

Analysis of initial ability factors causing students' low mathematical literacy abilities

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ABSTRACT

Mathematical literacy is a crucial competency at the high school level, but its achievement is often hampered by unmet prior knowledge. This study aims to analyze students' low mathematical literacy by identifying indicators of unmet prior knowledge. Using a qualitative descriptive method, this study involved three eleventh-grade science students at SMAN 2 Kotabumi, selected using a purposive sampling technique based on their low literacy category. Data were collected through two instruments: a three-item mathematical literacy test and a semi-structured interview guide. The results indicate that the inability to mathematical literacy stems from a weak mastery of prerequisite material and misconceptions about basic concepts, particularly decimal numbers. Collectively, the study subjects experienced difficulties in connecting prior knowledge with new knowledge, thus hindering the development of systematic problem-solving strategies. These findings confirm that without strong prior knowledge, students cannot fully implement the mathematical literacy process. The implications of this study indicate the need to strengthen diagnostics of prerequisite material and refine basic concepts before entering more complex material.

1. Introduction

Mathematical literacy skills are one of the important competencies that 21st century students need to have [1]. Mathematical literacy helps individuals understand the function of mathematics in life so they are able to make the right decisions and solve everyday problems [2]. Mathematical literacy is very necessary to face real problems, global change, and improve the quality of human resources [3]. Mathematical literacy skills are also the main aspect assessed in PISA (Programme for International Student Assessment) [4]. PISA is an international student assessment program conducted by the OECD (Organization for Economic Co-operation and Development) to

evaluate students' literacy levels [5]. Mathematical literacy includes the ability to formulate, apply, and interpret mathematical concepts in various life situations, including understanding mathematical concepts, procedures, and tools to solve real-life problems [6], [7], [8], [9].

Based on the results of the PISA survey, the level of mathematical literacy skills of students in Indonesia is still low [10], [11]. In 2022, Indonesia obtained a mathematics score of 366 which is far below the international average of 472, placing Indonesia in 63rd position out of 76 countries [12]. This low mathematical literacy ability is also in line with several previous research findings such as [13] stating that students are only able to solve level 1

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mathematical literacy questions which are classified as low in the PISA assessment, thus indicating that mathematical literacy skills are also low. This is in line with [14], although students are able to solve level 1 mathematical literacy questions by applying systematic steps, students have not been able to interpret and apply representations for level 2 and 3 questions, and have not been able to communicate the results of the answers. In addition, [15] revealed that only one student was able to meet the mathematical literacy ability indicators on the first question and no students were able to meet the indicators on the other questions.

Problems related to low mathematical literacy skills were also encountered at SMAN 2 Kotabumi. Based on the results of a preliminary study using a mathematical literacy test, it was found that students' mathematical literacy skills were still low. The test results showed that only two students were able to solve problems according to the mathematical literacy indicators. Several students were only able to apply formulas procedurally without understanding the concept, four students solved the problems mechanically, five students used inappropriate steps, and seventeen other students only wrote the final answer without a clear solution process. Furthermore, several students were unable to solve mathematical literacy problems due to weak mastery of initial skills, especially the basic concept of percentage which is a prerequisite in solving the given problems.

The low mathematical literacy ability of students cannot be separated from various internal factors. Internal factors are things that come from within the student [4]. Previous research can be categorized into three main focuses. First, non-cognitive factors such as motivation, self-confidence, interest, perception, mathematical disposition, learning independence, metacognition, educational level, kindergarten education, and school discipline [4], [16], [17], [18]. Second, cognitive factors such as intellectual ability, numerical ability, verbal ability. Third, cognitive factors of initial ability. Research that is the basis of this study shows that initial ability is one of the internal factors causing low mathematical literacy ability of students. Mastery of initial ability is an important foundation to facilitate the implementation of learning [19]. Low initial ability causes students to have difficulty in understanding and solving the problems they face [20].

Although several previous studies have examined internal factors contributing to students' low mathematical literacy skills, not all studies have focused on prior knowledge. A preliminary study at

SMAN 2 Kotabumi showed that weak prior knowledge was the cause of students' difficulties in solving mathematical literacy problems. The fundamental difference and novelty of this study lies in its analytical focus, which specifically identifies unmet prior knowledge indicators as the primary mechanism causing low mathematical literacy. While previous studies tended to focus on internal factors in general, this study makes a specific contribution by investigating how gaps in prior knowledge indicators directly trigger students' failures in solving mathematical problems. Therefore, the results of this study are expected to serve as a basis for developing more effective learning strategies based on strengthening students' prior knowledge. Based on this description, the purpose of this study is to analyze students' prior knowledge factors as a cause of low mathematical literacy skills by identifying unmet indicators.

2. Method

2.1 Research Design

This study used a descriptive qualitative method. This method was selected because the research aimed to describe in depth and systematically the phenomena found in the field without giving special treatment to the participants [21]. The study focused on students' low mathematical literacy and examined how unmastered prior knowledge appeared in students' problem-solving processes.

2.2 Participants and Subject Selection

The research participants were selected from 24 grade XI science students at SMAN 2 Kotabumi. After the initial mathematical literacy test, three students in the low category were selected as research subjects using purposive sampling. The three subjects were coded as SR1, SR2, and SR3. Subject selection was based on low mathematical literacy scores and the availability of students to participate in follow-up tests and interviews [22].

$$x = \frac{SPS}{SMI} \times 100 \quad (1)$$

Information:

x = Mathematical Literacy Ability Score

SPS = Student Achievement Score

SMI = Ideal Maximum Score (10)

Table 1

Categories of Students' Mathematical Literacy Abilities

Score Range	Category
Mathematical Literacy Skills	
$x \geq 80$	Tall
$60 \leq x < 80$	Medium
$x < 60$	Low

2.3 Instruments and Data Collection

Based on the mathematical literacy test results, three students in the low category were selected for further analysis. The limited number of subjects was intended to obtain deeper data and to allow the researcher to trace students' thought processes in detail through written work and interviews [20].

Data collection was conducted in stages. After each test, member checking was carried out with students to ensure that their written work accurately represented their thinking and ability. The data collection process involved mathematical literacy tests, follow-up tasks, semi-structured interviews, and documentation of students' written answers.

2.4 Data Analysis

Data analysis followed the Miles and Huberman model, which consists of data reduction, data presentation, and conclusion drawing and verification. In the reduction stage, the researcher selected and organized data related to students' ability to recall, understand, and connect prior knowledge. In the presentation stage, students' written answers and interview excerpts were arranged descriptively. Conclusions were drawn by comparing the patterns found in the test results and interview data.

3. Results and discussion

3.1 Overview of Students' Mathematical Literacy Categories

This study involved 24 students of grade XI IPA of SMAN 2 Kotabumi who were grouped into high, medium, and low mathematical literacy ability categories based on test results. Students with scores below 60 were categorized as having low mathematical literacy ability, and from this group three students were selected as research subjects, namely Low Subject 1 (SR1), Low Subject 2 (SR2), and Low Subject 3 (SR3) as listed in Table 2.

Table 2

Research Subjects

No	Subject Code	Mathematical Literacy Test Score	Category
1	SR1	40	Low
2	SR2	40	Low
3	SR3	30	Low

Data analysis was conducted on each research subject based on the results of the second and third mathematical literacy tests and semi-structured interviews. The test and interview results were then analyzed to identify students' initial ability factors, which include remembering prior knowledge, understanding prior knowledge, and connecting prior knowledge with new knowledge. The following presents the data analysis of each subject's initial ability factors.

3.2. Initial Ability Profile of Subject SR1

3.2.1. Ability to Recall Prior Knowledge

Based on the test results, SR1 demonstrated no ability to recall prior knowledge relevant to the given problem. SR1 was unable to cite prerequisite material or mathematical concepts used in solving the problem. This inability to recall led SR1 to solve the problem simply by operating on the numbers displayed in the problem without a clear conceptual foundation. The following is an excerpt from an interview with SR1 regarding his ability to recall prior knowledge.

P : "The first time you read the question, what material was it? What do you remember right away?"

SR : "The first material, if I'm not mistaken...what is it... remember the lady"

P : "In your opinion, the mathematical concept that used in what concept questions?"

SR : "What concept is it...what is it...I don't remember, sis"

The interview revealed that SR1's inability to solve the problem was due to an inability to recall previous knowledge. SR1 had difficulty recalling prerequisite material from his long-term memory. This condition caused SR1 to experience confusion from the start.

3.2.2. Ability to Understand Prior Knowledge

SR1's inability to recall prior knowledge also affected the ability to understand previous mathematical concepts. SR1 performed calculations without understanding the meaning of the operations used. As a result, the solution did not reflect an appropriate interpretation of the problem context.

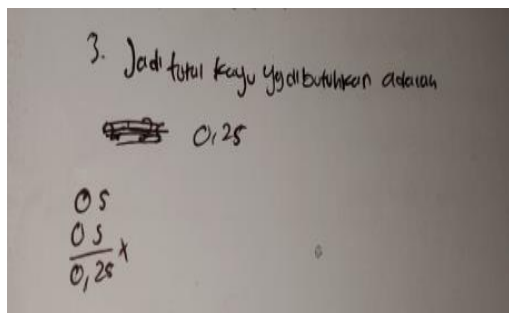


Fig. 1. Student answers

P : "When you work on the questions, use what concept or formula?"

SR : "There's no such thing, miss, just multiply it directly."

P : "Why multiply?"

SR : "You were told to multiply it in the question, ma'am."

The interview indicated that SR1 did not understand the concepts and formulas required to solve the problem. Because the subject did not understand the underlying concepts, the calculations were carried out mechanically and resulted in an inaccurate solution.

3.2.3. Ability to Connect Prior Knowledge with New Knowledge

P : "Is it because you have already encountered the problem? Like this before, it helps you in solving new problems?"

SR : "I don't remember anymore sis"

The analysis showed that SR1 was unable to connect previously learned knowledge with the new problem context. Although SR1 had encountered similar material in earlier grades, the knowledge was not sufficiently retained or organized to support problem solving. This indicates that SR1's low mathematical literacy was closely related to weak initial ability, particularly in recalling, understanding, and connecting prerequisite knowledge.

3.3 Initial Ability Profile of Subject SR 2

3.3.1. Ability to Recall Prior Knowledge

The test results showed that SR2 could recall several procedural steps, such as counting the number of squares and multiplying by the size of each square. However, SR2 could not recall the underlying mathematical concept or explain why the procedure was appropriate. This indicates that SR2's recall was procedural rather than conceptual

P : "When you first read the question, what material was covered? What do you remember right away?"

SR2 : "Eee... I forgot, sis, fill it in as best you

can, sis."

P : "What mathematical concepts do you remember? Can you explain?"

SR2 : "Eee...I forgot too, sis."

The interview showed that SR2 did not remember the material or mathematical concepts needed to solve the problem, although the subject had studied similar material in grade X. This limitation prevented SR2 from using mathematical reasoning to support the solution.

3.3.2. Ability to Understand Prior Knowledge

SR2 demonstrated limited understanding of prior knowledge. The subject understood the steps taken in a mechanical sense but could not explain the mathematical concepts underlying those steps. Thus, SR2's understanding remained procedural and had not developed into conceptual understanding.

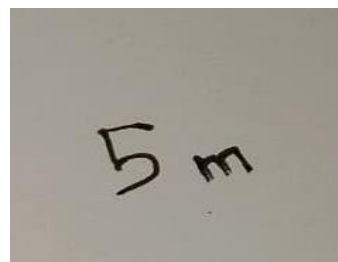


Fig. 2. Student answers

P : "When you work, the concept or formula what do you use?"

SR2 : "Nothing, just multiply it."

P : "Yes, how do you do it?"

SR2 : "Here, sis, the box is here 10multiplied 0,5by the result 5m"

The interview indicated that SR2 understood the need to count but did not build this understanding into an appropriate mathematical concept. SR2 only counted the number of squares on one side and multiplied it by the number shown in the problem without interpreting the meaning of the result.

3.3.3. Ability to Connect Prior Knowledge with New Knowledge

P : "Is there any previous knowledge that help you solve this problem?"

SR2 : "Hmm...it seems...it seems there aren't any, sis."

SR2 had difficulty representing problem information in an appropriate mathematical model. The subject's prior knowledge could not be integrated with the new context, which made the problem-solving process incomplete. The interview further confirmed that SR2 was unable to connect previously learned knowledge with new knowledge when solving the problem.

3.4 Initial Ability Profile of Subject SR3

3.4.1. Ability to Recall Prior Knowledge

SR3 demonstrated limitations in recalling prior knowledge. This limitation directly affected the mathematical procedures used because SR3 tended to calculate without using appropriate formulas or procedures. The inability to recall prerequisite material became an obstacle from the beginning of the problem-solving process.

P : "When you first read the question, the material What do you immediately remember?"

SR3 : "I don't remember, sis."

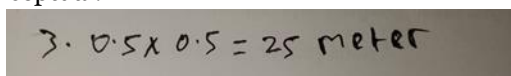
P : "When working on problems, mathematical concepts what do you use?"

SR3 : "I don't remember anymore, sis."

The interview showed that SR3 did not remember the material or concepts needed to solve the problem, although similar material had been studied in grade X. This condition affected the accuracy and structure of the mathematical work produced by the subject.

3.4.2. Ability to Understand Prior Knowledge

SR3's difficulty in understanding prior knowledge was evident in the mastery of basic decimal concepts. The subject made inaccurate calculations and could not explain the mathematical meaning of the operation used. This shows that the problem was not only procedural but also conceptual.



$$3.0.5 \times 0.5 = 25 \text{ meter}$$

Fig. 3. Student Answers

P : "When you work on a problem, a concept or What formula is used?"

SR3 : "Nothing, just multiply it."

P : "Can you explain why the result is 25 meters?"

SR3 : "That's right, ma'am, 0 times 0 is 0, then 5 times 0 is 0. 5 times 5 is 25, so the result is 25 meters"

The interview confirmed that SR3 did not understand the concept of decimal multiplication. This lack of understanding caused SR3 to produce an incorrect answer and prevented the subject from interpreting the problem appropriately.

3.4.2. Ability to Connect Prior Knowledge with New Knowledge

SR3 found it difficult to understand the problem because the subject felt that the material had never been

studied before. After further questioning, the subject realized that similar material had been encountered previously, but the knowledge could not be used to solve the new problem.

P : "When you work, what knowledge do you have? then what you have can help in do the questions?"

SR3 : "I don't remember, bro, that's all"

The interview showed that SR3 was unable to connect previous knowledge with new knowledge. SR3's low mathematical literacy was therefore caused by weak initial ability. Without adequate mastery of prerequisite concepts, SR3 could not formulate, apply, or interpret mathematical ideas in the given context.

3.5 Discussion

Based on the analysis of the three low-literacy subjects, the main obstacle to mathematical literacy was rooted in weak initial mathematical ability [23-28]. In the indicator of recalling prior knowledge, SR1 and SR3 were unable to identify relevant concepts, while SR2 could only remember procedural steps. This condition shows that students' prior knowledge was not sufficiently organized to support mathematical literacy tasks. Unlike SR1 and SR3, SR2 was able to recall some prior knowledge, but the recall was limited to procedural aspects. SR2 could carry out calculation steps mechanically based on previous learning experiences but could not explain the mathematical meaning behind the steps [29-33]. This distinction indicates that procedural memory alone is not enough to support mathematical literacy.

A deeper conceptual gap appeared in the indicator of understanding prior knowledge, particularly in interpreting mathematical operations [34], [35]. Ideally, students with good mathematical literacy are able to provide meaning to every operation used. However, the subjects in this study tended to perform calculations without understanding the concepts, which resulted in inaccurate solutions and weak interpretation of the problem context [36].

The obstacles experienced by the three subjects can be explained through Piaget's cognitive perspective on assimilation and accommodation. Assimilation did not occur effectively because the subjects lacked sufficient prior knowledge schemas. At the same time, accommodation was limited because students were unable to adjust or reorganize their existing knowledge to fit the new problem situation [37-38]. Thus, difficulties in recalling and understanding prior knowledge became the starting point for students' inability to achieve higher levels of mathematical literacy. Although this study provides an in-depth description of the role of prior knowledge, its findings are limited to a small number of subjects. Therefore, further studies with broader participants and varied contexts are needed [39].

4. Conclusion

Based on the findings, low mathematical literacy was closely related to insufficient mastery of prior knowledge. Students had difficulty completing the stages of mathematical literacy, particularly formulating, applying, and interpreting mathematical ideas. These difficulties appeared in their inability to recall prerequisite concepts, understand the meaning of procedures, and connect previous knowledge with new problem contexts.

Although this study provides an in-depth analysis, its findings are limited because the research involved only three students from one school. Therefore, the results cannot be generalized broadly. Practically, the findings suggest that teachers need to diagnose students' prerequisite knowledge before introducing new material and provide reinforcement activities that connect past knowledge with new concepts.

CRedit authorship contribution statement

Sepina Lestiani: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft.
Ratih Handayani: Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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