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Mathematical Literacy Problems in Exponential Material Based on Vocational Students' Self-Regulated Learning

Yolanda Pratiwi[1*], Kusno[2], Fitrianto Eko Subekti[3]
[1-3] Master of Mathematics Education Study Program, University of Muhammadiyah Purwokerto
Dukuhwaluh, Kecamatan Kembaran, Kabupaten Banyumas, Jawa Tengah, Indonesia

e-mail: * yollanda18y.p@gmail.com
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*corresponding author**

Abstract

This study explores the mathematical literacy challenges faced by students at SMK Negeri 2 Bawang, Banjarnegara Regency, in learning exponential concepts, which are analyzed through the lens of the Independent Regular Learning (SRL) level. Using a descriptive qualitative approach, this study involved three student subjects representing high, medium, and low SRL categories. Data was collected through mathematical literacy tests, SRL questionnaires, and interviews. The research findings indicate that variations in SRL levels significantly influence the types of difficulties students experience. Students with low SRL face various challenges, including understanding the context of the problem, building mathematical models, and interpreting results. Students with moderate SRL demonstrate the ability to understand problems but have difficulty selecting appropriate problem-solving strategies and accurately representing contextual situations in mathematical form.

Meanwhile, students with high SRL exhibit systematic and reflective thinking but encounter obstacles connecting mathematical outcomes to real-life contexts. These findings underscore the role of SRL in shaping students' mathematical literacy challenges. Further research is recommended to investigate additional internal factors that influence mathematical literacy in order to develop more adaptive and targeted teaching strategies.

Keywords: Exponential; Learning Challenges; Mathematical Literacy; Self-Regulated Learning; Vocational School Students

1. Introduction

In the era of globalization and the Industrial Revolution 4.0, mathematics education is not only expected to be able to convey basic concept, but also develop students' mathematical literacy skills. Mathematical literacy is a vital competency that reflects an individual's ability to formulate, apply, and interpret mathematics in a variety of real-life contexts (Apriliska et al., 2025). This ability is closely related to 21st-century competencies such as logical reasoning, representation, connections, communication, and mathematical problem-solving (Putri et al., 2022). Therefore, strengthening mathematical literacy through relevant, contextual, and future-oriented learning approaches serves as an essential foundation for preparing students to face complex challenges in the modern world.

Students' mathematical literacy goes beyond procedural problem-solving and includes more complex processes. This includes how students interpret the meaning of a given context, transform information into a mathematical model, interpret the results, and reflect on the problem-solving process. Many students have difficulty identifying relevant information, choosing appropriate solution strategies, and connecting calculation results to real-world contexts (Cardoso Espinosa, 2021). Burkhardt et al. (2024) emphasize that mathematics education should enable students to understand the relevance of mathematics in real-life situations, rather than simply memorizing procedures or formulas. Students' inability to connect mathematical concepts to real worls contexts highlights conceptual and contextual problems in mathematical literacy. This is in line with the perspective of Cardoso Espinosa's (2021) perspective, who emphasized that mathematical literacy serves as a foundation for developing quantitative thinking skills, including the ability to represent information through graphs, tables, and mathematical models that are important for decision-making.

Based on PISA's framework, mathematical literacy is defined as an individual's ability to apply, interpret, and engage with mathematics in various real-life contexts. This competency is vital not only for academic performance but also for making well-informed decisions in social, economic, and professional environments. As highlighted by Indonesian media, the official release of the 2022 PISA results took place on December 5, 2023. The report revealed that Indonesia ranked 68th, with scores of 379 in mathematics, 398 in science, and 371 in reading. These results indicate that Indonesian students have consistently struggled with mathematical literacy over the years. Furthermore, the OECD (2023) noted that Indonesia's average mathematics score declined from 379 in 2018 to around 368 in 2022, marking one of the lowest scores recorded since 2003. Only 18% of Indonesian students reached at least Level 2 proficiency, compared to 69% across OECD countries, and almost none achieved the highest proficiency levels (Level 5–6) in mathematics.

Most previous research on mathematical literacy has focused more on improving students' skills through various learning models without comprehensively addressing the root causes of the difficulties or challenges students face in learning mathematics. For example, Maysarah et al. (2023) examined the effectiveness of the Project-Based Learning (PjBL) model in improving mathematical literacy, showing significant improvements in students' abilities to identify facts, formulate problems, and interpret solutions. However, their studies focused solely on improving literacy outcomes without investigating the underlying factors contributing to students' difficulties. Similarly, Aritonang and Safitri (2021) explored the impact of blended learning during the COVID-19 pandemic, reporting a 30% increase in students' mathematical literacy compared to a 2.44% increase using traditional methods. While these studies highlight effective strategies for literacy improvement, they do not investigate the underlying challenges students experience.

Research by Anggraeni et al. (2020) identifies that learning difficulties in mathematics stem from both internal and external factors. Internal factors include students' negative attitudes towards mathematics, low interest in learning, weak motivation, and limited sensory abilities. On the other hand, external factors include the less than optimal role of teachers, inadequate learning facilities, and minimal support from family and society. Among these factors, one of the internal factors relevant to mathematical literacy is self-regulated learning (SRL), which plays an important role in shaping students' ability to manage and optimize their learning process independently.

Supporting this, a systematic literature review by Apriliska et al. (2025) identified three dominant internal factors affecting mathematical literacy in Indonesian students: learning motivation, self-regulated learning, and prior mathematical ability. Among these, learning motivation was the most influential, followed closely by SRL and initial mathematical competence. Students with low motivation often solve problems procedurally without analyzing context, while those with high motivation demonstrate deeper engagement and better literacy outcomes. Furthermore, students with strong SRL skills were more likely to meet higher-level literacy criteria, including the ability to reason abstractly, model mathematically, and solve non-routine problems. Although prior mathematical ability played a lesser role, it still served as a foundation for higher-level literacy development.

SRL is the ability of students to manage their learning process independently, including planning, monitoring, and reflecting on learning activities. Students with low SRL often have difficulty with learning strategies, time management, and evaluating their mistakes (Afrizal, 2023). As a result, they face challenges in understanding the context of problems, building appropriate mathematical models, and drawing accurate conclusions, all of which are important components of mathematical literacy. In contrast, students with strong SRL can plan solutions to math problems, monitor their understanding as they solve them, identify difficulties, adjust strategies if initial plans fail, and evaluate whether their solutions align with the problem context. SRL provides a framework for students to control their mathematics learning through goal setting, problem-solving strategies, reflection, and continuous improvement (Afrizal, 2023; Indriani & Wahyuni, 2022).

Mathematical literacy and self-regulated learning (SRL) are interrelated constructs that significantly contribute to students' capacity for effective mathematical reasoning and problem-solving. According to Gabriel et al. (2020), SRL which encompasses motivation, metacognition, and emotional regulation plays a vital role in improving students' mathematical literacy. Their findings indicate that perseverance, as a core aspect of SRL, enhances students' self-efficacy, which in turn has a strong positive effect on mathematical literacy outcomes. Similarly, Wang and Sperling (2020) reported that students with higher academic achievement tend to use a broader array of learning strategies and apply SRL techniques more frequently than their lower-achieving peers, highlighting the positive association between SRL and academic performance in mathematics.

Mathematical literacy involves not only applying but also interpreting mathematical concepts in real-world situations, while SRL encompasses goal setting, monitoring progress, and employing strategic approaches to learning (Sumarni et al., 2025). Without adequate SRL skills, students may face difficulties in solving mathematical problems, reflecting on their learning, or adapting strategies when encountering challenges. Research highlights that students with strong SRL tend to exhibit better problem-solving performance and resilience in mathematical tasks (Sumarni et al., 2025).

Findings by Yanti et al. (2022) also strengthens this interconnection, showing that students' mathematical literacy performance in solving higher-order thinking problems on matrix material is closely related to their abilities in communicating, mathematizing, and applying strategies. Their study found that students with low literacy levels not only struggled with symbolic representation but also in contextualizing mathematical problems, indicating the need for deeper cognitive and metacognitive engagement elements fostered through self-regulated learning (SRL). In line with this, Sapulete et al. (2023) highlight that students' problem-solving abilities in mathematics are influenced by their levels of SRL and self-efficacy. Although their study revealed that the quantitative contribution of SRL to problem solving was limited, it highlighted qualitative gaps in students' learning behavior, such as lack of planning, weak persistence, and use of surface-level strategies. This pattern of behavior reflects the core challenges in mathematical literacy as described in previous literature.

The concept of exponentials poses a significant challenge for vocational high school students because of its abstract yet practical application. In mathematical literacy assignments, students must not only understand formulas but also apply exponential concepts to real-world scenarios, such as population growth or asset depreciation.

This study identifies a critical gap in previous studies, most of which have focused on improving mathematical literacy and have not explored the root causes of students' difficulties in understanding mathematics, especially from the perspective of learning processes and SRL abilities. To address this gap, this study examines the mathematical literacy challenges faced by vocational high Scholle students with varying levels of SRL, especially in exponential material. Therefore, this study seeks to uncover the appropriate and fundamental issues, which form the basis for designing contextual and personalized learning intervention.

2. Method

This study employs a qualitative approach with a descriptive design. This methodology was chosen because it allows researchers to explore in depth students' experiences, strategies, and thought processes in solving mathematical literacy problems related to exponential material. Descriptive design is used to describe students' mathematical literacy systematically and accurately, particularly regarding differences in self-regulated learning (SRL) when solving exponential problems.

The population of this study consisted of all 36 students in Class X TE 5 at SMK Negeri 2 Bawang, Banjarnegara Regency, who had studied exponential material as part of the mathematics curriculum. The sample was selected using a purposive sampling technique, considering variations in students' levels of self-regulated learning.

This study used a purposive sampling method to select three representative samples categorized based on the level of Self-Regulated Learning (SRL): high (T1), medium (S1), and low (R1). One student from each category was selected as a representative sample, following the method used in the study by Rizqa et al. (2023) to examine differences in mathematical literacy abilities across SRL levels. This approach facilitates an in-depth qualitative case study, enabling a comprehensive understanding of each SRL category. However, the limited sample size restricts the generalizability of the findings to the broader population, making the results exploratory in nature and highlighting the need for further research with larger sample sizes to validate the findings.

Data collection for this study involved various instruments and techniques. The primary instrument was a mathematical literacy test, validated by the supervisor, designed to evaluate problem-solving abilities and the application of mathematical concepts using an approach grounded in mathematical literacy. The test questions, centered on exponential material, were developed to address three key literacy indicators based on OECD (2019) guidelines: (1) Formulate, which involves translating real-world problems into mathematical models; (2) Employ, which refers to applying mathematical concepts to solve problems; and (3) Interpret, which requires reinterpreting mathematical results, solutions, or conclusions in the context of the problem.

The Self-Regulated Learning (SRL) questionnaire was administered to assess students' levels of learning independence and to categorize them into high, medium, and low SRL groups. This instrument was adapted from validated questionnaires, particularly from Azwar as cited in Afrizal (2023). The SRL questionnaire utilizes a Likert scale ranging from 1 to 4, comprising both positive and negative statements. The scoring structure for the SRL scale items is detailed in the table below.

Both the mathematical literacy test and the SRL questionnaire were validated by experts or adapted from previously validated instruments, such as those developed by Azwar (Afrizal, 2023). This process ensures the credibility and reliability of the data collected in this study. The scoring arrangement for the SRL scale items is outlined in the following Table 1.

Table 1. SRL Scale Item Scoring Structure

Answer Categories	Positive	Negative
Strongly Disagree (STS)	1	4
Disagree (TS)	2	3
Agree (S)	3	2
Strongly Agree (SS)	4	1

Source: Adapted from Azwar (Afrizal, 2023)

The following is an example of a question related to exponents:

A workshop produces certain components of a Motorcycle. On the first day (day 0), the workshop successfully produces 10 components. It turns out that every day the number of components produced increases exponentially with a growth factor a (with a>1).

The exponential function is expressed as:
$f(x) = P0 \bullet \alpha^x$ where:
- F (x) = number of components produced on day x
- α = daily growth factor (where a>1)
- x = number of days after the first day.

Question:
a) Explain how you would construct a mathematical model to describe the growth of component production in this workshop? Explain why α >1?
b) Suppose α = 1.2 (meaning a 20% increase every day). Use the formula $f(x) = 10 \bullet (12)^x$ to calculate how many components are produced on the 5th day. Show your calculation steps clearly.

Based on your calculation results, draw a graph of the growth in production volume over 7 days and explain the growth pattern seen based on the graph.

Figure 1. Example Questions.

To categorize students' levels of Self-Regulated Learning (SRL), positive and negative scores obtained from the SRL questionnaire are analyzed based on predetermined intervals. The range of positive and negative scores is calculated using the maximum and minimum data values. The difference between these scores is the main indicator for determining a student's SRL category. SRL levels are classified into three categories: high, medium, and low, as outlined by Wijayanto, et al (2024). Next, the data collection technique is through In-depth Interviews. These interviews aim to explore, in detail, students' problem-solving strategies, obstacles encountered, and thought processes. This technique has been demonstrated to be effective in studies examining mathematical literacy and Self-Regulated Learning (Afrizal, 2023).

Data analysis was conducted using a qualitative descriptive approach, adhering to systematic stages to ensure comprehensive and meaningful findings. The qualitative analysis process involved three key steps: data reduction, data presentation, and conclusion drawing. These steps, as outlined by Qomaruddin and Sa'diyah (2024), were implemented using four identified analysis techniques to provide a thorough understanding of the research phenomenon. The first stage, data reduction, involved filtering and grouping data collected from questionnaires, tests, and interviews based on their relevance to mathematical literacy indicators and students' SRL levels. Reduced data were then presented systematically in a narrative format, highlighting problematic patterns.

Subsequently, the researcher interpreted the data by connecting the findings to mathematical literacy theory. This step identified the core challenges students face in their mathematical literacy processes on exponential material and formulated recommendations to address these issues. Finally, conclusion drawing was performed through a triangulation process, comparing data obtained from various collection methods (tests and interviews) to ensure reliability and validity.

Additionally, the principles for developing mathematical literacy proposed by Cardoso Espinosa (2021) served as a foundation for this study, particularly emphasizing the integration of technology and innovative learning strategies to enhance students' mathematical literacy. Below are the questions used to assess students' mathematical literacy skills on exponential material.

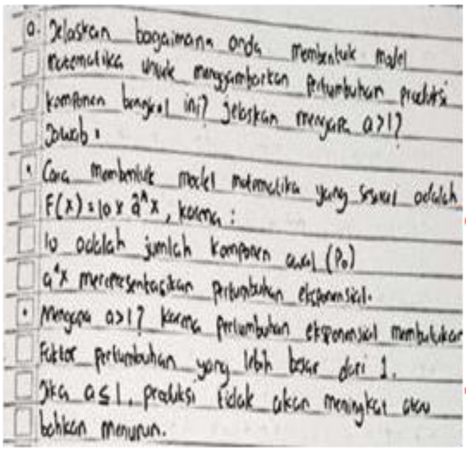
3. Results and Discussion

3.1 Results

This study aims to describe the forms of students' mathematical literacy problems based on high, medium, and low self-regulated learning (SRL) categories. Each student category is analyzed using the results of mathematical literacy tests and in-depth interviews, specifically focusing on the indicators of formulating, applying, and interpreting within the context of exponential material.

3.1.1 Students with high self-regulated learning (T1)

The following are the result of the students answers with high self regulated learning.


a. Jelaskan bagaimana anda membentuk model matematika untuk menggambarkan pertumbuhan produksi komponen bengkel ini? Jelaskan mengapa a>1?
Jawab:
• Cara membentuk model matematika yang sesuai adalah F(x) = 10 × a^x, karena:
10 adalah jumlah komponen awal (P₀)
a^x merepresentasikan pertumbuhan eksponensial.
• Mengapa a>1? karena pertumbuhan eksponensial membutuhkan faktor pertumbuhan yang lebih besar dari 1.
Jika a≤1, produksi tidak akan meningkat atau bahkan menurun.

Formula, namely formulating real problems mathematically

a. Explain how you would construct a mathematical model to describe the growth in production of this workshop component? Explain why $a > 1$?

Answer:

- The way to form a suitable mathematics model is $F(x) = 10 \times a^x$, because:
  10 is initial number komponen
  a^x presentation exponential growth.
- Why $a > 1$? Because exponential growth requires greater growth factor than 1.
  If $a \leq 1$, production will not increase or even decrease.

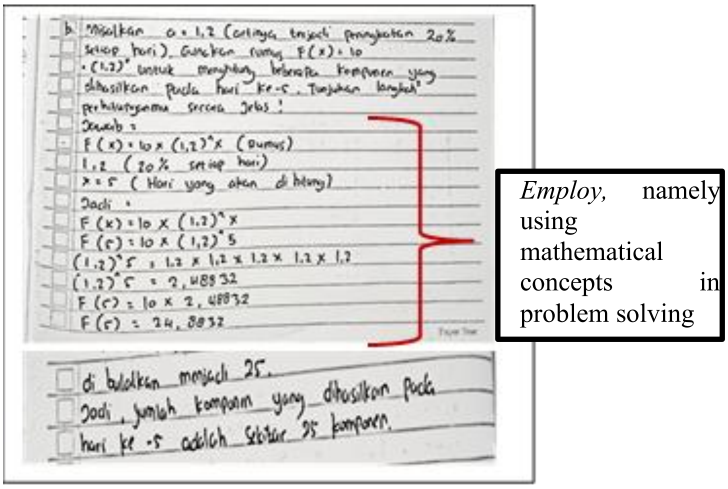
Figure 2. Subject T1's Answer.

Based on Figure 2, the mathematical literacy process of students with high Self Regulated Learning, students do not experience problems in formulating problems. This is shown through the preparation of accurate mathematical models and clear reasons for choosing exponential models, such as the growth factor a>1 which is relevant to the context of the problem. In terms of applying the concept (employ), students also do not show any obstacles in writing exponential formulas to calculate the number of components on the 5th day in detail and systematically, including in the process of calculating numbers.

In the interpreting and communicating indicator, students have no difficulty in describing the growth graph of the number of components accurately and explaining the exponential growth pattern descriptively. However, the problem that appears is that students do not create the right scale in visualizing the graph so that the graph points look rather linear even though they are exponential.

Based on the interview results, student T1 also did not show any problems in solving exponential problems. The interview results showed that student T1 had a systematic approach in solving exponential problems. At the stage of formulating the problem, students stated that they had no difficulty in understanding the context of the problem and could identify important elements, such as the daily growth factor (a) and its relationship to changes in the number of component production each day. Students also showed how to integrate the information in the problem with relevant mathematical concepts, and explained the relationship between the parameter a>1 and exponential growth in a real context without any difficulty. The following is a transcript of the interview with T1.

Researcher : *"Tell me what was the first thing you did when you read the question?"*
Subject : *"I read the question carefully to understand what was asked. I noticed that the question asked to calculate the amount of production on a certain day using the exponential formula. Then, I noted down important information such as the initial value of production and the daily growth factor, ma'am."*



b. If $a = 1,2$ (meaning an increase every day). Use formula $F(x) = 10.(1,2)^x$ to calculate some of the components produced on the 5th day. Show the steps of the calculation clearly!
Answer:
$F(x) = 10 \times (1,2)^x$ (rumus)
1,2 (20% every day)
$x = 5$ (day to be counted)
So,
$F(x) = 10 \times (1,2)^x$
$F(5) = 10 \times (1,2)^5$
$(1,2)^5 = 1,2 \times 1,2 \times 1,2 \times 1,2 \times 1,2$
$(1,2)^5 = 24,8832$
Rounded up to 25
The number of components produced on the 5th day is approximately 25 components.

Figure 3. Subject T1's Answer.

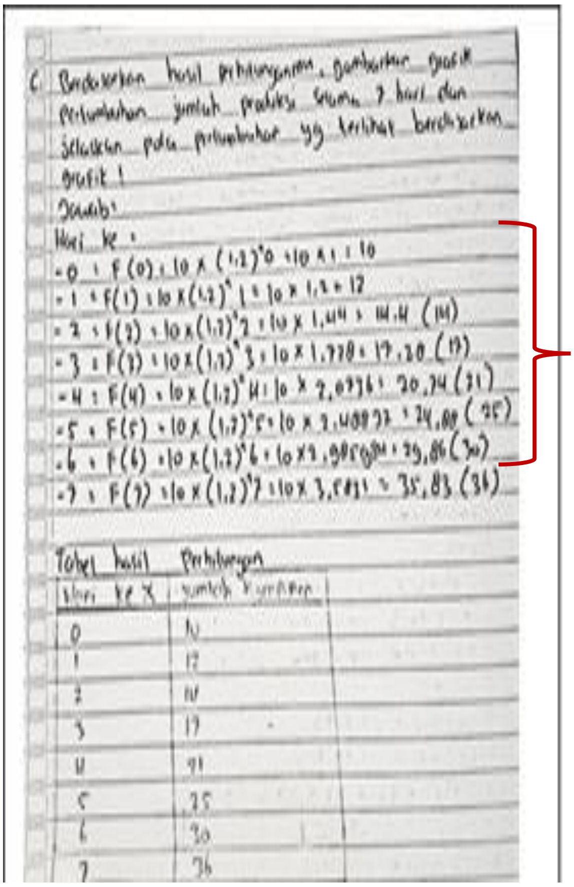
Based on Figure 3, in applying the conceptual aspect (employ), students do not experience difficulties in applying the exponential growth formula $f(x)=P0 \cdot a^x$, students can calculate the production value on the 5th day carefully, and ensure the accuracy of the results through rechecking. Students can also visualize data well through clear graphs, and explain changes in value quantitatively and qualitatively. This is shown during the interview.

Researcher : *"Once you understand the problem, what steps do you take to solve it?"*
Subject : *"I start by plugging the known values into the formula. For example, on day 5, I replace x with 5 and calculate the result. After that, I also draw a graph based on the calculation results to visualize the production growth."*

Based on Figured 4, in the aspect of interpreting and communicating (interpret), students are able to provide comprehensive explanations related to the calculation results, such as how the value of a affects the growth of production volume and the relevance of exponential patterns to the real situation presented in the problem.

Based on Figure 5, students not only conclude that production increases steadily, but are also able to connect the calculation results with graphs, showing in-depth analysis of growth patterns. This is demonstrated during the interview.

Researcher : *"Do you have difficulty calculating or drawing graphs? How do you overcome it?"*
Subject : *"Not really, ma'am. If I have any difficulties, I usually double-check the results with a calculator and see if the results match. For graphs, I make sure that the scale and values I use match the data in question."*



Interpret, namely reinterpreting mathematical results, solutions, or conclusions into the context of the problem.

c. Based on the calculations, draw a graph of the growth in production volume over 7 days and explain the growth seen based on the graph

Answer:

Day to

$0 = f(0) = 10 \times (1{,}2)^0 = 10 \times 1 = 10$

$1 = f(1) = 10 \times (1{,}2)^1 = 10 \times 1{,}2 = 12$

$2 = f(2) = 10 \times (1{,}2)^2 = 10 \times 1{,}44 = 14{,}4(14)$

$3 = f(3) = 10 \times (1{,}2)^3 = 10 \times 1{,}728 = 17{,}28\ (17)$

$4 = f(4) = 10 \times (1{,}2)^4 = 10 \times 2{,}0736 = 20{,}736\ (21)$

$5 = f(5) = 10 \times (1{,}2)^5 = 10 \times 2{,}48832 = 24{,}8832\ (25)$

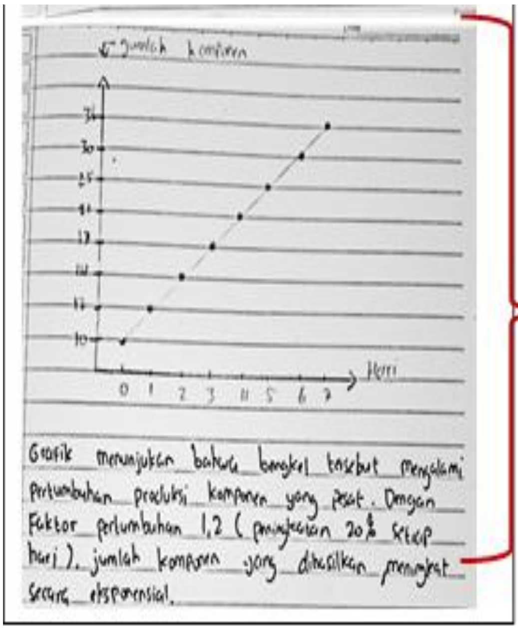
$6 = f(6) = 10 \times (1{,}2)^6 = 10 \times 2{,}985984 = 29{,}85984\ (30)$

$7 = f(7) = 10 \times (1{,}2)^7 = 10 \times 3{,}5831808 = 35{,}831808\ (36)$

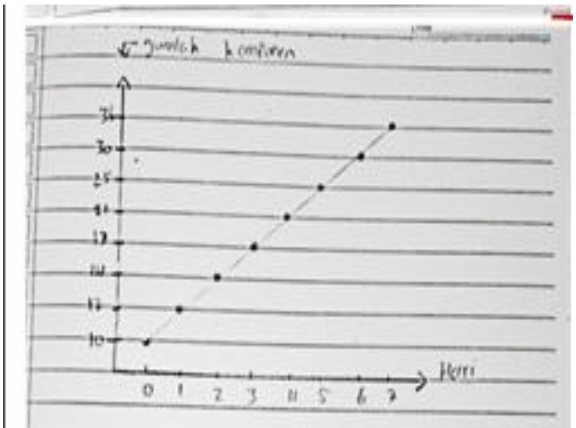
Calculation result table

Day to x	Number of component
0	10
1	12
2	14
3	17
4	21
5	25
6	30
7	36

Figure 4. Subject T1's Answer.



Interpret, namely reinterpretin g mathematica l conclusions into the context of the Probem.



The graph shows that the workshop is experiencing rapid growth in component production. With a growth factor of 1,2 (a 20% increase each day), the number of components produced is increasing exponentially.

Figure 5. Subject T1's Answer.

From the interviews and the results of the students' answers, it was identified that students with high Self-Regulated Learning did not have difficulty with mathematical literacy in answering exponential problems. However, the findings in this study, students with high Self-Regulated Learning had the main problem located at the graphic representation stage, especially in the aspects of scale accuracy and visual interpretation of mathematical models. Students were able to use effective learning strategies, including reflection on the steps taken and the ability to elaborate mathematical concepts independently. This shows that students not only master procedural skills, but also understand concepts and can apply them in various contexts meaningfully.

3.1.2 Students with moderate self-regulated learning (S1)

The following are the result of the students answers with moderate self regulated learning.

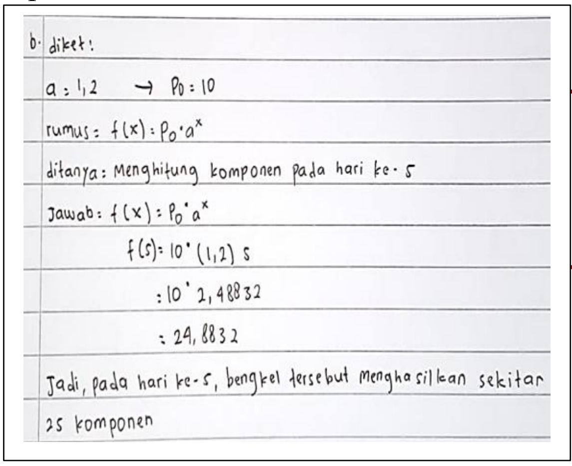
1\. a. (a) adalah faktor pertumbuhan harian, dimana (a>1) menunjukkan bahwa jumlah komponen yang dihasilkan meningkat setiap harinya. Jika (a=1), maka tidak ada pertumbuhan, dan jika (a<1), maka jumlah komponen yang dihasilkan akan menurun. Oleh karena itu, untuk menunjukkan pertumbuhan, kita memerlukan (a) lebih besar dari 1

Formula, namely formulating real problems mathematically

(a) is the daily growth factor, where $(a > 1)$ indicates that the number of components produced increase everyday. If $(a = 1)$, then there is no growth, and if $(a < 1)$, then the number of components produced will decrease. Therefore, to indicate growth, we need (a) to be greater than 1.

Figure 6. Subject S1's Answer.

Based on Figure 6, this explanation is not deeply connected to the mathematical model $f(x)=P0 \cdot a^x$ where in the question students are asked to explain how to form a mathematical model to describe the growth of component production in the workshop, but students do not explain it, so students do not fully utilize the information in the question to build a stronger mathematical representation



b. diket:
a : 1,2 → P_0 : 10
rumus : $f(x) : P_0 \cdot a^x$
ditanya : Menghitung komponen pada hari ke-5
Jawab : $f(x) : P_0 \cdot a^x$
$f(5) : 10 \cdot (1,2)\ 5$
$: 10 \cdot 2,48832$
$: 24,8832$
Jadi, pada hari ke-5, bengkel tersebut menghasilkan sekitar 25 komponen

Employ, use concepts in problem solving

b. Known
$1,2 \rightarrow P_0 = 10$
Formula = $f(x) = P_0 . a^x$
Questions: count components on day 5
Answer:
$f(x) = P_0 . a^x$
$= 10 . (2,48832)$
$= 24,8832$
So, on the 5th day, the workshop produced about 25 components.

Figure 7. Subject S1's Answer.

Based on Figure 7, in the aspect of applying the concept (employ), students can write down the concept and do not experience difficulties in using the given formula correctly, students can calculate the value of f(5)=24, and describe the exponential growth graph correctly. However, students seem to only focus on the calculation procedure without providing validation of the results or explaining how the numbers are relevant in the context of the problem where the problem requires students to show the calculation steps clearly. When applying the concept of exponents, students are able to use relevant mathematical formulas, although the steps are sometimes less systematic. This can be seen from the students' answers during the interview.

Researcher : "Once you understand the problem, how do you determine the steps to solve it?"

Subject : "I immediately used the formula f(x)=P0·ax that has been taught. But, sometimes I forget to check whether the numbers are correct or not, so I recalculate several times to make sure."

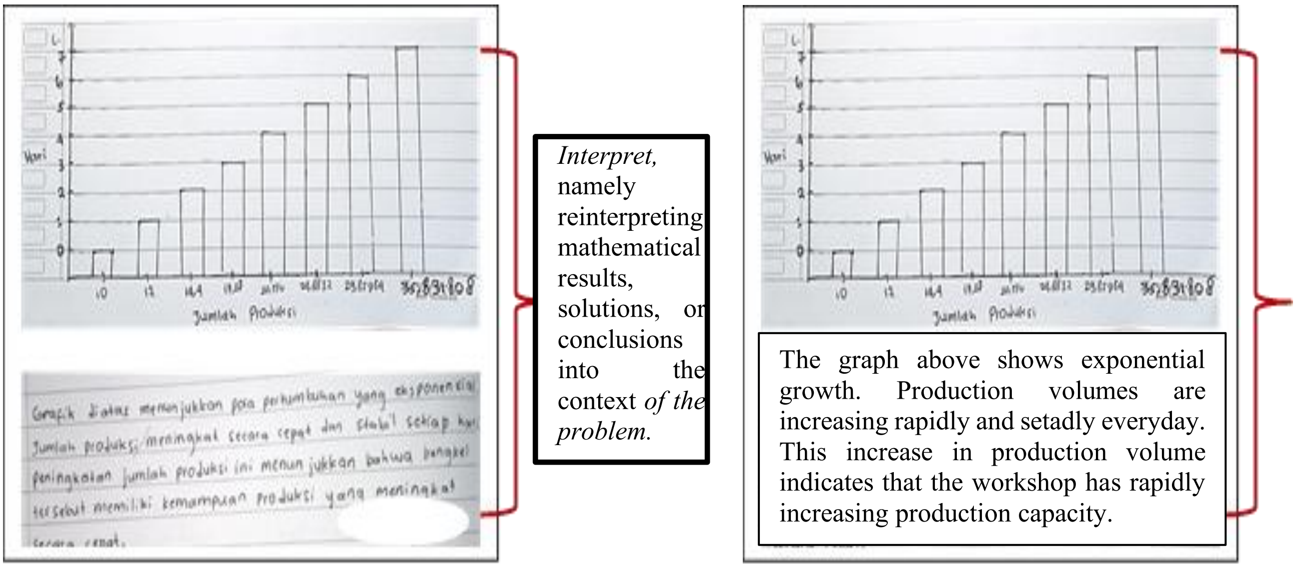


Figure 8. Subject S1's Answer.

Based on Figure 8, in the aspect of interpreting and communicating (interpret), students successfully concluded that the amount of production on the 5th day was around 25 components and described the graph with a bar chart as a stable exponential growth pattern. However, even though students have shown the correct calculations and presentation of data in the form of graphs, problems arise in the aspect of visual interpretation and reinterpretation of mathematical results into the context of the problem.

Students choose to use a bar chart to represent the amount of production over seven days, but the graph presented does not fully reflect the characteristics of exponential growth accurately. This is evident from the use of a horizontal axis that does not follow the convention of a time-to- production growth bar chart, the horizontal axis should be filled by day 1, day 2, and so on and the vertical axis filled with production value. In addition, the graph is depicted with a scale range that appears inappropriate and disproportionate to the student's calculation data, as a result the exponential growth visual becomes dull, or even looks like it is rising slowly and steadily when in fact it should be increasing faster.

Then the student's written interpretation states that the growth occurs "fast and steady every day," which is less in accordance with the true exponential nature, where growth occurs increasingly quickly and is not linear. This indicates that although the student understands that there is an increase in production, he has not been fully able to critically interpret the exponential pattern or relate the graph and calculations back to the context of the problem as a whole. Thus, the main problem lies in the student's limitations in communicating mathematical information into accurate visual representations and contextual narratives.

Students also showed particular difficulties when entering values into formulas, as expressed in their statements.

Subject : *"Sometimes I'm confused about what position x represents, so I try it out until the result is right."*

At the stage of interpreting and communicating results, students can explain part of the process but not in depth.

Researcher : *"What about the graph you made? What were your steps in drawing it?"*

Subject : *"I made a graph based on the calculation results only. However, I only plotted a few important points, such as day 1 and day 5. I didn't pay much attention to the overall shape of the graph."*

Researcher : "From the graph you created, what can you conclude about the exponential growth pattern?"
Subject : "The graph shows a steady increase in growth, but I don't really understand why it is like that. Maybe because the growth factor is more than 1."

Students also showed that the process of evaluating their work was not yet fully optimal. When the researcher asked,

Researcher : "How do you evaluate the results of your work? Do you feel confident with your answers?"
Subject : "I usually see if the end result makes sense, but sometimes I forget to check the process in detail. If I have more time, I like to ask a friend to make sure."

Overall, the main problems experienced by students with moderate Self-Regulated Learning include difficulties in understanding the meaning of context, inaccuracy and imprecision in constructing graphs, and limitations in explaining mathematical relationships descriptively. Although students already have the awareness to solve problems independently, suboptimal self- regulation has an impact on their ability to integrate mathematical understanding, strategies, and communication as a whole. This reinforces that mathematical literacy does not only rely on procedural knowledge, but requires integrated reflective, representative, and communicative thinking skills.

3.1.3 Students with Low Self Regulated Learning (R1)

The following are the result of the students answers with low self regulated learning,

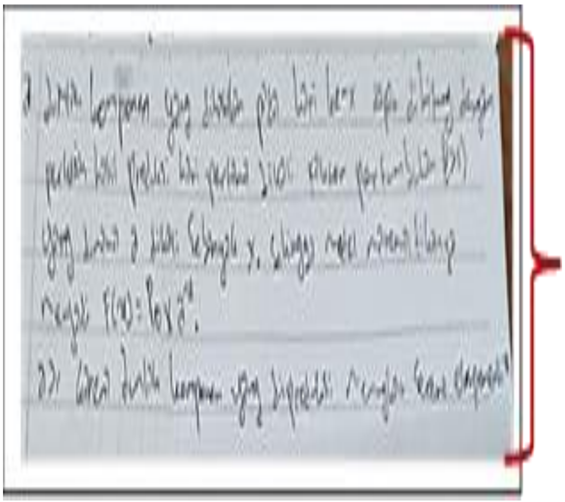
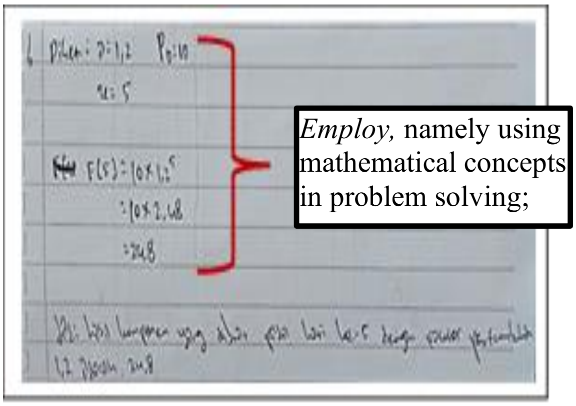


Figure 9. Subject R1's Answer.

Based on Figure 9, the results of students' work that are included in the low Self-Regulated Learning category, there are a number of problems in mathematical literacy skills. In the formula aspect, students have indeed mentioned basic parameters such as the initial value of production ($P0$=10) and growth factors (a=1,2), and tried to determine the number of components on the 5th day. However, students were unable to formulate a mathematical model in a complete and contextual manner. Model(x) = 10·(1,2)^X used without any explanation regarding the reasons for its selection or its relevance to the context of the motorcycle component production problem. This shows that students have not been able to relate real situations to mathematical models in a meaningful way.

Based on interviews with students, it appears that they still need more time to understand the context of the problem and identify important information such as initial values and growth factors. This indicates that students need a more systematic strategy in understanding the problem. The following is a transcript of the interview between the researcher and subject R1.

Researcher : "What was the first thing you did when you saw the question?"
Subject : "I read the questions first, but sometimes I'm confused about which information is important. So I try to find the initial numbers and growth factors, but it takes time to be sure."



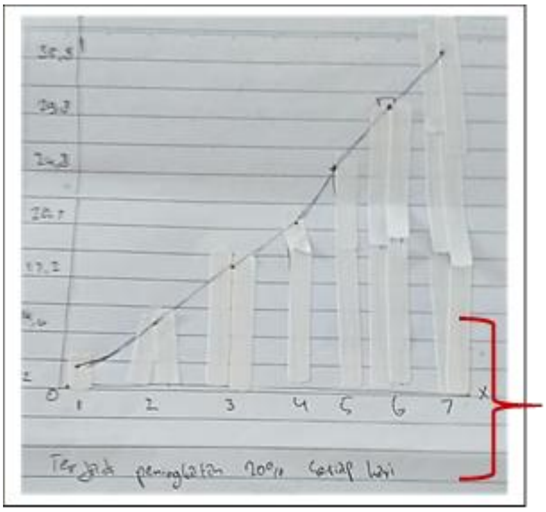
Known:
$a = 1{,}2 \quad P_0 = 10$
$x = 5$
$f(5) = 10 \times 1{,}2^5$
$= 10 \times 2{,}48$
$= 24{,}8$
So, the result of the component made on the 5th day with growth factor of 1,2 is 24,8.

Figure 10. Subject R1's Answer.

Based on Figure 10, in the aspect of applying the concept (employ), students use the given exponential formula and calculate the value of f(5) = 24. Students also appear to have a fairly good procedural understanding in calculating the value of the exponential function from day 1 to day 7. However, striking problems are seen in the application of the concept to the form of a graph. The graph drawn appears disproportionate and inaccurate, both in terms of scale and placement of data points. As a result, the graph that should show exponential growth actually appears almost linear. Furthermore, although students write that there is an increase of "20% every day", which corresponds to the growth factor value of 1.2, there is no further explanation regarding how this information reflects the overall exponential growth pattern. This indicates limitations in understanding the concept of growth ratio and connecting it visually and verbally.

In applying the exponential concept, students are able to use the appropriate formula but are not yet fully systematic in the solution steps.

Researcher : "After understanding the problem, how do you determine the steps to solve it?"
Subject : "I immediately used the formula f(x) = P₀.aX that was taught, but sometimes I forget to check whether the numbers I use are correct. So I recalculate to make sure."



Interpret, namely reinterpreting mathematical results, solutions, or conclusions into the context of the problem.

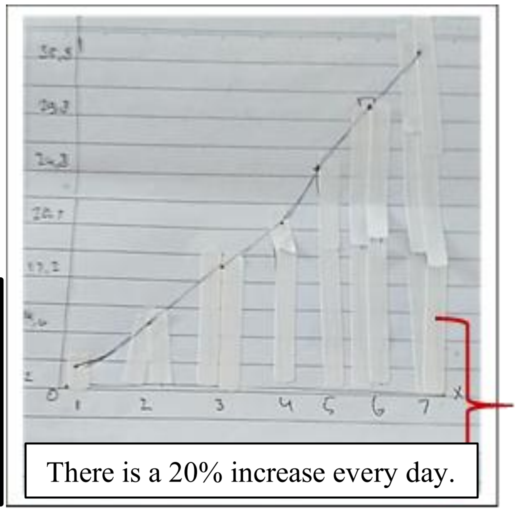


Figure 11. Subject R1's Answer.

Based on Figure 11, in the aspect of interpreting and communicating results (interpret), students do not provide meaningful explanations of the mathematical results obtained. The written explanation is limited to one short sentence that is not yet able to express the relationship between mathematical results and the real context in the problem. There is no attempt to explain the impact of growth on production activities in the workshop, or how the growth pattern can be used for planning purposes. In addition, there is no reflection on the suitability of the graph with the calculation or the possibility of inaccuracy in the visualization.

In addition, students experienced confusion in placing the value of x in the formula, which caused them to try several approaches before finding the appropriate answer.

In the aspect of interpreting and communicating results, students can explain most of the process but not in depth.

Researcher : "What about the graph you made? What are the steps in drawing it?"
Subject : "I plot important points, like day 1 and day 5, but don't pay much attention to the overall shape of the graph."

Researcher : "From the graph you created, what can you conclude about the exponential growth pattern?"
Subject : "The graph keeps going up, but I don't really understand why it looks like that. Maybe because the growth factor is more than 1."

Students also indicated that the process of evaluating their work was not yet fully optimal

Researcher : "How do you evaluate your answers? Are you confident with the results you get?", the student answered, "I usually see if the final result makes sense, but rarely check the process in detail. If I have more time, I like to ask my friends to make sure"

Overall, the problem of mathematical literacy of students with low SRL levels lies not only in the procedural aspect, but more in the inability to understand, represent, and communicate mathematical concepts contextually. Table 2 presents a comparison for student with high, medium and low Self regulated Learning,

Table 2. Comparison of Mathematical Literacy Across High, Medium, and Low SRL Levels

Aspect	High SRL (T1)	Moderate SRL (S1)	Low SRL (R1)
Problem Formulation	No difficulties; able to formulate mathematical models with clear reasoning.	Able to formulate problems but less optimal in explaining the mathematical model in depth.	Identifies basic parameters but fails to relate real situations to relevant mathematical models.
Concept Application	Systematic in calculating, visualizing data, and explaining changes quantitatively and qualitatively.	Uses the correct formula but lacks systematic steps and does not validate the results.	Uses basic formulas but struggles with solution steps, leading to often inaccurate results.
Result Interpretation	Explains results in-depth and relevant to the context but lacks accuracy in graphical representation.	Able to conclude results but inaccurately represents exponential patterns in graphs.	Limited explanation and fails to connect mathematical results to real-world contexts meaningfully.

Aspect	High SRL (T1)	Moderate SRL (S1)	Low SRL (R1)
Interview Conclusions	Demonstrates reflective and independent learning strategies; step evaluation is well executed.	Aware of weaknesses but learning strategies remain partial, and result evaluation is suboptimal.	Passive learning strategies, less reflective, and often reliant on others for result validation.
Main Issues	Inaccuracy in graph scaling and mathematical visual interpretation.	Difficulty in understanding problem context and selecting appropriate solution strategies.	Poor understanding of problem context, disproportionate graph representation, and limited reflection and communication.

3.2 Discussion

Based on the analysis of the research data and the comparison in the Table 2, it was found that students in the high self-regulated learning (SRL) category did not experience significant difficulties in understanding the context of the questions, formulating problems, determining solution strategies, and logically interpreting the results in ways relevant to real life. This indicates that students with strong self-regulation skills tend to manage their learning process independently, from planning and implementation to evaluating outcomes, which contributes to a better mathematical literacy process. This finding aligns with the theory put forward by Zimmerman (2002), which defines SRL as comprising metacognitive, motivational, and strategic behavioral processes that interact to support academic success. In the context of mathematics education, these abilities positively impact students' capacity to understand concepts and apply them in real-world situations.

Similarly, Aripin et al. (2024) found that students with high SRL were capable of accurately and carefully solving PISA-based contextual problems. These students demonstrated a clear understanding, unit conversion skills, and logical interpretations. They also applied effective problem-solving strategies, such as identifying irrelevant information and selecting optimal solutions in real-life scenarios like smartphone storage. In the same vein, Kholifasari et al. (2020) showed that students with high learning independence performed well in mathematizing and representing real-world problems, although some still faced challenges in reasoning and argumentation.

These results are corroborated by Tuti et al. (2025), who found that students with high SRL levels reached level 5 in mathematical literacy competency. These students were able to identify relevant information, apply appropriate mathematical procedures, and reflect critically on their solutions within various geometric contexts. Their high level of self-regulation enabled them to carry out multi-step reasoning and represent real-world problems mathematically with accuracy and coherence, further demonstrating the integral link between SRL and mathematical literacy.

On the other hand, students with moderate SRL exhibited several obstacles, particularly in understanding contextual problems and selecting appropriate solution strategies. Their thinking processes tended to be fragmented, and their ability to monitor and reflect on their solution steps was still limited. Santika and Khotimah (2023) observed that students frequently struggled at the problem formulation and interpretation stages when solving PISA-style problems. These difficulties were linked to limited understanding of contextual information and an inability to choose suitable strategies. This is consistent with Aripin et al. (2024), who noted that students with moderate SRL could understand problem structures and propose relevant strategies but often made careless computational errors or misinterpreted results. Likewise, Kholifasari et al. (2020) emphasized that students with moderate learning independence often struggle particularly in devising problem-solving strategies, especially in algebraic contexts.

The study by Tuti et al. (2025) also confirmed that students with moderate SRL were typically only able to achieve level 4 in mathematical literacy. While they demonstrated a basic grasp of the problem and could apply known procedures, their reflections and strategic flexibility were limited. These students often failed to complete problems that required synthesis, comparison, or abstract reasoning, suggesting that further support is needed to help them transition from routine to complex mathematical tasks.

Similar findings were reported by Mahajani et al. (2024) and Erli Rahmayanti et al. (2024), who concluded that students' mathematical literacy skills are significantly influenced by their level of learning independence. Students with low independence could generally identify problems and draw simple conclusions but had difficulty developing appropriate solution strategies. In contrast, highly independent learners showed mastery across all mathematical literacy indicators, including solving higher-order thinking skills (HOTS) problems in contextual settings. These findings suggest that mathematical literacy is not solely dependent on cognitive ability, but also heavily influenced by affective and metacognitive factors such as learning independence and self-regulation. In the context of 21st-century education, these competencies are crucial for helping students meaningfully understand and apply mathematical concepts to real-life situations (Mahajani et al., 2024; Rahmayanti et al., 2024).

Students in the low SRL category demonstrated difficulties at nearly every stage of the mathematical literacy process, from understanding the problem context and formulating the problem to interpreting the results. These students tended to be passive, lacked initiative in learning, and were less reflective about their mistakes. This finding aligns with research by Nurvicalesti (2021), who stated that students with low SRL levels exhibit limited mastery of mathematical literacy indicators. They often struggle to solve verbal problems and fail to grasp the purpose of the questions. Additionally, low-SRL students are generally unable to find or utilize relevant learning resources, which further impairs their ability to effectively solve context-based problems.

Kholifasari et al. (2020) further noted that students with low learning independence often encounter difficulties in mathematizing and tend to lack operational accuracy, conceptual understanding, and logical reasoning. Aripin et al. (2024) similarly found that although some low-SRL students could identify relevant information, they often failed to convert it into appropriate mathematical representations or complete logical steps in contextual problem-solving tasks.

Supporting these observations, the study by Tuti et al. (2025) revealed that students with low SRL were only able to reach level 3 in mathematical literacy. Their performance indicated a reliance on routine procedures and a struggle with abstract representation and complex reasoning. These students had difficulty transferring knowledge to new contexts and often left tasks incomplete, signaling a need for explicit scaffolding and motivation-focused interventions in mathematics instruction.

These findings reinforce the idea that the ability to organize, monitor, and evaluate the learning process is a key factor in enhancing students' mathematical literacy. Students with strong SRL skills are better equipped to independently understand problem contexts, identify important information, and apply suitable strategies in solving mathematical problems, including those involving exponential or geometric concepts that require deep understanding and real-life relevance. Students who display high levels of SRL are more perseverant and persistent in their learning than students with low levels of SRL (Gabriel et al., 2020).

Based on these insights, the researchers recommend implementing instructional strategies that emphasize the development of self-regulated learning. One effective method is the use of problem-based learning (PBL), as supported by the findings of Friska et al. (2024). In addition to the PBL approach, students' mathematical literacy can be further enhanced through the integration of interactive learning media and the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. According to Aripin et al. (2024), incorporating technology-based learning tools, such as interactive visual applications and contextual simulations, can help students develop a more concrete understanding of mathematical concepts in real-life settings.

This interdisciplinary approach not only supports the growth of students' learning independence but also contributes directly to improving their mathematical literacy. With structured, real-world problem-based learning supported by strong SRL, students will be better equipped to understand, process, and communicate mathematical information across various contexts, thereby solving problems more effectively and meaningfully.

4. Conclusion

This study confirms that Self-Regulated Learning (SRL) plays a significant role in helping vocational high school students overcome various challenges in mathematical literacy, particularly in solving problems related to exponential material. Mathematical literacy encompasses the ability to formulate, apply, and interpret mathematical concepts in various real-world contexts. Students with high SRL abilities demonstrate better independence in organizing learning strategies, understanding concepts deeply, and evaluating as well as reflecting on their learning processes. These skills make them better prepared to address problems requiring advanced mathematical thinking. The results showed that students with high SRL were significantly more effective in solving exponential problems compared to those with low SRL.

However, this study has limitations, particularly the absence of direct interventions designed to systematically enhance students' SRL abilities. This presents an important opportunity for further research to explore effective strategies for supporting SRL development while simultaneously improving students' mathematical literacy. Examples include the use of interactive digital tools or reflective approaches that encourage students to understand the connections between mathematical concepts and their real-life applications. Furthermore, a more in-depth analysis is required to identify specific SRL indicators that contribute to improving students' abilities to formulate, apply, and interpret mathematical concepts.

Based on these findings, educators in vocational schools are encouraged to implement learning strategies that actively strengthen SRL while supporting the development of mathematical literacy. Context-based learning or the use of interactive media can help students connect mathematical concepts with real-world problems. Additionally, further research is needed to explore other factors influencing SRL development and their impact on mathematical literacy skills in a more comprehensive manner.

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