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Mathematical Literacy in Statistics Following Differentiated Learning Using Outdoor Modeling Mathematics

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ABSTRACT

Indonesia's students continue to show low literacy and numeracy performance. In PISA, Indonesia ranked 68th out of 81 countries with a mathematics score of 379. This study describes eighth-grade students' mathematical literacy in statistics after differentiated learning implemented through the Outdoor Modeling Mathematics (OMM) model. The study was conducted at SMPN 5 Pelepat Ilir in May 2025 using a qualitative descriptive design. Six students were selected purposively from a class of 33 based on learning readiness: high (S1KBT, S2KBT), moderate (S1KBS, S2KBS), and low (S1KBR, S2KBR). Data were collected through a mathematical literacy test and semi-structured interviews and were analyzed using three literacy processes: formulating situations mathematically, employing mathematical concepts, facts, procedures, and reasoning, and interpreting and evaluating mathematical results. The findings show that all six students met the three processes, indicating a high level of mathematical literacy after the intervention.

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Introduction

Mathematics, as a discipline with broad applications, plays an essential role in everyday life. People use mathematics in commercial transactions, construction, measurement, time estimation, and population calculations. Mathematics is often regarded as a foundational science that supports many fields of knowledge (Hayati & Jannah, 2024). According to Permendiknas No. 22, as cited in Masitoh & Prabawanto (2016), mathematics education aims to enable students to (1) understand concepts, (2) use reasoning, (3) solve problems, (4) communicate ideas, and (5) appreciate the usefulness of mathematics in life. These five competencies align closely with the core elements of mathematical literacy that students need to develop in order to participate effectively in modern society.

Mathematical literacy is critical because it enables students to interpret graphs, tables, and diagrams, and to apply mathematical knowledge in real-life situations (Saputra et al., 2021). In this context, mathematical literacy refers to the ability to process information from a problem, select relevant concepts, and use mathematics across different contexts. Individuals with strong mathematical literacy can analyze and address daily challenges, such as managing a personal budget, measuring recipe ingredients, or interpreting statistical information in news reports. Therefore, developing mathematical literacy strengthens technical competence while also improving the capacity to deal with real-world problems.

However, Indonesian students' mathematical performance remains relatively low. The PISA 2022 results show that Indonesia ranked 68th out of 81 participating countries, with a mathematics score of 379, indicating performance in the low category (Lusiana et al., 2025). Hayati & Jannah (2024) also argue that strong motivation toward mathematical literacy supports students in solving problems, which can reduce the perception that mathematics is inherently difficult. In line with the PISA framework, mathematical literacy in school learning can be described through three key processes: (1) formulating real-world problems into mathematical form, (2) employing mathematical concepts, facts, procedures, and reasoning to solve problems, and (3) interpreting and evaluating mathematical results in relation to the original context.

Although mathematical literacy is relevant across most mathematics topics, this study focuses on statistics. Based on classroom observations and interviews with eighth-grade mathematics teachers at SMPN 5 Pelepat Ilir, students' mathematical literacy remains relatively low. This condition was also evident in students' responses to test questions administered by the researcher. An analysis of one student's work indicates that the student did not meet the indicators of mathematical literacy. For the first indicator, the student did not identify the known information and immediately substituted quantities into a formula. For the second indicator, the student was able to obtain a correct result but did not explicitly state the mathematical model or procedure. For the third indicator, the student did not provide a conclusion or interpret the result in the problem context, indicating weaknesses in interpreting, applying, and evaluating mathematical outcomes.

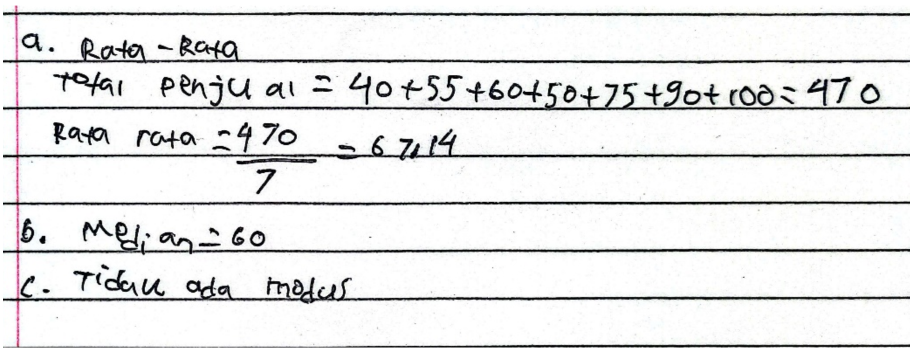

Figure 1. Evidence from a student response

Strengthening students' mathematical literacy is essential because low literacy can hinder learning in several ways. Students may struggle to understand concepts deeply, rely on memorizing formulas without meaning, and experience difficulties in solving contextual problems. This condition may also lower students' confidence and motivation, reduce academic performance, and constrain the development of critical thinking. Weak mathematical literacy often relates to factors involving teachers, students, and instructional approaches. At SMPN 5 Pelepat Ilir, teachers frequently use conventional instruction that positions the teacher as the main source of knowledge. As a result, students tend to remain passive and find it difficult to connect mathematical ideas with real-world contexts. Interviews with teachers also suggested that one-way communication and limited contextualization reduce students' opportunities to construct meaning from mathematical tasks.

To address this issue, differentiated learning offers a student-centered strategy that adapts instruction to students' interests, learning profiles, and readiness, in line with the "Merdeka Belajar" policy (Herwina, 2021). This approach can increase student engagement and support the development of mathematical literacy. One instructional model that aligns with differentiated learning is Outdoor Modeling Mathematics, which integrates real-world contexts through structured outdoor learning activities. In this study, Outdoor Modeling Mathematics is positioned as an approach to implement differentiated learning based on students' learning readiness. Outdoor learning refers to learning activities conducted outside the classroom, where the surrounding environment becomes an integral component of the learning process (Sofnidar et al., 2017). Hikmah et al. (2020) describe Outdoor Modeling Mathematics as an outdoor-based approach that can support students' development across physical, social, emotional, cultural, and intellectual dimensions. Syawardhan & Noer (2022) also suggest that outdoor learning can be an alternative for mathematics instruction that increases student activity and supports mathematical literacy. Consistently, Mauliska et al. (2024) reported a meaningful and positive relationship between classroom learning, outdoor activities, and students' interest in mathematics.

In practice, the Outdoor Modeling Mathematics model brings students to locations outside the classroom where teachers facilitate observation, active participation, measurement, estimation, and calculation. According to Sofnidar et al. (2017), the model consists of six phases: (1) orienting students to contextual outdoor problems through discussion, (2) developing real models and collecting data based on students' understanding, (3) preparing a solution plan using mathematical models, (4) conducting experiments according to the model, (5) presenting results through data processing and interpretation, and (6) reflecting collaboratively for validation and feedback. This study extends a previous study that implemented differentiated learning through the Outdoor Modeling Mathematics model with eighth-grade students. The earlier study focused on implementation procedures and general outcomes, but it did not examine students' mathematical literacy in depth. Therefore, this study aims to re-examine the existing data more intensively to provide a more comprehensive description of students' mathematical literacy in statistics after the intervention, with particular attention to variations in learning readiness.

Method

Settings

This study used a qualitative descriptive design. The study did not manipulate variables or introduce experimental treatment; instead, it described the phenomenon as it occurred in the natural setting. The findings are presented narratively to provide a clear and detailed account of field conditions. Qualitative research enables an in-depth examination of a phenomenon by analyzing cases individually, where the characteristics of each case may vary. Its purpose is to develop a comprehensive understanding of a particular situation through rich descriptions within a natural context (Haryoko et al., 2020). Therefore, a qualitative descriptive approach allows researchers to portray the participants' conditions based on observable facts and specific characteristics, expressed in written and verbal descriptions.

This study is a follow-up analysis of a previous study that implemented differentiated learning through the Outdoor Modeling Mathematics (OMM) model with eighth-grade students. The present study analyzed data from the earlier implementation. No new classroom intervention was conducted. Instead, this follow-up focused on a deeper exploration of students' mathematical literacy after the differentiated learning program using OMM. The study describes students' mathematical literacy in statistics after differentiated learning based on learning readiness using OMM. The description was derived from students' written test responses and supported by semi-structured interviews, which were used to clarify and deepen evidence obtained from the written work.

Samples and Data Sources

The data in this study represent students' mathematical literacy achievement after differentiated learning based on learning readiness using OMM in statistics. The dataset included: (1) learning readiness scores derived from an initial competency test, (2) students' responses to a mathematical literacy test in statistics, (3) written-answer descriptions coded using mathematical literacy indicators, and (4) interview data from selected participants. In qualitative research, primary data typically consist of words and actions, supported by documents as additional sources (Haryoko et al., 2020). The researcher serves as the main instrument and engages directly in the field through observation and interviews. The participants were eighth-grade students at SMPN 5 Pelepat Ilir. Participants were selected purposively based on recommendations from the mathematics teacher, who was familiar with students' characteristics and could support selection aligned with the research aims. Supporting instruments included: observation sheets documenting teacher and student activities during the differentiated learning implementation using OMM, Mathematical Initial Ability (KAM) scores from the initial competency test, mathematical literacy test sheets to assess students' ability to solve statistical problems, and interview guidelines for exploring students' mathematical literacy in depth.

Instruments

Mathematical Initial Ability (KAM)

KAM was obtained from initial competency test scores administered prior to the learning implementation. KAM provides an overview of students' prior mathematical ability and is used to group students into high, medium, and low categories (Saragih, 2011, as cited in Rifa'i, 2021). The categorization follows in Table 1

Table 1. Categorization Mathematical Initial Ability

Criteria	Category
$KAM \geq \bar{X} + s$	High
$\bar{X} - s < KAM < \bar{X} + s$	Medium
$KAM \leq \bar{X} - s$	Low

Source: Rifa'i (2021)
Notes: $\bar{X}$ = mean score; s = standard deviation.

In this study, KAM grouping served as the basis for learning-readiness categories used in differentiated learning (high, medium, low).

Observation Sheets

Observation sheets were used to document the implementation of teacher and student activities during differentiated learning based on learning readiness using OMM in statistics.

Observations were conducted during the learning process to capture the dynamics of classroom interaction and student engagement.

Mathematical Literacy Test

The main instrument was a mathematical literacy test developed based on relevant competencies and indicators. The test consisted of essay items on statistics for eighth-grade junior high school students. The essay format allowed the researcher to examine students' solution processes in detail and assess mathematical literacy comprehensively. The test was evaluated using the following mathematical literacy indicators (OECD, 2023) in Table 2

Table 2. Mathematical Literacy Indicators

Mathematical Literacy Indicators	Descriptors
Formulating situations mathematically	Simplifying a situation so it becomes mathematically analyzable, identifying relevant aspects, and connecting the problem to appropriate concepts, facts, or procedures.
Employing mathematical concepts, facts, procedures, and reasoning	Developing and applying solution strategies; using facts, rules, algorithms, and structures; reflecting on arguments; and explaining and justifying results.
Interpreting and evaluating mathematical results	Interpreting results in the real-world context and evaluating the results relative to the original problem.

Interview Guidelines

Semi-structured interviews were used to explore students' reasoning beyond what appeared in written responses. The interview guide focused on what students did, why they did it, and how they interpreted their work. The guide remained flexible, allowing follow-up questions based on participant responses while still adhering to the established outline. As described by Haryoko et al. (2020), semi-structured interviews include core questions while allowing the interviewer to adjust the sequence and add probing questions as needed. Interviews were transcribed verbatim and analyzed alongside written test data. Prior to use, the interview guide was reviewed by expert lecturers to support instrument validity and data appropriateness.

Procedures

Data collection is a critical stage in research because the primary aim is to obtain credible and high-quality data. In this study, data collection involved administering a mathematical literacy test aligned with three literacy processes: (1) formulating situations mathematically, (2) employing mathematical concepts, facts, procedures, and reasoning, and (3) interpreting and evaluating mathematical results (OECD, 2023). After the test, selected participants participated in semi-structured interviews to deepen understanding of their mathematical literacy performance. Interviews were conducted in a comfortable setting and were guided by students' prior written responses. All interviews were recorded and transcribed.

Overall, data collection followed these steps: (1) The researcher reviewed initial competency test results to identify students' prior mathematical ability (KAM); (2) Students were categorized into KAM groups (high, medium, low) as the basis for learning readiness in differentiated learning; (3) Teaching and learning activities were conducted using the OMM model; (4) Students completed the mathematical literacy test in statistics; (5) The researcher reviewed and coded students' written responses using the literacy indicators; (6) The researcher consulted the mathematics teacher to select interview participants; (7) Interviews were conducted with selected participants on a different day; and (8) Data credibility was strengthened through triangulation of techniques and sources. Technique triangulation compares interview data with written problem-solving results from the same participants. Source triangulation compares data across different participants to support credibility. This approach enabled a deeper and more trustworthy description of students' mathematical literacy in solving statistical problems.

Analysis

This study used descriptive qualitative analysis. Data were analyzed and reported in the form of detailed descriptions. Students' written solutions and interview transcripts were examined to identify evidence of mathematical literacy performance, including the strategies and reasoning used to solve problems. Data analysis followed the Miles and Huberman framework, as cited in Haryoko et al. (2020), comprising data reduction, data display, and conclusion drawing. Data reduction involved summarizing, selecting relevant information, identifying themes and patterns, and removing irrelevant data. In this study, data reduction focused on portions of students' written work and interview responses that demonstrated the three mathematical literacy processes. Written responses that showed strong or unclear evidence of the indicators were used to guide interview probes. The reduced data were then organized into analytic notes for further interpretation.

Data display involved organizing information in a systematic form to support interpretation and conclusion drawing. In qualitative research, narrative text is commonly used. In this study, data were presented as narrative descriptions of students' responses per item and per indicator, supported by interview excerpts that clarified students' reasoning. Conclusions were drawn by integrating evidence from written work and interviews, with explicit reference to the mathematical literacy indicators. The conclusions describe students' mathematical literacy in statistics after differentiated learning based on learning readiness using the OMM model.

Research Findings

The results of the study revealed that the evaluation of mathematical literacy skills on the topic of statistics was conducted through tests in class VIII 3 at SMP Negeri 5 Pelepat Ilir. Previously, the researcher observed the differentiated learning process tailored to students' learning readiness using the outdoor modeling mathematics model. The test was then given to all students, followed by an assessment of the answers and a discussion with the mathematics teacher to determine the research subjects. The subjects were selected based on the highest scores in each learning readiness category, namely two students from the high group, two from the medium group, and two from the low group, for a total of six students selected. They were then interviewed to gain an in-depth understanding of their mathematical literacy skills. The initial data on student abilities was classified according to Initial Mathematical Ability (KAM) for the high, medium, and low differentiated learning categories using the outdoor modeling mathematics model. Based on the table, there were 7 students in the high category, 19 in the medium category, and 7 in the low category, with a total of 33 students.

Table 3. Distribution of students by learning readiness (N = 33)

Group	Total of Students
High Learning Readiness	7
Medium Learning Readiness	19
Low Learning Readiness	7

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Total	33

The description of the observation results of the implementation of teacher and student activities in differentiated learning shows an average percentage of teacher activities of 86.05% (good category, range 80-89%) and students 83.65% (also good). Overall, the average percentage of teacher and student activities reached 84.55%, indicating good implementation. The description of the data from the mathematical literacy test and interviews, after the learning observation, involved testing all students in class VIII 3. Statistics questions were evaluated based on mathematical literacy indicators, namely formulating situations mathematically, using mathematical concepts, facts, procedures, and reasoning, as well as interpreting, applying, and evaluating mathematical results. To facilitate the analysis of the three indicators of mathematical literacy skills above, coding was provided.

Table 4. Mathematical literacy indicators and codes

No	Mathematical Literacy Indicators	Code
1.	Formulating situations mathematically	**KLM 1**
2.	Using mathematical concepts, facts, procedures, and reasoning	**KLM 2**
3.	nterpreting, applying, and evaluating mathematical results	**KLM 3**

The indicators of mathematical literacy skills found in the mathematical literacy skills test

Table 5. Indicator coverage across test sub-questions

No	Mathematical Literacy Indicators	Question Number						
		1.a	1.b	1.c	1.d	1.e	1.f	1.g
1.	Formulating situations mathematically	√	√	–	–	–	–	–
2.	Using mathematical concepts, facts, procedures, and reasoning	–	–	√	√	√	–	–
3.	nterpreting, applying, and evaluating mathematical results	–	–	–	–	–	√	√

Question Number The mathematical literacy test was conducted on June 9, 2025, in class VIII 3. After the students finished the test, the researcher checked the students' answer sheets according to the mathematical literacy scoring guidelines. Based on the results of the mathematical literacy test, the following conclusions were drawn

Table 6. Literacy level by learning readiness (N = 33)

Differentiated Learning Based on Learning Readiness	Mathematical Literacy Skills			Total
	High	Medium	Low	
High	3	4	0	7
Medium	1	10	7	18
Low	1	2	4	7
Grand Total				33

Based on the data in the table, in differentiated learning using the outdoor modeling mathematics model, there were 7 students with high learning readiness, consisting of 3 students with high mathematical literacy and 4 students with moderate abilities. In the moderate learning readiness category, there were 18 students, namely 1 student with high mathematical literacy skills, 10 students with moderate skills, and 7 students with low skills. Meanwhile, the low learning readiness category included 7 students, comprising 1 student with high mathematical literacy skills, 2 students with moderate skills, and 4 students with low skills. After analyzing the test results, six students were selected as research subjects based on the criteria of the highest scores in mathematical literacy in each category, namely students T5 and T8 from the high learning readiness group, S4 and S9 from the moderate group, and R20 and R31 from the low group.

The selection of subjects was carried out using purposive sampling, which took into account the recommendations of mathematics teachers and the highest test scores from each learning readiness category (Haryoko et al., 2020). This approach aimed to reveal the maximum potential of students in understanding and applying mathematical literacy, thereby reflecting the peak achievement in each group. In addition, this method facilitates the comparison of subject characteristics from various ability levels, which is useful for identifying differences and similarities in students' mathematical literacy. The six subjects were then given special codes to facilitate the analysis process.

S1KBT	:	Subject 1 in Differentiated Learning Based on High Learning Readiness
S2KBT	:	Subject 2 in Differentiated Learning Based on High Learning Readiness
S1KBS	:	Subject 1 in Differentiated Learning Based on Medium Learning Readiness
S2KBS	:	Subject 2 in Differentiated Learning Based on Moderate Learning Readiness
S1KBR	:	Subject 1 in Differentiated Learning Based on Low Learning Readiness
S2KBR	:	Subject 2 in Differentiated Learning Based on Low Learning Readiness

In questions 1.a and 1.b, the indicator evaluated was the ability to formulate situations mathematically (KLM 1). S1KBT was able to identify the known and unknown information, even though he did not record it on the answer sheet. Based on the interview transcript, S1KBT had achieved this indicator, as he was able to mention these elements. This shows that the formulation process had taken place in his mind, even though it was not fully reflected in his written answers.

S1KBT in Formulating Situations Mathematically

For Questions 1.c–1.e (KLM 2), S1KBT demonstrated strong performance. The answer sheet and interview indicate that the subject selected appropriate strategies, used the given data effectively, and applied statistical concepts accurately, including the mean, median, and mode. The subject explained solution steps in a coherent sequence and provided clear reasoning, particularly when arguing that the mean is a more appropriate indicator of class activity than the mode. Although some calculation details were not fully written on the answer sheet, the interview confirmed conceptual understanding and the ability to justify and check the results. Overall, S1KBT showed solid competence in applying mathematical concepts and reasoning to support conclusions.

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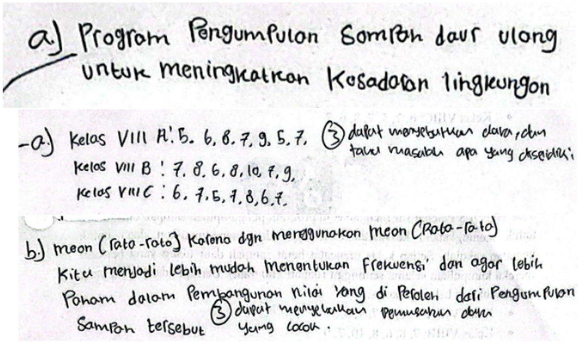

Figure 2. S1KBT in Formulating Situations

S1KBT in using mathematical concepts, facts, procedures, and reasoning

S1KBT demonstrated strong mathematical literacy across the indicators assessed. In Question 1.c, the student accurately identified the mean as the appropriate measure and explained both the formula and the underlying rule, showing clear procedural understanding rather than mere computation. In Question 1.d, S1KBT applied a systematic strategy by sorting the data, locating the median correctly for an odd-sized dataset, and identifying a bimodal distribution, which indicates sound knowledge of statistical concepts and procedures. In Question 1.e, the student went beyond giving an answer by critically evaluating a peer's claim that the class with the highest mode is the most active; S1KBT justified disagreement by explaining that the mode reflects only the most frequent value and does not represent overall contribution, and then argued that the mean is more appropriate because it incorporates all data points. For KLM 3 (Questions 1.f–1.g), the student effectively interpreted the computed results in the real-world context of the recycling program by identifying the class with the highest average as an indicator of higher participation, while also recognizing the limitation of the mean for judging consistency and proposing standard deviation as a more suitable statistic for assessing variability. Overall, these responses suggest that S1KBT not only applied statistical procedures correctly but also selected and evaluated measures based on the purpose of interpretation in context.

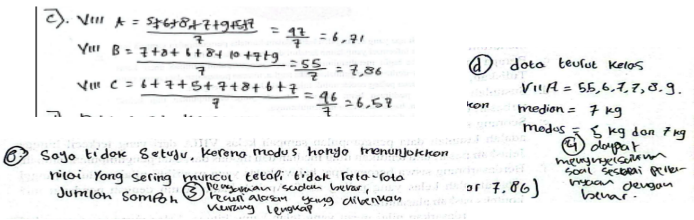

Figure 3. S1KBT in using mathematical concepts, facts, procedures, and reasoning

S1KBT in Interpreting, applying, and evaluating mathematical results

In Questions 1.f and 1.g (KLM 3), S1KBT demonstrated a strong capacity to interpret and evaluate statistical results in context. The student interpreted the mean of 7.86 kg for Class VIII B as an estimate of average daily waste collection, and used it to justify a contextual conclusion that this class was the most successful in supporting the school recycling program compared with the other classes. Importantly, S1KBT did not treat the mean as a final decision tool; instead, the student evaluated its limitation for judging consistency and proposed standard deviation as a more appropriate statistic to assess stability. The explanation that small standard deviation indicates data close to the mean, while large standard deviation indicates greater fluctuation, reflects an understanding of variability and the need to align statistical measures with the purpose of interpretation. In contrast, for Questions 1.a and 1.b (KLM 1), S2KBT showed an adequate but more surface-level formulation process: the subject reported beginning by reading the problem, identifying relevant given and asked information, and attempting to connect the context to calculations, although this was not consistently documented in writing. This suggests initial awareness of key variables and a general modeling approach, but it also indicates that the rationale for selecting mathematical representations and strategies still requires deeper articulation and refinement.

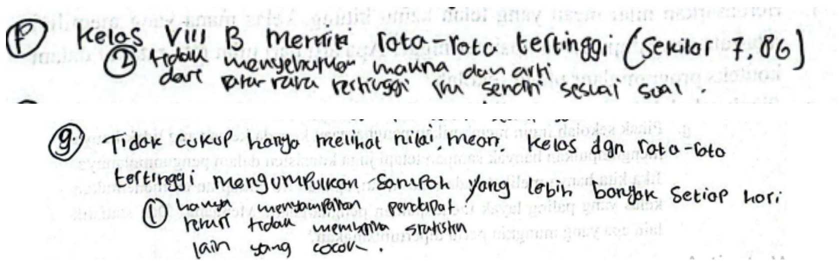

Figure 4. S1KBT in Interpreting, applying, and evaluating mathematical results

S2KBT in Formulating Situations Mathematically

In Questions 1.a and 1.b (KLM 1), S2KBT demonstrated an adequate ability to formulate situations mathematically. The interview indicates that the student began by reading the problem to grasp its context, then focused on identifying key quantitative information, such as the amount or weight of waste collected by each class across days and over a week. S2KBT also described a general approach to mathematization by "converting known data" and using the "formula requested," suggesting awareness that contextual information must be translated into measurable variables before computation. However, the responses also imply a largely procedural orientation, where mathematization is framed as locating numbers and applying a given formula rather than explicitly constructing or justifying a mathematical representation.

For KLM 2 (using mathematical concepts, facts, procedures, and reasoning), S2KBT showed mixed performance. The student did not consistently demonstrate full conceptual clarity, particularly in identifying and explaining the concept of the mean, applying mathematical rules with explicit justification, considering alternative strategies, and routinely checking results. At the same time, S2KBT performed more confidently on tasks involving median and mode by describing basic but correct procedures, such as sorting data and identifying the middle value and most frequent value(s). In Question 1.e, the student provided stronger reasoning by rejecting the use of mode as the sole indicator of class activity, indicating emerging evaluative thinking. Overall, S2KBT appears to have a solid procedural base, but still needs support to strengthen conceptual precision, strategy flexibility, and independent verification habits.

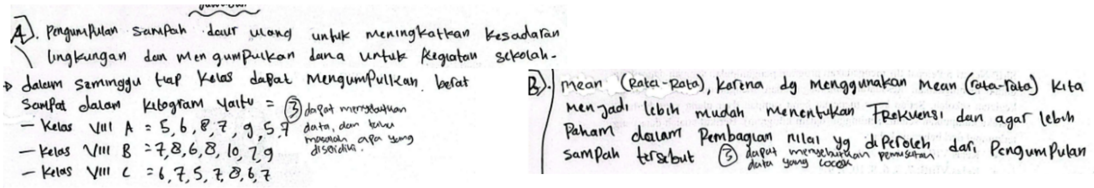

Figure 5. S2KBT in Formulating Situations.

S2KBT in Using Mathematical Concepts, Facts, Procedures, and Reasoning

In Questions 1.c–1.e (KLM 2), S2KBT relied mainly on procedural actions and showed limited conceptual articulation. In Question 1.c, the student could perform the mean procedure by "adding and dividing," but could not name the concept or justify why that procedure fits the task. This signals an operational skill without a clear conceptual anchor. In Question 1.d, the student described correct rule-based steps for median and mode, such as sorting data, taking the middle value, and identifying frequent values, yet framed this as "not using a formula." This suggests the student treats statistics as informal routines rather than as formal concepts with criteria for use. In Question 1.e, the student provided a stronger rationale by rejecting mode as an indicator of "most active," because mode reflects frequency rather than the overall or representative amount. However, the decision process still appeared definition-matching rather than goal-driven comparison of measures, which indicates incomplete reasoning flexibility.

In Questions 1.f–1.g (KLM 3), S2KBT demonstrated better competence in connecting results to context. The student interpreted the mean as a representation of typical daily waste collection and correctly identified Class VIII B (7.86) as the highest. This shows the ability to translate a numerical result into a contextual claim. Yet the interpretation leaned on an assumption that a higher mean automatically implies greater activity, without explicitly testing whether mean is the most appropriate indicator for the program's purpose. The strongest evidence of evaluation emerged in Question 1.g, where the student recognized that the mean alone cannot capture consistency and that variability across days matters. This reflects an emerging capacity to critique the adequacy of a measure, although the student still needs support to justify measure selection more systematically and to propose or apply variability measures when the context requires them.

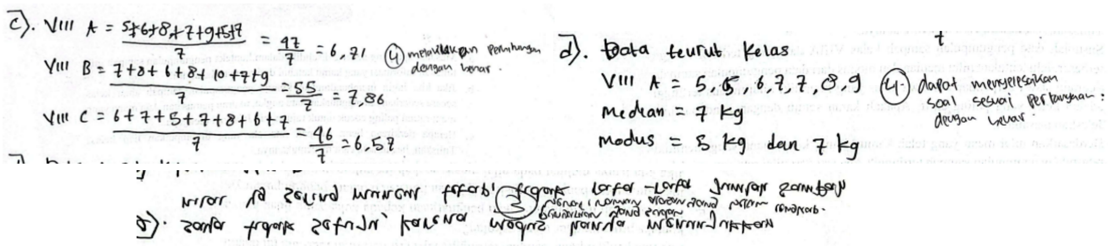

Figure 6. S2KBT in Using Mathematical Concepts, Facts, Procedures, and Reasoning

S2KBT in Interpreting, Applying, and Evaluating Mathematics Results

In Questions 1.f–1.g (KLM 3), S2KBT linked the numerical result to the context, but the link remained oversimplified. When the student stated that the class "collects the most trash every day," they treated the weekly mean as a direct description of daily dominance, not as a representative value that summarizes a week of fluctuating data. The explanation "I counted everything and divided it by seven" shows procedural fluency, yet it also reveals a narrow view of meaning. The student focused on how to compute the mean, not on what the mean can and cannot claim about daily performance. This indicates that interpretation still depends on calculation rather than on modeling the real situation.

In Question 1.g, S2KBT showed stronger evaluative thinking by adding an important qualification: a high average signals activity, but it does not guarantee consistency. This response suggests the student has begun to distinguish between "level" and "stability" in data. Conceptually, this is a key step toward statistical reasoning, because it recognizes that two classes can share a similar mean but differ in day-to-day variation. However, the student did not yet move from that insight to an explicit evaluative action, such as proposing a spread measure or explaining what pattern of data would count as "inconsistent." So, S2KBT demonstrates an emerging ability to interpret and critique results in context, but still needs support to translate that critique into a clear statistical decision rule.

For S1KBS in KLM 1 (Questions 1.a–1.b), the evidence suggests that the student could identify relevant information and restate what the problem asks, which indicates successful mathematical formulation at a basic level. Still, the current description is not precise in English and mixes indicators with conclusions. It should emphasize that S1KBS recognized key variables in the context (waste amounts, classes, time period) and could express them as data to be processed, even when the written work did not fully document the "known-asked" structure. This shows that the formulation step occurred cognitively, but the written representation of that step remained incomplete.

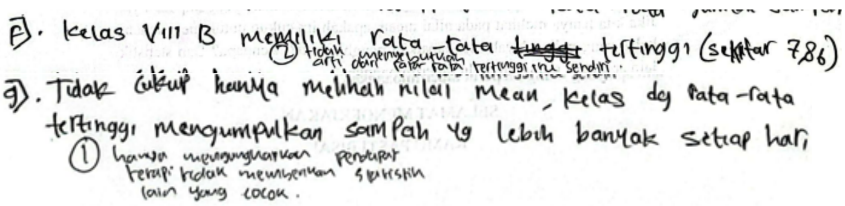

Figure 7. S2KBT in Interpreting, Applying, and Evaluating Mathematics Results

S1KBS in Formulating Situations Mathematically

S1KBS demonstrated adequate performance on KLM 1 (Questions 1.a–1.b) by recognizing the situation as realistic and identifying the key variables needed for mathematization. The student explicitly connected the task to a familiar school activity and described the core modeling move as "turning the situation into numbers." This indicates that S1KBS could translate a contextual narrative into quantifiable data. However, the student's phrasing remained general and did not specify which quantities were selected, how the data were organized (per class, per day, per week), or what assumptions were used. In other words, S1KBS showed awareness that a real context can become data, but the articulation of the modeling structure stayed at a surface level.

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i1.3958 Volume 6, No 1, January - March 2026, pp. 109 – 128

For KLM 2 (Questions 1.c–1.e), the interview evidence suggests that S1KBS could plan a solution and use the available information appropriately, especially when selecting a statistic that "represents" the overall data for comparison across classes. This points to emerging reasoning about representativeness as a justification for choosing a measure of central tendency. Still, an informed skeptic could note that the student may be relying on a heuristic, such as "choose the average because it represents all data," without explicitly checking whether the mean is appropriate under possible skewness or outliers, or whether the comparison requires consistency rather than level. The logic is mostly sound for the task as described, but the gap lies in why the chosen procedure fits the context and what alternative measures would imply. A practical improvement is to make the student's reasoning explicit: name the variables, state the comparison goal, justify why the mean supports that goal, and mention at least one alternative measure and why it was not selected.

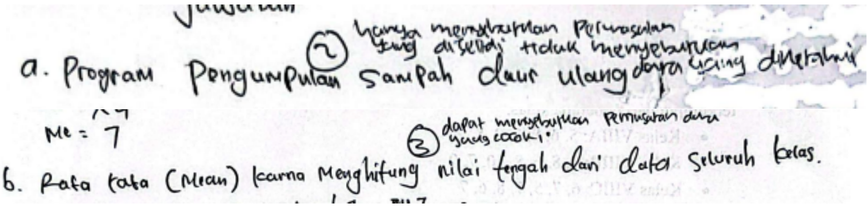

Figure 8. S1KBS in Formulating Situations Mathematically

S1KBS in Using Mathematical Concept, facts, Procedures, and reasoning

S1KBS showed strong performance on KLM 2 (Questions 1.c–1.e) because the student did more than apply procedures. The student linked each step to a clear statistical rule and explained why the step fits the task. In Question 1.c, S1KBS correctly operationalized the mean as "sum of the weekly data divided by 7," which indicates an understanding that the unit of analysis is daily data across a week. The student also reported checking the sequence and recalculating before submitting the answer, which reflects emerging verification habits and procedural control, not mere computation. In Question 1.d, S1KBS described the standard workflow for median and mode, sorting the data and selecting the central value because the number of observations is odd. The correction about the mode is important. The student initially wrote "no mode," then revised the claim after recognizing that two values repeat (5 and 7). This episode suggests that S1KBS can self-correct when prompted and can handle a common conceptual nuance in mode, namely the possibility of multiple modes. In Question 1.e, S1KBS demonstrated higher-level reasoning by challenging an intuitive but flawed claim ("highest mode means most active"). The student correctly argued that mode only captures the most frequent value, not the overall magnitude of contributions, and provided a concrete counterexample showing how a class can have a frequently occurring high value yet still produce a smaller total than a class with more varied but larger values. This indicates that S1KBS can evaluate the validity of a statistical argument by relating a measure to what it can and cannot represent.

For KLM 3 (Questions 1.f–1.g), S1KBS interpreted statistical outputs as evidence for decisions in the recycling program. The student used the highest mean (7.86 for class VIII B) to justify the conclusion that the class appears most active, while also raising an important limitation: "activity" and "consistency" are not the same construct. This distinction shows that S1KBS does not treat the mean as a universal answer. Instead, the student recognizes that a high average can coexist with unstable daily outcomes, so additional measures are needed to judge consistency. The reasoning is conceptually sound because it separates the decision goal (rewarding the most active vs the most consistent class) from the statistical evidence required. A skeptical reading would note one gap: S1KBS did not specify a concrete consistency metric in the excerpts you provided, so the evaluation remains correct in principle but still incomplete at the level of methodological detail. Even so, the interview data supports the claim that S1KBS can interpret results, critique the suitability of a measure, and justify conclusions with context-sensitive reasoning.

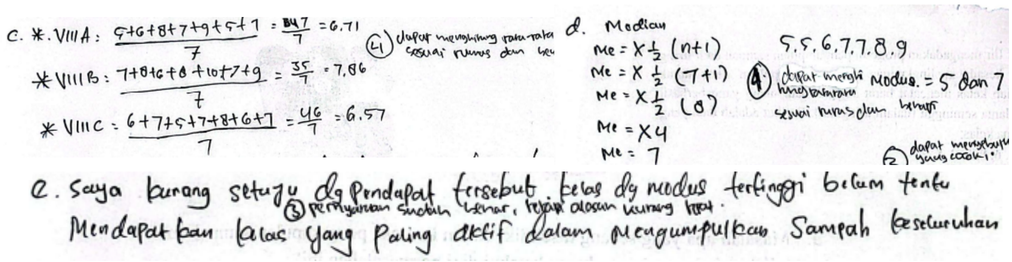

Figure 9. S1KBS in Using Mathematical Concept, facts, Procedures, and reasoning

S1KBS in Interpreting, Applying, and Evaluating Mathematics Results

S1KBS's responses in Questions 1.f–1.g (KLM 3) show that the student can connect statistical outputs to the decision context of the school recycling program, but the interpretation still concentrates almost entirely on the mean. Although the researcher asked about the meaning of the median, S1KBS immediately shifted to "the average value" and used it to justify the conclusion that Class VIII B collected the most recyclable waste. This pattern suggests that S1KBS treats the mean as the primary summary for "performance," while the median and mode play a secondary role that the student does not yet articulate clearly in context. At the same time, S1KBS made an important evaluative move by stating that the mean alone is insufficient and that it is better to consider consistency. This indicates emerging awareness that different indicators answer different questions: the mean can support a claim about "overall activity," but it cannot fully support a claim about "stable effort across days." In other words, S1KBS begins to distinguish level of performance from stability of performance, which is a core feature of higher mathematical literacy.

For S2KBS (KLM 1, Questions 1.a–1.b), the data indicate a solid ability to formulate the situation mathematically. S2KBS identified key information about waste amounts and time span, related the problem to daily school experience, and translated the context into a set of numerical data suitable for analysis. The fact that S2KBS did not always write "known" and "asked" on the answer sheet, yet could explain them in the interview, suggests that the formulation occurred cognitively but was not consistently externalized in writing. The interview also shows conceptual growth: S2KBS attempted to justify the mean, then corrected the definition after reflection, and explicitly compared the mean with the median and mode to argue why the mean best supports cross-class performance comparison. This combination of contextual recognition, identification of variables, and model selection indicates that S2KBS

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i1.3958 Volume 6, No 1, January - March 2026, pp. 109 – 128

meets KLM 1 with a meaningful understanding of how a real-world situation becomes a mathematical task.

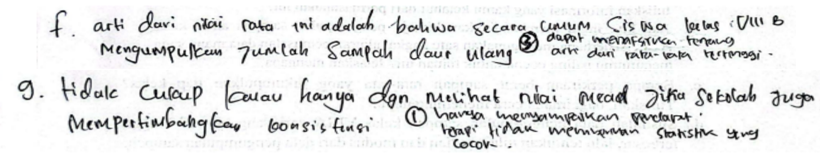

Figure 10. S1KBS in Interpreting, Applying, and Evaluating Mathematics Results

S2KBS in Formulating Situations Mathematically

S2KBS shows a clear ability to formulate the situation mathematically (KLM 1). The student immediately linked the task to a familiar school activity, then identified the key quantitative structure: daily waste weights across three classes over one week. This indicates that S2KBS can recognize variables, time span, and data units, then shift from a narrative context to a dataset that can be analyzed. In Question 1.b, S2KBS also demonstrated early competence in model selection, because the student understood that the problem asks for an appropriate measure of central tendency to compare class performance. The brief confusion between "mean" as "middle value" and "mean" as "average representing all data" is important evidence of conceptual development. The student corrected the definition after being challenged, which suggests reflective thinking and the capacity to revise reasoning when confronted with a conceptual mismatch.

For using mathematical concepts, facts, procedures, and reasoning (KLM 2), S2KBS performed at a moderate level with uneven depth across sub-tasks. In Question 1.c, the student could apply the mean formula and execute the basic procedure of summing and dividing, but did not justify why the mean was the best choice for that context, and did not report checking the accuracy of computations. In Question 1.d, S2KBS showed stronger procedural control by sorting data, identifying the median, and revising the mode after re-examining frequencies, which signals growing attention to data structure and error correction. However, the reasoning still relied on routine steps rather than flexible strategy use. The main weakness appeared in Question 1.e: S2KBS struggled to evaluate whether mode can support a claim about "largest contribution" or "most active class," and did not compare it critically with alternatives such as mean or total. This suggests a gap in argumentation and evaluative reasoning, where the student can compute measures but has not yet internalized their interpretive limits in decision-making contexts. Overall, the interview evidence supports the conclusion that S2KBS has a solid procedural foundation, but needs stronger habits of verification, wider strategy exploration, and deeper justification when selecting and defending statistical measures.

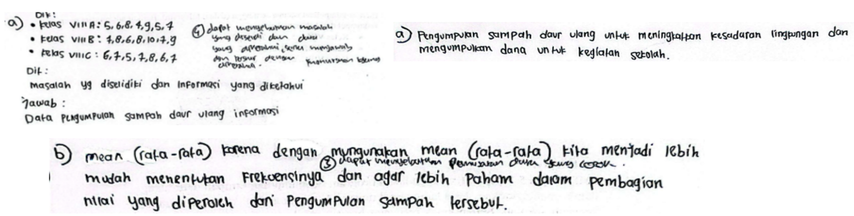

Figure 11. S2KBS in Formulating Situations Mathematically

Discussion

This study examined students' mathematical literacy through three indicators: (KLM 1) formulating situations mathematically, (KLM 2) using mathematical concepts, facts, procedures, and reasoning, and (KLM 3) interpreting, applying, and evaluating mathematical results. The analysis combined written test responses and follow-up interviews from six focal students (S1KBT, S2KBT, S1KBS, S2KBS, S1KBR, and S2KBR) who learned statistics through differentiated learning using the outdoor modeling mathematics model. Overall, the findings show a stable pattern at KLM 1, relatively strong procedural performance at KLM 2 with uneven conceptual justification, and the greatest variation at KLM 3, particularly when students were required to evaluate the adequacy of a statistical measure for judging consistency.

For KLM 1 (questions 1.a and 1.b), all subjects demonstrated the ability to identify key quantities and the main goal of the contextual problem, such as recognizing that the recycling program provided weekly waste-weight data across classes and that the task required comparing class performance using statistics. Even when students did not explicitly write "known" and "asked" information on their answer sheets, interviews showed that most students had already selected relevant variables, focused on the data structure, and framed the problem in mathematical terms (Lusiana et al., 2025).. This suggests that the outdoor context and modeling stages supported students in recognizing what needed to be mathematized, simplifying the real-world situation, and translating it into a form that could be processed using statistical concepts. In OECD's framework, this indicator involves identifying mathematical aspects in context, making assumptions or simplifications where needed, and representing the situation mathematically, and the students' responses reflect those core processes (Saputra et al., 2021).

For KLM 2 (questions 1.c, 1.d, and 1.e), students generally managed routine statistical procedures, but their reasoning quality varied across tasks and across data sources (written vs interview). In question 1.c, most subjects applied the mean through a standard procedure, yet some students struggled to articulate the underlying concept, justify why the mean was appropriate, or explain the "rule" beyond performing addition and division. This gap indicates that procedural fluency did not always coincide with conceptual clarity (Syawardhan & Noer 2022). In question 1.d, performance was more consistent because the task structure led students to follow recognizable steps, such as sorting data and locating the middle value for the median, and identifying the most frequent values for the mode; interviews also showed that some students corrected earlier misunderstandings once prompted to re-check the data. In question 1.e, the task demanded higher reasoning because students had to evaluate a claim about "most active class" based on the mode. Several students were able to reject the claim by arguing that the mode reflects frequency rather than overall contribution, and then propose more informative alternatives such as the mean or total, even when their written explanation was brief (Hikmah et al., 2020). However, some students still relied on definitional matching without exploring alternative strategies or checking whether their reasoning aligned with the context (Lusiana et al., 2025).. In OECD's terms, KLM 2 requires selecting a strategy, carrying out procedures accurately, and supporting the choice with reasoning, and the present findings suggest that the outdoor modeling approach supported procedural execution but did not fully equalize students' ability to justify and evaluate strategy choices (Amadi et al., 2023).

For KLM 3 (questions 1.f and 1.g), students were generally able to interpret results in context, but fewer students moved from interpretation toward evaluation of model adequacy. In question 1.f, all subjects could connect the highest mean value (e.g., class VIII B with 7.86) to the real-world meaning of performance in the recycling program, indicating that they understood the mean as a representative daily or weekly summary for comparison. The

https://doi.org/10.51574/kognitif.v6i1.3958 Volume 6, No 1, January - March 2026, pp. 109 – 128

challenge became more evident in question 1.g, which required evaluating whether the mean alone could capture "consistency" and proposing a more appropriate statistic. A smaller number of students showed advanced evaluation by explicitly recognizing variability and suggesting a dispersion measure such as standard deviation (Hikmah et al., 2020). By contrast, some students assumed that a high mean implied consistency, and others were unable to propose an alternative measure beyond the mean, indicating limited repertoire for evaluating the suitability of a statistical model (Haryoko et al., 2020).. This pattern suggests that students could interpret an output, but not all could assess the reasonableness of using a single measure for a different construct (consistency), which is central to the "evaluate" component in OECD's mathematical literacy description.

An important methodological finding is the discrepancy between written test evidence and interview evidence. Several students showed stronger indicator attainment during interviews than in their written responses, implying that some understanding was present but not fully expressed in writing. At the same time, interviews may also function as scaffolding because probing questions can cue students to recall procedures or reconsider their answers. Therefore, interview improvements should be interpreted as evidence of potential or emerging competence rather than purely independent mastery (Herwina, 2021). This written–oral gap points to a practical implication: learning designs and assessment tasks should explicitly train students to communicate reasoning in written form, not only to obtain correct numerical results (Hayati & Jannah, 2024)..

Taken together, the discussion indicates that differentiated learning through outdoor modeling mathematics supported students' ability to mathematize contextual statistical problems (KLM 1) and execute core procedures (KLM 2), while higher-level evaluation (KLM 3), especially reasoning about variability and model adequacy, remained uneven. Instructionally, this suggests the need to strengthen tasks that require students to justify the selection of mean, median, or mode in context, and to incorporate explicit prompts and activities about "consistency" and "spread," including introducing and using dispersion measures when the context demands them (Herwina, 2021). Such refinements can help students progress from interpreting results to evaluating whether a mathematical model appropriately represents the phenomenon under investigation, which is a key feature of mathematical literacy as framed by OECD (2023).

Conclusion

Based on the findings, students' mathematical literacy in solving statistics problems after differentiated learning using the outdoor modeling mathematics model showed different levels of attainment across learning-readiness groups. Students with high learning readiness (S1KBT and S2KBT) demonstrated strong and consistent performance across the three indicators. They could formulate contextual situations mathematically, apply statistical concepts and procedures with coherent reasoning, and interpret results critically, including justifying the use of the mean over the mode and proposing standard deviation to evaluate consistency. Students with moderate learning readiness (S1KBS and S2KBS) also performed well. They could formulate and solve problems appropriately and responded positively during reflection, although some conceptual clarification emerged during interviews, particularly in selecting and justifying the most suitable measure of central tendency. Students with low learning readiness (S1KBR and S2KBR) were generally able to identify relevant information and translate the context into mathematical form, but they experienced difficulties in deeper conceptual explanation and evaluative interpretation, such as assuming that the mean alone was sufficient to judge consistency and showing limited familiarity with alternative measures. These patterns indicate the need for more intensive scaffolding for students with low readiness, especially for tasks that require evaluating the adequacy of statistical measures.

Theoretically, this study provides a descriptive account of how students demonstrate mathematical literacy in statistics after differentiated learning through outdoor modeling. The results suggest that the model supports contextual understanding by helping students connect statistical ideas with real situations and by strengthening performance particularly among students with moderate readiness. Practically, the findings can inform teachers and schools in designing differentiated instruction that not only improves procedural performance but also promotes justification and evaluation in statistical reasoning. Overall, the outdoor modeling mathematics model appears promising as a contextual approach for strengthening mathematical literacy in statistics, especially for supporting students' ability to interpret results and evaluate the appropriateness of statistical measures.

Based on these results, several recommendations are proposed. First, teachers should integrate differentiated instruction with outdoor modeling activities and provide explicit prompts that require students to justify the choice of measures (mean, median, mode) and to evaluate consistency using dispersion-related reasoning. Second, students should be encouraged to engage actively in learning tasks that require explaining their reasoning, both orally and in writing, to strengthen their literacy performance. Third, future studies may extend this work by examining differentiated learning based on students' interests or learning styles, as the present study focused only on learning readiness.

Conflict of Interest

The author declares no conflict of interest.

Authors' Contributions

The first author, K.N.Y.A., conceived the research idea, collected data, prepared research instruments, designed the methodology, organized and analyzed data, and contributed to the discussion of results. S. and D.I., as research supervisors, actively participated in theoretical guidance, methodology, data analysis, results discussion, and approval of the final version. All authors have read and approved the final manuscript. The total percentage contribution to the conceptualization, drafting, and revision of this paper is as follows: K.N.Y.A.: 40%, S.: 30%, D.I.: 30%.

Data Availability Statement

The authors declare that data supporting the findings of this study will be made available by the corresponding author, [K.N.Y.A.], upon reasonable request.

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