improve students' abilities to solve problems and communicate mathematical ideas more independently and critically.

After in-depth interviews regarding the student's learning style and school learning environment, it can be concluded that the subject demonstrated fairly good mathematical literacy skills, particularly in communicating problem information into symbolic mathematical models such as linear equations, performing basic calculations, and applying technical problem-solving strategies. However, weaknesses were observed in their ability to present reasoning

verbally or in writing, use visual representations, explore alternative strategies, and provide logical arguments especially in problems requiring reflective thinking and solution comparison.

These obstacles are closely related to the classroom learning methods that still focus on lectures, emphasize final answers, minimally apply contextual learning and open-ended questions, and an environment that does not support active discussion and independent exploration. Limitations in facilities, time, and rigid teacher approaches further reinforce procedural learning patterns and hinder the comprehensive development of students' critical thinking and mathematical communication skills.

3. Kinesthetic Research Subject

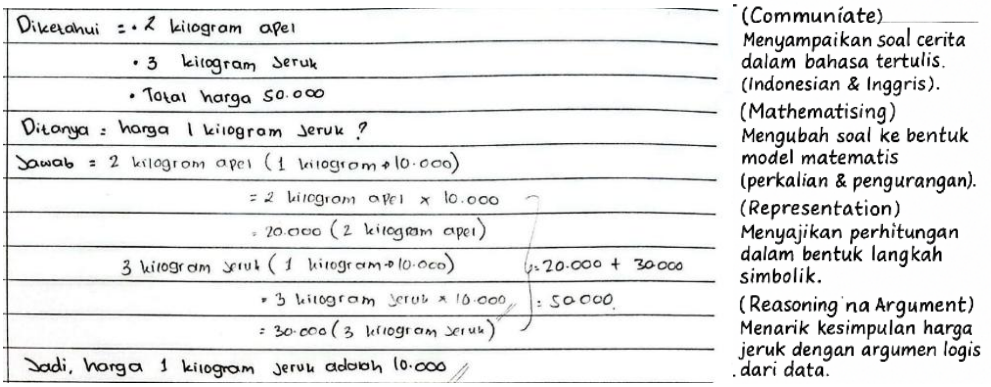


Figure 11. Answer of Kinesthetic Subject Number 1

Figure 11 shows that the student is able to communicate the known and asked information quite clearly. They organize data such as the weight of apples, oranges, and the total price into simple points that facilitate step-by-step processing. Their kinesthetic learning style is evident in their practical and structured approach to solving the problem, as if they are imagining the actual purchasing process. In terms of mathematization, the student demonstrates good ability by converting contextual information into mathematical form. They first calculate the total price of apples (2 kg × Rp10,000), then subtract it from the overall total to find the price of the oranges. The representation used consists of numbers and basic operations written sequentially and logically, reflecting their preference for concrete activities and systematic processes. Their problem-solving strategy is appropriate and efficient, showing an understanding of the relationship between price components. The language and symbols used are still simple but suitable for the level of the problem and reflect the practical thinking style typical of kinesthetic learners. Their reasoning is coherent, and the final conclusion that the price of 1 kg of oranges is Rp10,000 is correctly presented.

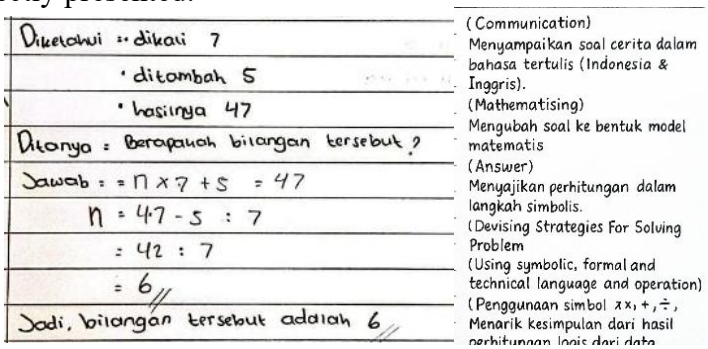


Figure 12. Answer of Kinesthetic Subject Number 2

In the second question, the subject demonstrated the ability to convert verbal information into a simple algebraic expression, namely $n \times 7 + 5 = 47$ (see Figure 12). Their kinesthetic

learning style is reflected in a direct, step-by-step approach, as if they are visualizing the calculation process concretely. Their mathematization skills are very good, shown by modeling the situation into a simple yet accurate mathematical form. The solution process was carried out in the correct sequence subtracting 5 from 47, then dividing by 7 and the problem-solving strategy was systematic. A simple symbolic representation was used functionally, although algebraic symbols appeared only in the initial stage. This aligns with the kinesthetic learning style's emphasis on direct application rather than abstract symbolic manipulation. Mathematical language and simple formal symbols were used appropriately, and their reasoning was logical. The subject correctly concluded that the number is 6.

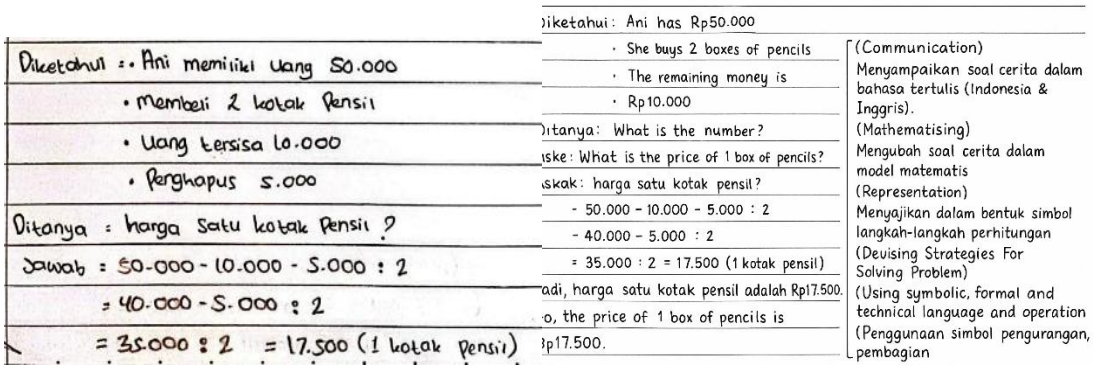


Figure 13. Answer of Kinesthetic Subject Number 3

In the third question, the subject demonstrated accurate calculations and a good understanding of the problem context (see Figure 13). Their kinesthetic learning style is evident in the way they organize information concretely by noting the total money, expenses, and remaining amount, which helps visualize the real situation described in the problem. The mathematization process was carried out step-by-step and systematically, starting with subtraction to find out the amount spent, followed by division to determine the price of one pencil box. The representation used was numerical and easy to understand, aligning with the kinesthetic characteristic of prioritizing clarity and physical involvement or concrete steps. The problem-solving strategy was logical and direct, using an elimination approach with known information to find the unknown variable. Symbolic operations were done correctly according to the rules, and the subject's reasoning demonstrated an understanding of the relationships between the elements in the problem in a functional and structured manner.

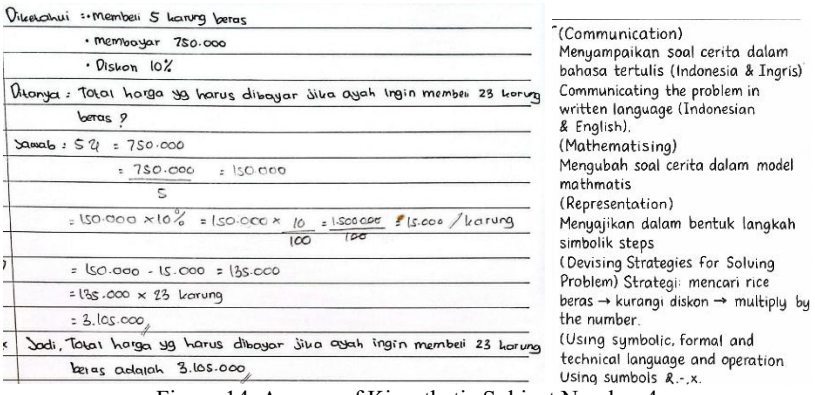


Figure 14. Answer of Kinesthetic Subject Number 4

In the fourth question, the kinesthetic learner demonstrated a good understanding of the concept of discounts and their application in the context of bulk purchases (see Figure 14). They organized the calculation process concretely and sequentially, starting by determining the price of one sack of rice, then calculating a 10% discount for the purchase of 23 sacks, and finally

summing the total cost. Their learning style is reflected in a practical and step-by-step problem-solving strategy, as if breaking down a large problem into smaller, more manageable parts. The representation used consisted of numbers and text arranged logically, although it lacked visual symbols or diagrams. The mathematization process was carried out systematically by converting contextual information into clear, straightforward arithmetic operations. Symbolic language was used appropriately according to the problem's needs, and the reasoning demonstrated was fairly thorough, showing mastery of the discount concept. The subject appeared comfortable with an approach based on real actions, which aligns with the kinesthetic learner's preference for learning through direct practice.

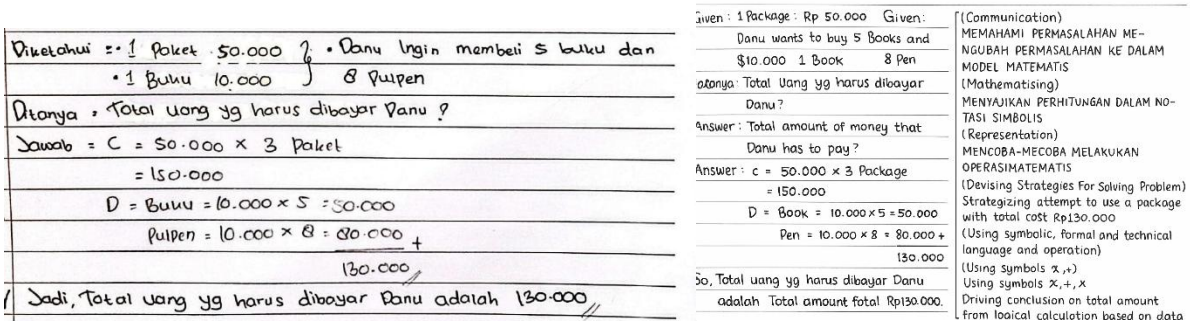


Figure 15. Answer of Kinesthetic Subject Number 5

In the fifth question, the kinesthetic learner was able to solve the problem by directly comparing two purchasing options: buying items individually or as a package. The subject demonstrated practical and exploratory thinking by creating two separate calculation models one for the package purchase and another for the individual purchase (see Figure 15). Their problem-solving strategy reflected a step-by-step and active approach, similar to exploring both choices through calculation simulations. Mathematical communication was presented clearly and systematically, with numerical representations that were easy to follow. Although the subject did not use visual aids like tables or diagrams, they were still able to concretely compare both options. The mathematization process was systematic, indicating a good understanding of the problem context. The use of symbols and formal operations was accurate, and the reasoning showed logical thinking in deciding the most cost-effective option. The kinesthetic learning style was evident from the subject's direct, practical approach that relied on sequential actions to reach the final conclusion.

Based on the interview results, the subject demonstrated fairly good communication skills in systematically writing mathematical information but had difficulties explaining the problem-solving process verbally or in extended explanations, especially when not supported by visual or concrete aids. In terms of mathematization, the subject was able to convert contextual problems into basic mathematical forms but felt confused when required to transform information into equations or face complex conditions, such as comparison problems involving two options. The subject was more comfortable using concrete and visual representations, such as drawings or real objects; however, the lack of facilities to use teaching aids or visual representations in class limited the development of this ability. Their problem-solving strategy tended to rely on a single familiar method without exploring alternatives, and they struggled to compare strategies without direct simulation. Although the subject could understand basic symbols, they had difficulty with more complex symbolic concepts like discounts or proportions, especially without visual explanations. Their reasoning was adequate for simple problems, but they found it challenging to provide logical arguments or comparisons for more complex problems due to a lack of explicit practice with visual aids in class.

After conducting in-depth interviews regarding students' learning styles and their learning environments at school, it can be concluded that students' mathematical literacy abilities show

considerable variation among individuals, particularly in the aspects of communication, mathematization, representation, problem-solving strategies, use of symbols, and reasoning. The subjects were able to present problem-solving steps systematically, model problems into symbolic forms, and effectively use problem-solving strategies and formal notation. The main obstacles stem from teaching methods that focus heavily on lectures, multiple-choice exercises, and an outcome-oriented approach, which cause students to be unaccustomed to expressing their thinking processes in written or verbal form. A lack of discussion, limited use of visual media, and restricted facilities further constrain the development of diverse representations and problem-solving strategies. Additionally, one-way teacher-student interactions and low encouragement for reflective thinking result in students being less practiced in providing logical arguments or thoroughly explaining their thought processes.

3.2 Discussion

Based on the influence of the learning environment at school, the role of the environment is very decisive in how each learning style can develop, especially in the context of mathematical literacy. A learning environment that is not designed to accommodate the diversity of students' learning styles can become a serious obstacle to mastering comprehensive mathematical literacy indicators, such as mathematization, representation, communication, problem-solving strategies, symbolic operations, and reasoning and argumentation. This is in line with the results of Azma (2019) studies which shows how the environment influences the achievement of learning outcomes, even though the research she conducted was not in the field of mathematics. Ozerem & Akkoyunlu (2016) also emphasized that the environment is a factor that plays an important role in determining how students learn, and how students' learning styles can develop in achieving the expected mathematics learning outcomes.

For students with a visual learning style, a learning environment that does not provide visual media such as pictures, graphs, diagrams, or schemes directly impacts their ability to understand and solve math problems. Visual learners show that when there are no visual elements accompanying the problems or explanations, they struggle to identify important information and organize solution strategies. This results in weak skills in creating mathematical models (mathematization), as well as in constructing logical reasoning and arguments. Mathematical communication also becomes less structured because they tend to have difficulty explaining their thought process in writing without visual aids. Meanwhile, visual representation is an important bridge for them to understand relationships between mathematical information. This is because visual representations can help teach students how to discern important connections between variables, quantities, and relational terms in word problems (Jitendra & Woodward, 2019).

The learning implication for visual learners is that teachers should use methods such as visual mapping, infographics, tree diagrams, mind maps, or dynamic geometry software. Presenting problems in visual form and using digital whiteboards or interactive presentation media will greatly help the process of representation and modeling. Teachers are also encouraged to ask students to redraw problems or present solution steps in a visual flow.

Students with an auditory learning style heavily rely on verbal stimuli. A learning environment with minimal oral interaction, such as learning that emphasizes only written assignments or independent reading, causes auditory learners difficulty in fully understanding concepts. Auditory learners tend to follow familiar patterns without understanding the concepts behind the strategies when there is no verbal explanation from the teacher. The mathematical models they create may be incomplete or even misguided. Problem-solving strategies and reasoning also become passive because there is no habit of discussion or verbal expression of opinions.

The learning implication for auditory learners is that teachers need to integrate small group discussions, gradual verbal explanations, story-based learning (storytelling), and audio learning (Sadri & Alvindi, 2025; Hasani & Xhomara, 2022). Methods such as think-pair-share, interactive Q&A, and student verbal presentations are highly recommended to encourage them to explore ideas, construct mathematical arguments, and deepen problem-solving strategies reflectively.

Meanwhile, students with a kinesthetic learning style are greatly affected by a passive learning environment that is too focused on static activities such as reading, note-taking, and working on exercises in notebooks. Without physical activity, concrete tools, or practice-based learning, kinesthetic learners show decreased interest and concentration in mathematics learning. Kinesthetic learners demonstrate that when they are not directly involved in the learning process such as through experiments, educational games, or the use of learning aids they fail to show a systematic and in depth thinking process. Mathematical representation becomes very limited, only in the form of numbers and basic operations, without exploration of visual or manipulative forms. Problem-solving strategies tend to be singular and unreviewed, and mathematical reasoning is minimal due to a lack of active practice. This result is in line with the research results of Rahman & Ahmar (2017), where compared to students with other learning styles, students with kinesthetic learning tend to be weaker in obtaining mathematics learning outcomes.

The learning implication for kinesthetic learners is that teachers can apply project-based learning, mathematical experiments, educational board games (math games), or the use of concrete teaching aids such as fraction blocks, scales, and rulers. Irvine (2019) offers several suggestions for learning methods for students with a kinesthetic learning style, including Quadratic Aerobics, Jigsaw, and Inside/Outside Circle. Additionally, methods such as gallery walks, mathematical role play, and learning station activities can make them physically and cognitively active, thus improving concept understanding and reasoning skills.

Therefore, it can be concluded that a non-adaptive learning environment hinders the development of mathematical literacy indicators in each learning style. When learning is uniform, one-way, and does not allow room for diverse learning approaches, students' abilities to think mathematically in depth in terms of communication, representation, modeling, strategies, and reasoning will not develop optimally. Hence, it is important for teachers and schools to design inclusive and responsive learning environments, by adjusting methods, media, and learning activities to the characteristics of students' learning styles. In this way, all students have equal opportunities to develop comprehensive and meaningful mathematical literacy.

4. Conclusion

This study shows that students' learning styles visual, auditory, and kinesthetic are closely related to their achievement in mathematical literacy, especially when influenced by the learning environment at school. Visual learners excel in numerical representation and written communication but experience difficulties using formal symbols without visual support. Auditory learners understand procedures through verbal explanations but are less capable of constructing arguments and alternative strategies. Kinesthetic learners tend to succeed in solving contextual problems through practical activities but are weak in visual representation and formal reasoning. A uniform and non-adaptive learning environment has been proven to hinder the development of important aspects of mathematical literacy, such as representation, reasoning, and argumentation. Therefore, it is necessary to design learning approaches that are responsive to the diversity of learning styles to support more optimal achievement in mathematical literacy.

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