The Use of Moodle in Problem-Based Learning with a Realistic Approach to Improve Mathematical Literacy

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***Abstract*—The study explores how the implementation of a problem-based learning strategy, combined with a realistic approach and facilitated through Moodle, can contribute to the development of students' mathematical literacy. The study involved seventh-grade students from SMP Negeri 20 Semarang during the 2023/2024 academic year and employed a quantitative research design. Data were collected through testing to assess students' learning outcomes. The data analysis involved prerequisite testing of the pretest and posttest data, followed by hypothesis testing on the posttest results. The study demonstrates that utilizing a problem-based learning approach, integrated with realistic contexts and facilitated through Moodle, substantially improved students' mathematical literacy, effectively addressing all phases of instruction: planning, implementation, and evaluation.**

***Keywords*—mathematical literacy, realistic approach, moodle**

I. Introduction

Education serves as a fundamental driver of a nation's development. Education serves as a crucial asset for shaping and advancing the nation's future, as outlined in the 1945 Constitution (UUD 1945). The Indonesian government is continually striving to optimize and enhance the education system to ensure the educational goals are met. Among the scientific disciplines, mathematics plays a vital role in Indonesia's education system. Owing to its wide-ranging benefits and practical relevance in everyday life, mathematics is recognized globally as a core subject across all educational levels [1]. This is why mathematics is often referred as the "mother of all sciences". The goals of mathematics education in Indonesia, as stated in the Regulation of the Minister of National Education No. 22 of 2006, highlight the cultivation of a broad range of competencies—extending beyond fundamental numeracy—to include the enhancement of mathematical literacy.

One of the most pressing challenges of the 21st century is how students can apply the knowledge and abilities they acquire in school to their everyday lives [2]. In today's world of accelerating technological advancement and increasing global integration, mathematical literacy has emerged as a critical competency. Conventional rote-based instructional methods are no longer sufficient, as students must develop competencies that correspond to the evolving demands of contemporary society. Within this framework, mathematical literacy serves as essential preparation for a future in which critical thinking, data interpretation, and mathematical reasoning are vital across diverse professional and industrial domains [3]. Embedding mathematical literacy within education represents a strategic response to modern-day challenges, enabling students to acquire not only conceptual understanding but also the analytical and practical competencies essential for success in an increasingly dynamic and complex world.

Mathematical literacy refers to the capacity to utilize mathematical reasoning, knowledge, and tools effectively in addressing real-world problems [4]. It enables individuals to make informed decisions by utilizing mathematical functions in everyday situations. Mathematical literacy refers to the capacity to formulate, utilize, and interpret mathematics across various real-life situations. It involves mathematical reasoning and the effective use of appropriate concepts, methods, facts, and tools, enabling individuals to make thoughtful, informed, and reflective decisions [5]. Based on this definition, mathematical literacy extends beyond merely recognizing and understanding the role of mathematics; it also entails the ability to interpret and apply mathematical knowledge within more complex and varied contexts [6]. The complexity of mathematical literacy is evident in the indicators used in PISA 2022 assessment, such as communication, mathematizing, representation, reasoning and argumentation, problem-solving strategies, the use of formal and technical language and operations, and the use of mathematical tools [7]. These indicators underscore that mathematical literacy functions not merely as an instructional approach, but also as a forward-looking response to the shifting educational demands of 21st-century learners.

According to the OECD 2022 report, the PISA score have declined compared to the 2018 assessment. Indonesia's mathematical literacy score in PISA 2018 was 379, which decreased by 13 points to 366 in PISA 2022. The results from the PISA 2022 study showed that Indonesia ranked 71st out of 81 participating countries, a position that remained largely unchanged from the 2018 ranking [7]. This indicates that mathematical literacy in Indonesia remains at a relatively low level. This finding is consistent with observations made at SMP Negeri 20 Semarang. One of the mathematics teachers reported that students at this school have not yet mastered mathematical literacy, noting challenges as difficulties in understanding and solving word problems, converting problems into mathematical models, representating the problems accurately, and developing strategies to solve them. The preliminary study revealed an average of 31,275 on students' mathematical literacy tests. The data indicate that the mathematical literacy levels of students at SMP Negeri 20 Semarang remain within the low category.

One promising approach to overcoming these challenges is through innovation in mathematics instruction. In alignment with the demands of the 21st century—where technology assumes a pivotal role—mathematics education stands to gain

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significantly from the integration of contemporary technological advancements. For example, employing a Learning Management System (LMS) as a medium for mathematics instruction offers a potentially effective instructional strategy. In this study, the LMS employed is the Modular Object-Oriented Dynamic Learning Environment (Moodle), which has been widely utilized to support classroom-based learning over an extended period [8]. Moodle is an educational platform designed to offer educators and learners a unified, secure, and dependable system for developing customized learning environments [9]. Moodle enables students to participate in a "digital classroom" where they can access learning materials, quizzes, electronic journals, and more [10]. Research by Fitriyaningsih *et al*. [11] demonstrates that the use of Moodle significantly enhances students' mathematical literacy, suggesting a positive influence on overall learning outcomes. The study also found that Moodle had a stronger effect compared to traditional methods. This aligns with other research showing that Moodle offers substantial benefits for educators and promotes effective collaboration between teachers and students [12]. Furthermore, Moodle allows for flexible learning, enabling students to study anytime and anywhere, while encouraging them to actively seek additional learning resources outside those provided by the teacher, such as information and materials available on the internet.

Another form of instructional innovation involves the implementation of teaching approaches designed to strengthen students' mathematical literacy, such as the Indonesian Realistic Mathematics Education (PMRI) approach. PMRI is a localized adaptation of the Realistic Mathematics Education (RME) framework, distinguished by its alignment with the specific characteristics and needs of the Indonesian educational context [13]. This approach places a strong emphasis on incorporating real-life contexts into mathematics instruction, making the material more relevant and easier to undersand. In other words, the problems presented to students are drawn from real-life situations [14]. PMRI has gained widespread acceptance within Indonesia's educational system due to its effectiveness in enabling students to solve mathematical problems that are directly connected to real-life situations within their surroundings [15, 16].

This approach begins with contexts that are meaningful and real to students, emphasizing the process of engaging in mathematics through exploration, discussion, collaboration, and argumentation with peers to construct their own understanding. Ultimately, students are guided to apply mathematics to solve problems both individually and collaboratively [17]. Research has shown that RME supports teachers in enhancing students' mathematical abilities [18]. This is because RME fosters critical thinking, encourages active discussion, and promotes the resolution of real-world problems. Consequently, the implementation of PMRI in classroom instruction is expected to cultivate students' mathematical literacy—not only by strengthening conceptual understanding but also by fostering practical application—thereby better preparing them to face everyday challenges. This is further supported by studies indicating that mathematics instruction using the PMRI approach can be considered effective [19].

In addition to the learning approach, the implementation of an instructional model that aligns with students' needs can also contribute to addressing these challenges. A model that supports students in connecting mathematical concepts to real-world contexts—consistent with the PMRI approach—is one that emphasizes problems or adopts a Problem-Based Learning (PBL) framework [20]. In the PBL framework, students are prompted to investigate mathematical concepts by engaging with case studies rooted in real-world environmental problems [21]. It has been emphasized that the PBL model fosters student engagement by prompting them to investigate authentic case studies [22]. This instructional approach enables learners to acquire knowledge that is directly relevant to the problems being examined, particularly within real-world contexts. Moreover, PBL enhances students' problem-solving abilities, which are critical for navigating real-life situations. This is reinforced by research indicating a significant improvement in the mathematical literacy of students at SMP Negeri 4 Semarang after the implementation of mathematics instruction utilizing a PBL model integrated with the PMRI approach, and supported by e-learning platforms such as Schoology and Edmodo [23].

In line with the aforementioned discussion, this study was conducted under the title "The Use of Moodle in Problem-Based Learning with a Realistic Approach to Improve Mathematical Literacy". In light of this background, the research question is formulated as follows: Does the implementation of a problem-based learning model, integrated with a realistic approach and assisted by Moodle, exhibit adequate quality to improve students' mathematical literacy?

II. Literature Review

A. Mathematical Literacy

Mathematical literacy can be described as the capacity of an individual to engage in mathematical reasoning, translate real-world problems into mathematical representations, apply appropriate concepts, procedures, and tools, and critically evaluate and interpret the results to address various problems encountered in everyday life [24]. As outlined in the PISA 2021 mathematics framework, mathematical literacy consists of three primary components or domains—content, context, and process—as shown in Fig 1.

Table 1 presents a detailed overview of the components or domains outlined in the PISA 2021 mathematics framework [24].

Table 1. PISA Assessment components or domains

No.	Domain	Aspects
1.	Content	Quantity; Space and Shape; Change and Relationship; Uncertainty.
2.	Context	Personal; Occupational; Societal; Science.
3.	Process	Formulate; Employ; Interpret.

Furthermore, PISA outlines seven fundamental mathematical competencies that are vital for developing mathematical literacy. These include the ability to communicate mathematical ideas, engage in mathematization, use various forms of representation, construct logical reasoning and arguments, devise strategies for solving problems, apply symbolic, formal, and technical language and operations, and effectively utilize mathematical tools [25].

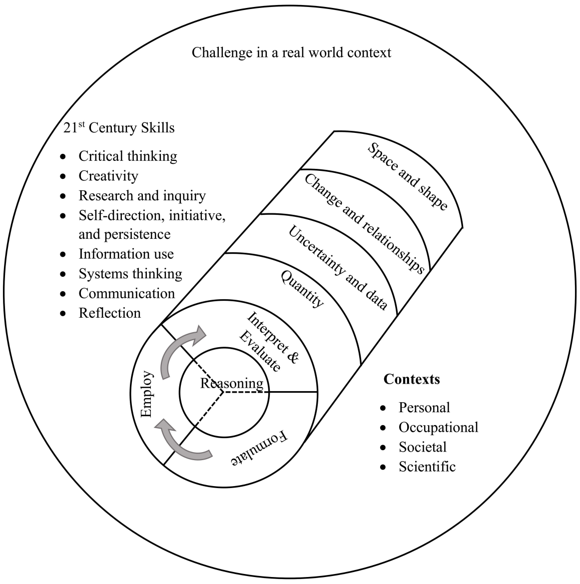

Fig. 1. PISA 2021 mathematics framework.

B. Realistic Approach

This study adopts a realistic approach to mathematics instruction, drawing upon the concept of RME, which was initially introduced by Hans Freudenthal in the Netherlands in the early 20th century. RME is an instructional approach that enables students to solve mathematical problems by connecting them to real-life experiences [26]. This approach is considered effective in enhancing students' comprehension and mastery of mathematical concepts when implemented in school-based mathematics instruction [27]. The realistic approach begins by engaging students in solving problems from their immediate environment using their existing knowledge. Consequently, this approach is expected to contribute significantly to enhancing students' mathematical understanding.

De Lange [28] in 1987 identified five key characteristics of the PMRI approach:

1) Use of contextual problems (Phenomenological exploration or the use of contexts). The learning process is initiated through the presentation of real-life problems, which function as the foundation for subsequent instructional activities. These problems should be imaginable and relatable for students.
2) Use of models (Model application or conceptual bridging through hierarchical tools). Models act as bridges to help students connect contextual problems with formal mathematical concepts.
3) Recognition of students' diverse strategies and contributions (The use of students themselves). Students are actively engaged in the learning process and are encouraged to articulate their ideas and problem-solving strategies openly.
4) Interactivity (The engaging and reciprocal aspects of teaching and learning). The learning process is marked by dynamic two-way interactions, occurring both between teachers and students as well as among the students themselves.
5) Integrated with other learning topics (The intertwining of various learning strands). Mathematical learning is connected to previously learned material and other subject areas, promoting coherence and continuity in learning.

C. Moodle

Moodle is an e-learning platform developed to convert instructional content into a web-based format while preserving its pedagogical function. This application enables learners to participate in a "digital classroom," where they can access learning resources, quizzes, electronic journals, and various other tools to support online learning [10]. Moodle, as a web-based platform, supports and optimizes the execution of online learning processes. The name 'Moodle' stands for Modular Object-Oriented Dynamic Learning Environment, emphasizing its function as a versatile and interactive educational tool grounded in modular and object-oriented architecture.

Several advantages of Moodle include:

1) Simplicity and compatibility—It is lightweight, efficient, and compatible with various web browsers and operating systems.
2) Multilingual support—Moodle is easy to install and supports multiple languages, including Bahasa Indonesia.
3) Site management features—It provides comprehensive site management capabilities, allowing administrators to customize themes, manage modules, and configure other settings.
4) Extensive module availability—Moodle includes a variety of built-in modules such as chat, polls, forums, journals, quizzes, surveys, and workshops, with the flexibility to add more as needed.

III. Materials and Methods

This research adopted a quantitative approach through a quasi-experimental method, specifically using a nonequivalent control group design. In this setup, both the experimental and control groups were administered the same pretest to assess their initial comparability. The pretest outcomes were analyzed to confirm that students in both groups possessed comparable prior knowledge or skill levels. Subsequently, each group received a distinct instructional intervention. Upon completion of the intervention period, a posttest was administered to both groups to assess whether the differing instructional approaches led to significant variations in student learning outcomes. The structure of this quasi-experimental design is depicted in Fig. 2.

The population of this study comprised all seventh-grade students at SMP Negeri 20 Semarang. The sample consisted of students from class VII-G (32 students) as the experimental group—taught using a PBL model integrated with the RME approach and assisted by Moodle—and class VII-F (34 students) as the control group, which received instruction through a PBL model combined with a scientific approach. The sampling process employed a random sampling technique.

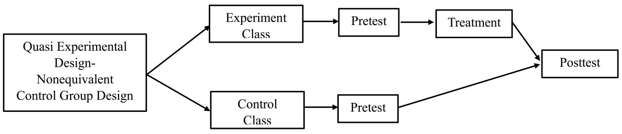

Fig. 2. Quasi-experimental flowchart.

In this study, the independent variable was the instructional method applied: the experimental group received a PBL model integrated with a RME approach and supported by Moodle, while the control group was taught using a PBL model combined with a scientific approach. The dependent variable was students' mathematical literacy.

Data were obtained through a written assessment centered on the topic of data representation. The mathematical literacy test consisted of open-ended, descriptive items designed to assess students' ability to apply mathematical reasoning. Prior to its administration, the test underwent a pilot study to assess its validity, reliability, discriminatory power, and difficulty level. Only after meeting established psychometric criteria was the test administered to both the control and experimental groups.

Before instruction began, all students completed the pretest to establish baseline data on their mathematical literacy. The instructional treatment spanned four sessions, with each session lasting two h.

In the experimental group, instruction was delivered using a PBL model integrated with a realistic approach (PMRI) assisted by Moodle as a digital learning environment. Moodle provided access to contextual problems grounded in real-life scenarios, aligning with the RME philosophy of bridging abstract mathematical concepts with authentic experiences. Instructional materials included realistic problem contexts, and Moodle's forum and chat features facilitated student discussion, collaboration, and reasoning—key elements of the RME approach. Students submitted individual and group assignments via Moodle, allowing for formative assessment and feedback. Additional digital tools, such as visualization plugins and spreadsheets, supported students in modeling and interpreting mathematical ideas, thus reinforcing the PMRI principle of moving from concrete experience to abstract understanding. Moodle's interactive features enabled structured learning through guided discussions, timely feedback, and integrated assessments, ensuring the seamless integration of digital tools into the learning process.

Conversely, the control group received instruction using a PBL model with a scientific approach, without the integration of Moodle or the realistic context emphasis. At the final session, all students were administered the posttest to evaluate the development of their mathematical literacy following the different instructional treatments.

To visualize the digital learning environment utilized in the experimental group, the figures below display key Moodle features, including the login interface, student dashboard, course overview with uploaded materials, individual assignment submission area, and discussion forum. These elements played a central role in supporting student interaction, accessing contextual problems, and receiving timely feedback, in accordance with the principles of the PMRI framework.

Students accessed the platform using individual accounts for personalized learning access, as shown in Fig. 3.

The dashboard provided students with a clear overview of their enrolled courses and upcoming academic activities, as shown in Fig 4.

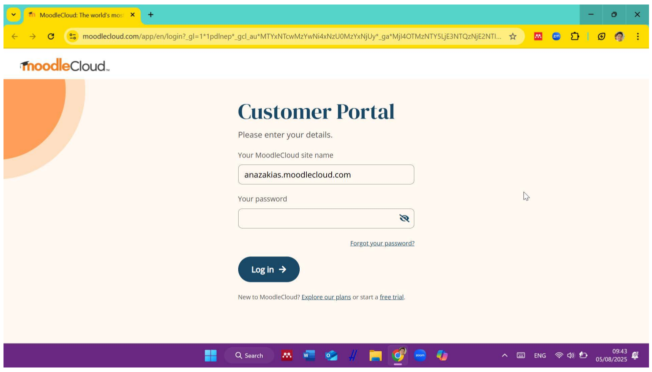

Fig. 3. Login page.

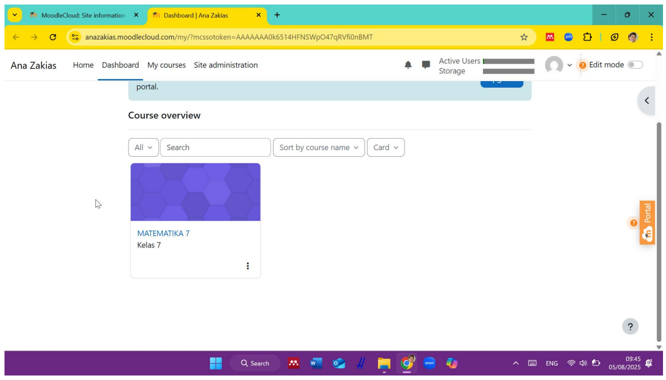

Fig. 4. Dashboard page.

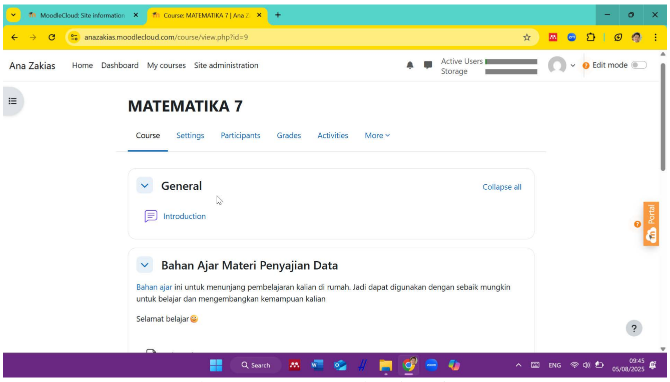

Fig. 5. Course overview interface.

Displayed subject materials, quizzes, and downloadable worksheets for each session as shown in Fig 5.

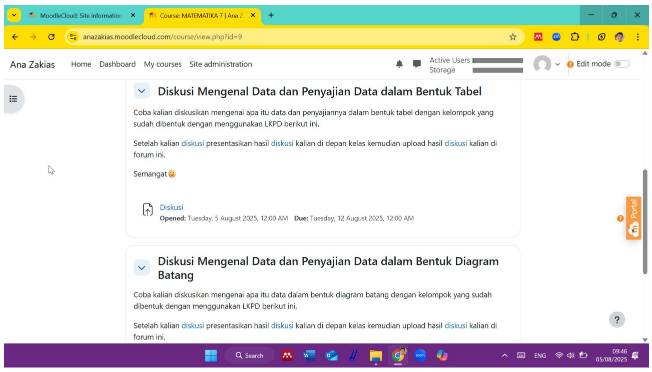

Fig. 6. Learning materials view.

Contextual problem scenarios were embedded in each module for students to explore and analyze, as shown in Fig. 6.

Used to facilitate peer discussions and the exchange of reasoning, aligned with the principles of PMRI, as shown in Fig. 7.

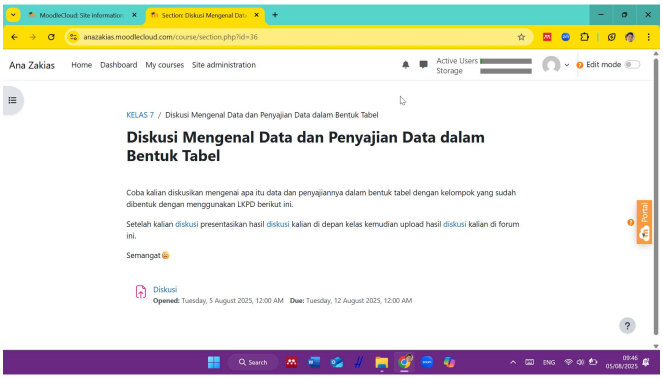

Fig. 7. Discussion column.

The quantitative data analysis was divided into two phases: preliminary analysis and final analysis. Preliminary analysis was conducted using students' pretest scores in mathematical literacy. This phase included tests for normality, homogeneity, and mean equivalence between the experimental and control groups to confirm baseline comparability. The final analysis was conducted using students' posttest scores in mathematical literacy. The procedures involved a normality test, homogeneity test, individual mastery analysis, classical mastery analysis, mean difference test, proportion difference test, and calculation of the average N-Gain improvement. The criteria used for each statistical test followed standard benchmarks to determine significance and effectiveness of the instructional intervention.

1) Normality Test

Hypothesis:

H_0: The mathematical literacy data originate from a population that follows a normal distribution.

H_1: The mathematical literacy data do not originate from a population that conforms to a normal distribution.

Testing criteria: Accept H_0 if the significance value (*Sig.*) in the *Kolmogorov–Smirnov* column of the Test of Normality table is greater than the significance level (0.05).

2) Homogeneity Test

Hypothesis:

$H_0: \sigma_1^2 = \sigma_2^2$: The variances of the two samples are equal (homogeneous).

$H_1: \sigma_1^2 \neq \sigma_2^2$: The variances of the two samples are unequal (inhomogeneous).

Testing Criteria: Accept H_0 if the *Sig.* value in the *Test of Homogeneity of Variances table > Level of Significant* (0.05).

3) Equality of Means Test (Initial Condition)

Hypothesis:

$H_0: \mu_1 = \mu_2$: The mean initial mathematical literacy scores of the experimental and control groups are equal.

$H_1: \mu_1 \neq \mu_2$: There is a significant difference in the mean initial scores between the experimental and control groups.

Testing Criteria: H_0 is accepted if the Sig. (2-tailed) value from *Levene's Test for Equality of Variances* in the independent samples t-test exceeds the significance level of 0.05.

4) Individual Mastery Test

Hypothesis:

$H_0: \mu \leq 65$: The average posttest score of students' mathematical literacy in the experimental group did not meet the individual mastery standard as defined by the BTA and KKTP benchmarks.

$H_1: \mu > 65$: The average posttest score has reached the individual mastery based on the average scores of BTA and KKTP.

Statistical Test: the one-sample t-test ($t = \frac{\bar{x}-\mu_0}{\frac{s}{\sqrt{n}}}$) was conducted using Microsoft Excel, applying the appropriate statistical formula for comparing the sample mean to a predefined standard value.

Testing Criteria: Reject H_0 if the computed t-value is greater than the critical t-value derived from the t-distribution table at the specified significance level ($\alpha = 0.05$).

5) Classical Mastery Test

Hypothesis:

$H_0: \pi \leq 75\%$: The proportion of students in the experimental class whose mathematical literacy posttest scores meet the BTA and KKTP standards is less than or equal to 75%.

$H_1: \pi > 75\%$: The proportion of students in the experimental class achieving mathematical literacy posttest scores that satisfy the BTA and KKTP criteria is greater than 75%.

Calculation Statistic: A one-proportion z-test $z = \frac{\frac{x}{n}-\pi_0}{\sqrt{\frac{\pi_0(1-\pi_0)}{n}}}$ was performed using Microsoft Excel.

Testing Criteria: Reject $H_0 H_0$ if the calculated z-value exceeds the critical z-value from the z-distribution table at the specified significance level ($\alpha = 0.05$).

6) Mean Difference Test

Hypothesis:

$H_0: \mu_1 \leq \mu_2$: The mean posttest score of students in the experimental class (PBL with a realistic approach assisted by Moodle) is less than or equal to that of students in the control class (PBL with a scientific approach).

$H_1: \mu_1 > \mu_2$: The mean posttest score of students in the experimental class exceeds that of students in the control class.

Calculation Statistic: An independent samples t-test $t = \frac{\overline{x_1}-\overline{x_2}}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}$ with $s = \sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}}$ was conducted using Microsoft Excel.

Testing Criteria: Reject H_0 if the calculated t value exceeds the critical t value from the t-distribution table at the specified significance level ($\alpha = 0.05$).

7) Proportion Difference Test

Hypothesis:

$H_0: \pi_1 \leq \pi_2$: The proportion of students achieving mastery in the experimental class (PBL with a realistic approach assisted by Moodle) is less than or equal to that in the control class (PBL with a scientific approach).

$H_1: \pi_1 > \pi_2$: The proportion of students achieving mastery in the experimental class is greater than that in the control class.

Calculation Statistic: A two-proportion z-test $z = \frac{\frac{x_1}{n_1} - \frac{x_2}{n_2}}{\sqrt{pq\left\{\frac{1}{n_1} + \frac{1}{n_2}\right\}}}$ was conducted using Microsoft Excel.

Testing Criteria: Reject H_0 if the computed z value exceeds the critical value from the z-distribution table at the specified significance level ($\alpha = 0.05$).

8) N-Gain Average Improvement Test

Hypothesis:

$H_0: \mu_{g_1} \le \mu_{g_2}$: The average gain in mathematical literacy among students in the experimental class (PBL with a realistic approach assisted by Moodle) is less than or equal to that of the control class (PBL with a scientific approach).

$H_1: \mu_{g_1} > \mu_{g_2}$: The average gain in mathematical literacy among students in the experimental class is greater than that of the control class.

Calculation Statistic: A z-test for comparing average normalized gain (N-Gain), computed using: $(g_E) = \frac{\overline{x_{E_2}} - \overline{x_{E_1}}}{100 - \overline{x_{E_1}}}$ and $(g_K) = \frac{\overline{x_{K_2}} - \overline{x_{K_1}}}{100 - \overline{x_{K_1}}}$. A N-Gain conducted using Microsoft Excel.

Testing Criteria: Reject H_0 if the value of $z \ge z_{(0,5-\alpha)}$ (from the z-distribution table at $\alpha = 0.05$).

IV. Result and Discussion

A. Quality of Learning

The quality of learning in this study will answer the research objectives. Instructional quality in this research is defined by the application of a problem-based learning model with a realistic approach, facilitated through Moodle, within the experimental class. There are three aspects or stages that are considered in assessing the quality of learning, namely (1) the learning planning stage; (2) the learning implementation stage; and (3) the learning evaluation stage. Before conducting research, the planning stage is the first stage carried out by researchers. At this planning stage, all learning devices and research instruments that have been prepared by researchers must be tested or validated by validators. There are two validators in this study, namely the supervisor as an expert validator (validator 1) and the math teacher of SMP Negeri 20 Semarang as a practitioner validator (validator 2). The learning tools that will be validated are the Flow of Learning Objectives (ATP), independent curriculum teaching modules, teaching materials, and Learner Worksheets (LKPD). To interpret the validation results, percentage criteria were used, as presented in Table 2.

Table 2. Interpretation criteria for the validation results of learning instruments

Percentage Range (%)	Category	Interpretation
85–100	Very Good	Highly valid; the instrument is usable without revision.
70–84	Good	Valid; the instrument is usable with minor revisions if necessary.
55–69	Fair	Moderately valid; the instrument requires revision before being used.
<55	Poor	Not valid; the instrument requires substantial revision or redevelopment.

At the planning stage, the research instruments requiring validation included the mathematical literacy pretest and posttest, the GEFT cognitive style test, student response questionnaires, teacher observation forms, and interview protocols. The validation process resulted in a recapitulation of the outcomes related to both instructional tools and research instruments, as shown in Table 3.

Table 3. Recapitulation of validation results of learning devices and research instruments

No.	Component	Class	Validation Result		Average (%)	Criteria
			Validator 1 (%)	Validator 2 (%)		
1	Flow of Learning Objectives (ATP)	Experiment	90	100	95	Very Good
		Control	92.5	100	96.25	Very Good
2	Teaching Module	Experiment	90.77	98.46	94.61	Very Good
		Control	90.77	98.46	94.61	Very Good
3	Teaching Materials	-	91.82	98.18	95	Very Good
4	Learner Worksheets (LKPD)	-	91.43	97.14	94.28	Very Good
5	Test of Type A Question *(Pretest)*	-	90	100	95	Very Good
6	Test of Type B Question *(Posttest)*	-	91.43	100	95.71	Very Good
7	*GEFT* Cognitive Style Test Trial	-	90	97.5	93.75	Very Good
8	Student Response Sheets	-	92.5	100	96.25	Very Good
9	Teacher Observation Sheets	-	91.43	100	95.71	Very Good
10	Interview Guidelines	-	91.11	100	95.55	Very Good
	Average		-	-	95.14	Very Good

The second stage is the learning implementation stage. The learning implementation was conducted in two groups: Class VII-G functioned as the experimental group and Class VII-F as the control. The lesson focused on Data Presentation, with the researcher serving as the instructor. Learning effectiveness was evaluated based on observations of instructional activities and student engagement. The observation of teacher activities aimed to assess the teacher's ability to deliver content aligned with the learning objectives through the application of a problem-based learning model combined with a realistic approach and assisted by Moodle.

To assess the quality of the learning implementation, a percentage-based observation rubric was used. The interpretation criteria are presented in Table 4.

Table 4. Interpretation criteria for the observation of learning implementation

Percentage Range (%)	Category	Interpretation
85–100	Very Good	The implementation is highly effective and fully aligned with the plan.
70–84	Good	The implementation is generally effective, with only minor deviations.
55–69	Fair	The implementation shows moderate effectiveness but needs improvement.
<55	Poor	The implementation is ineffective and requires major adjustments.

The outcomes of the observational evaluation of learning implementation over four instructional sessions are summarized in Table 5.

Table 5. Results of observational assessment on learning implementation

Learning to-	Percentage (%)	Criteria
1	93.52	Very Good
2	95.37	Very Good
3	97.22	Very Good
4	97.22	Very Good
Average	95.83	Very Good

As shown in Table 5, the average score is 95.83% which indicates that the teacher's skills in learning the problem-based learning model a with realistic approach assisted by Moodle have very good criteria.

In parallel, the observation of students' responses aimed to evaluate the practicality and effectiveness of the learning process as implemented by the teacher. The data on the value of students' responses obtained were analyzed using the average value of each statement item filled in by students.

The interpretation of students' responses to the learning process was based on percentage-based categories, as shown in Table 6.

Table 6. Interpretation criteria for the evaluation of student responses

Percentage Range (%)	Category	Interpretation
85–100	Very Good	Students responded with high levels of engagement and positive attitudes.
70–84	Good	Students showed positive responses, though with some lack of enthusiasm.
55–69	Fair	Responses were neutral or moderately engaged, indicating room for improvement.
<55	Poor	Students exhibited low engagement or negative responses toward the learning.

The results of the students' response evaluation are displayed in Table 7.

Table 7. Results of learner responses assessment

No.	Aspect	Percentage (%)	Criteria
1.	Learners' attitude towards the learning process in class.	82.97	Good
2.	Students' interest in learning mathematics with a problem-based learning model with realistic approach assisted by Moodle.	85.47	Very Good
3.	The relationship between mathematics learning in the classroom with the problem-based learning model with realistic approach assisted by Moodle on Data Presentation material.	88.45	Very Good
4.	Learning with Moodle.	88.96	Very Good
	Average	86.46	Very Good

As shown in Table 7, the average student response to the learning process using the problem-based learning model with a realistic approach assisted by Moodle reached 86.46%, which falls within the "very good" category. This indicates that the integration of Moodle into the problem-based learning framework effectively fostered student engagement and had a positive impact on their overall learning experience.

The instructional design employed in the experimental group, which combined problem-based learning with a realistic approach (PMRI) and was facilitated by Moodle, was a key factor in the observed improvement in students' mathematical literacy. The organized presentation of contextual problems, the facilitation of collaborative discussions, and the integration of digital tools within Moodle supported the implementation of PMRI principles. These factors contributed to the improvement of students' conceptual understanding and their capacity to apply mathematical reasoning in real-world contexts, as evidenced by the higher posttest scores and N-Gain values observed in the experimental class.

The analysis of the two assessments—teacher observations and student responses—confirmed that the implementation of the learning model met the very good criteria. This demonstrates that the teaching approach used effectively aligned with the learning objectives and enhanced the students' engagement.

Furthermore, the evaluation phase was conducted to measure the effectiveness of the problem-based learning model incorporating a realistic approach and assisted by Moodle in enhancing students' mathematical literacy. This evaluation was guided by five core indicators of learning effectiveness:

1) the average mathematical literacy score in the experimental class met the individual mastery criteria, as defined by the Actual Completion Limit (BTA) and the Criteria for Achievement of Learning Objectives (KKTP);
2) the classical mastery proportion in the experimental class also fulfilled the required threshold, indicating that a sufficient percentage of students achieved mastery according to BTA and KKTP benchmarks;
3) the average mathematical literacy score of students in the experimental class exceeded that of the control class, demonstrating the positive effect of the implemented intervention;
4) the proportion of students attaining classical mastery was greater in the experimental class than in the control class; and
5) the average gain in mathematical literacy among students in the experimental class was significantly greater than that of the control group, demonstrating improved learning outcomes over time.

The pretest and posttest results served as the basis for evaluating the learning process and its effectiveness in enhancing mathematical literacy in both the experimental and control groups.

B. Preliminary Data Analysis (Pretest)

An initial data analysis was performed to examine whether a statistically significant difference existed in the baseline mathematical literacy levels between the experimental and control classes. The mean pretest scores of both groups are presented in Table 8.

As shown in Table 8, the average pre-intervention mathematical literacy scores in both the experimental and control classes were relatively low. The initial stage of analysis included a normality test to determine whether the sample data conformed to a normal distribution. Utilizing the Kolmogorov–Smirnov test in IBM SPSS 25, the significance values for both groups exceeded the threshold of 0.05 (Sig. = 0.051 > 0.05 for experiment class and Sig. = 0.200 > 0.05 for control class). Consequently, the null hypothesis—stating that the data are drawn from a normally distributed population—was not rejected. These findings indicate that the distribution of pretest scores in mathematical literacy for both groups conformed to the assumption of normality.

Table 8. Mathematical literacy pretest mean score results

Class	Average
Control Class	53.82
Experiment Class	57.50

The second analysis involved a homogeneity test to determine whether the two groups exhibited equal variances. Based on Levene's Test conducted using IBM SPSS 25, the obtained significance value exceeded 0.05 (Sig. = 0.224 > 0.05). Therefore, the null hypothesis—stating that the variances of both groups are equal—was accepted. This finding indicates that the pretest scores of students in the experimental and control groups were statistically homogeneous.

In the third stage of analysis, an independent samples t-test was conducted to determine whether a statistically significant difference existed between the mean pretest scores of the experimental and control groups. The test produced a two-tailed significance value (Sig. (2-tailed) = 0.192), which exceeded the 0.05 threshold. Consequently, the null hypothesis—stating that there is no difference in the mean scores between the two groups—was retained. This outcome suggests that, prior to the instructional intervention, the experimental and control classes exhibited equivalent levels of mathematical literacy.

Based on the results of the normality, homogeneity, and two mean similarity tests, it can be concluded that both sample groups—Class VII-F and Class VII-G—are suitable for comparison in this study. They originate from populations that are normally distributed, have equal variances, and share equivalent levels of initial mathematical literacy prior to the implementation of the learning treatments.

C. Final Data Analysis (Posttest)

The posttest data analysis was conducted to evaluate the effectiveness of the problem-based learning model incorporating a realistic approach and assisted by Moodle. This evaluation was based on five indicators of learning effectiveness. Table 9 displays the average posttest scores of students' mathematical literacy in both the control and experimental classes.

Table 9. Mathematical literacy posttest mean score results

Class	Average
Control Class	63.82
Experimental Class	77.81

Prior to conducting the hypothesis testing, prerequisite tests were performed, including tests for normality and homogeneity. Normality Test based on the output from IBM SPSS 25, the Kolmogorov-Smirnov significance value for the experimental class was Sig. = 0.56 > 0.05 and for the control class was Sig. = 0.168 > 0.05. Since both values are greater than 0.05, the null hypothesis is accepted, indicating that the data in both groups are normally distributed. Meanwhile, Homogeneity Test with The Levene's test for equality of variances yielded a significance value of Sig. = 0.258 > 0.05. Since this value exceeds 0.05, the null hypothesis is accepted, indicating that the posttest scores of both groups exhibit homogeneous variances.

Given that the data satisfied the assumptions of normality and homogeneity, hypothesis testing was deemed appropriate to proceed. Before testing the hypotheses, the average values for the Minimum Completion Criteria (BTA) and the Criteria for Achieving Learning Objectives (KKTP) were determined. These values were used as benchmarks for assessing completeness and effectiveness. The average BTA and KKTP threshold was established at $65.04 \cong 65$.

The first hypothesis test, namely the individual mastery test, was carried out using a one-sample t-test. This test aimed to examine whether the average mathematical literacy score of students in the experimental class—who were taught using a problem-based learning model integrated with a realistic approach and assisted by Moodle—had met the established threshold for individual mastery. This threshold was defined by the Actual Completion Limit (BTA) in accordance with the Learning Objective Achievement Criteria (KKTP), with a minimum completeness benchmark of 65. The results of the one-sample right-tailed t-test are summarized in Table 10.

Table 10. One-sample t-test results

$\bar{x}$	s	n	t_{hitung}	$t_{(0.95);(31)}$	Conclusion
77.81	10.84	32	6.662	2.040	$\mu > 65$

As shown in Table 10, the experimental class attained a mean posttest score of 77.81 with a standard deviation of 10.84. The right-tailed t-test yielded a test statistic that exceeded the critical value, thereby meeting the rejection criteria for the null hypothesis ($t_{hitung} = 6.662 \geq t_{(0.95);(31)} = 2.040$). Therefore, it can be concluded that the mathematical literacy scores of students instructed through the problem-based learning model with a realistic approach assisted by Moodle met the individual mastery criterion of 65. Therefore, the students are categorized as having achieved individual mastery.

Table 11. One-sample proportion test results

Proportion (π_0)	z_{hitung}	$z_{(0.45)}$	Criteria	Conclusion
75%	2.041	1.65	$z_{hitung} \geq z_{(0.45)}$	$\pi > 75\%$

The second hypothesis test, namely the classical completeness test, was conducted using a one-sample proportion test (z-test). This test was conducted to determine whether the proportion of students in the experimental class who attained mathematical literacy scores equal to or exceeding the BTA and KKTP threshold of 65 met the criterion for classical completeness, defined as at least 75% of students. The z-test results are summarized in Table 11.

The third hypothesis was tested using a right-tailed Independent Samples T-Test to assess differences in the mean posttest scores between the experimental and control groups. This analysis aimed to determine whether the implementation of a problem-based learning model integrated with a realistic approach and assisted by Moodle resulted in significantly higher mathematical literacy outcomes compared to the same model combined with a scientific approach. The results of this analysis are displayed in Table 12.

The findings from the third hypothesis test showed that the experimental class obtained an average posttest score of 77.81 in mathematical literacy, while the control class recorded a lower mean score of 64.26. A one-tailed independent samples t-test was conducted to assess the difference between the two means. The resulting t-value exceeded the critical threshold, meeting the criteria for rejecting the null hypothesis. These results suggest that students who received instruction through a problem-based learning model integrated with a realistic approach and assisted by Moodle demonstrated significantly greater mathematical literacy than their peers who were taught using the same model combined with a scientific approach.

Table 12. Independent sample t-test results

$\overline{x_1}$	$\overline{x_2}$	t_{hitung}	$t_{(0.95);(64)}$	Criteria	Conclusion
77.81	64.26	5.457	1.998	$t_{hitung} \geq t_{(0.95);(31)}$	$\mu_1 > \mu_2$

The fourth hypothesis test was a proportion difference test, conducted using a right-tailed two-proportion z-test. This test aimed to evaluate whether the proportion of students in the experimental class who met the minimum mastery criteria—based on the Actual Completion Limit (BTA) and the Learning Objective Achievement Criteria (KKTP)—was greater than that of the control class. The results of this analysis are presented in Table 13.

Table 13. Right-tailed two proportion z-test results

z_{hitung}	$z_{(0.45)}$	Criteria	Conclusion
3.379	1.65	$z_{hitung} \geq z_{(0.45)}$	$\pi_1 > \pi_2$

The analysis yielded a z-value that met the threshold for rejecting the null hypothesis. Accordingly, it can be inferred that the proportion of students in the experimental class who met the mastery criteria was significantly greater than that observed in the control class. This finding affirms the effectiveness of the problem-based learning model with a realistic approach assisted by Moodle in enhancing students' mathematical literacy.

Table 14. Right-Tailed two-mean difference test of n-gain scores

$\overline{x_{g_1}}$	$\overline{x_{g_2}}$	t_{hitung}	$t_{(0.95);(64)}$	Criteria	Conclusion
0.5025	0.2046	5.457	1.998	$t_{hitung} \geq t_{(0.95);(31)}$	$\mu_1 > \mu_2$

To evaluate the fifth hypothesis, the analysis focused on students' mean improvement in mathematical literacy, as indicated by their N-Gain scores. A one-tailed independent samples t-test was applied to examine whether the experimental group achieved a significantly higher average gain than the control group. The results of this test are summarized in Table 14.

The analysis showed that the experimental class attained an average N-Gain score of 0.5025, whereas the control class achieved a lower average of 0.2046. Since the obtained t-value was greater than the critical value, the null hypothesis was rejected. This finding indicates that students in the experimental class experienced a significantly greater improvement in mathematical literacy than those in the control class. Moreover, according to the N-Gain score classification, students in the experimental group exhibited a moderate degree of improvement, whereas those in the control group showed only a low level of gain. A comparative summary of N-Gain scores for both groups is provided in Table 15.

As shown in Table 15, the average N-Gain score for students in the experimental group was g = 0.5025, indicating a moderate level of improvement in mathematical literacy resulting from the implementation of the problem-based learning model with a realistic approach assisted by Moodle. In contrast, the control group attained an average N-Gain score of *g* = 0.2046, which is categorized as low improvement, reflecting the outcome of instruction using the problem-based learning model with a scientific approach.

Table 15. N-gain score classification for experimental and control classes

Class	Average			Criteria
	Pretest	Posttest	N-Gain	
Experiment	57.50	77.81	0.5025	Medium
Control	53.82	63.82	0.2046	Low

Based on the results of hypothesis testing, the following conclusions were drawn regarding the impact of the instructional intervention: (1) students who received instruction through a realistic approach supported by Moodle achieved average mathematical literacy scores that met the established mastery benchmarks, namely the BTA and KKTP criteria; (2) the proportion of learners achieving classical mastery under this learning approach exceeded the required minimum threshold, indicating strong group-level performance; (3) in terms of average posttest scores, those taught using the realistic–Moodle-integrated model outperformed their peers who were instructed through the scientific variant of the problem-based learning model; (4) a higher percentage of students attained individual mastery under the realistic approach compared to those taught with the alternative method; and (5) the average gain in mathematical literacy, as indicated by the N-Gain score, was significantly greater for students engaged in the realistic–Moodle-supported learning, demonstrating more substantial improvement than that observed under the scientific approach.

This study's findings add to the expanding literature that underscores the role of educational technologies —especially LMS such as Moodle—to enhance students' mathematical literacy. Through features such as asynchronous access, interactive discussions, real-time feedback, and structured content delivery, technology provides students with opportunities to engage more deeply with mathematical concepts in authentic contexts. This is consistent with prior research indicating that digital learning environments can facilitate the development of essential aspects of mathematical literacy, such as reasoning, problem-solving strategies, and the ability to interpret and communicate mathematical ideas [11, 29]. Moreover, the integration of technology supports independent learning and enhances metacognitive awareness—both critical for enabling students to interpret real-world problems and apply mathematical concepts meaningfully. These findings underscore that, when combined with well-designed pedagogical frameworks such as problem-based learning and the realistic approach, technology can act as a powerful catalyst for advancing students' mathematical literacy in 21st-century learning contexts.

Based on the preceding discussion, it can be concluded that mathematics instruction using the problem-based learning model with a realistic approach assisted by Moodle is effective in enhancing students' mathematical literacy. This finding aligns with previous studies indicating that problem-based learning has a positive impact on the development of students' mathematical literacy skills [30]. The effectiveness of this model lies in its emphasis on contextual problem-solving, which actively engages students in addressing real-world challenges [31]. The problem-based learning model involves five key stages: (1) presenting problems to students, (2) organizing learning activities, (3) guiding investigations, (4) developing and presenting solutions, and (5) analyzing and evaluating the problem-solving process. This study incorporates a realistic approach that emphasizes learning through real-life contexts relevant to students. Implementing a problem-based learning model integrated with a realistic approach has been shown to enhance students' mathematical literacy [32]. This is because in its application, the application of a realistic approach makes it easier for students to understand concepts because the context raised has been adapted to everyday life [33]. A separate study found that the implementation of a problem-based learning model incorporating a realistic approach, supported by platforms such as Edmodo and Schoology, led to improvements in both the mathematization process and students' mathematical literacy at SMP Negeri 4 Semarang and SMP Negeri 15 Semarang [23, 34–36].

The learning process was assisted by the use of the Moodle LMS. Moodle played a key role in classroom implementation, as its user-friendly features facilitated both teachers and students in designing and engaging with the intended learning activities.

Moodle was used as a digital platform to actualize the principles of the realistic mathematics education (PMRI) approach [23, 28]. Specifically, Moodle facilitated the use of contextual problems through digital materials uploaded as learning resources and initial problem scenarios presented via the forum feature [29, 33]. This supports the first principle of PMRI: learning that starts from real and meaningful contexts for students. In addition, the use of the discussion forum and chat features enabled continuous interaction among students and between students and the teacher, reflecting the interactivity element of PMRI [11]. Students discussed real-world problems, compared strategies, and refined their mathematical models collaboratively in a digital environment.

The assignment module in Moodle was utilized to collect students' individual and group work, allowing teachers to provide formative feedback, in line with collaborative learning theory [12]. Furthermore, students were encouraged to use uploaded digital tools and simulations (e.g., graphs, data visualization) to model mathematical ideas, which connects to the PMRI principle of using models and bridging tools from reality to abstract concepts [9].

In addition to the learning model and approach, the utilization of the Moodle learning management system significantly contributes to enhancing students' mathematical literacy. These results are consistent with previous studies that have reported notable gains in students' mathematical literacy through the integration of Moodle into instructional practices. Easy access and can be done anywhere and anytime makes Moodle a learning management system that makes it easy for users, especially students to learn without knowing time and place. For teachers, the use of Moodle in learning can help teachers in planning and creating semester learning plans, managing learning activities and materials, and much more [36]. The use of Moodle in the learning process can facilitate students to be active in learning so that this is in line with the syntax of the problem-based learning model where learning is more student-centered [29].

Based on assessments conducted during the planning, implementation, and evaluation phases, it can be concluded that the problem-based learning model with a realistic approach assisted by Moodle demonstrates very high quality in enhancing students' mathematical literacy.

V. Conclusion

From the results of the research and discussion that have been described, the following conclusions are formulated. Learning with a problem-based learning model using the realistic approach assisted by quality Moodle can improve students' mathematical literacy, which is explained as follows:

1) The quality of learning at the planning stage meets the very good criteria based on the results of the validation assessment by validator 1 and validator 2 of the learning tools and research instruments.
2) The quality of learning at the implementation stage meets the very good category based on the results of teacher observation assessments and student responses to the implementation of learning that has been implemented.
3) The quality of learning at the evaluation stage meets the five assessment indicators, namely:
    a) Students taught using the problem-based learning model with a realistic approach assisted by Moodle achieved an average mathematical literacy score that met the mastery criteria (BTA and KKTP ≥65);
    b) The proportion of students achieving mastery reached 75%, meeting the classical completeness criteria;
    c) The average mathematical literacy of students in the experimental group was higher than that of students taught using the scientific approach;
    d) The proportion of students achieving mastery in the experimental group was greater than in the control group;
    e) The average gain in mathematical literacy was higher among students taught with the realistic approach and Moodle compared to those taught using the scientific approach.

The implementation of a problem-based learning model with a realistic approach assisted by Moodle can serve as an innovative strategy for mathematics instruction in schools to enhance students' mathematical literacy. Furthermore, the findings of this study may serve as a reference for future researchers seeking to apply this model to develop other student competencies beyond mathematical literacy.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

W conducted the conceptualization, research design, analysis, and wrote the paper; AZS contributed to the conceptualization, data collection, and writing of the paper;

SM performed the statistical data analysis and reviewed the manuscript; ARH contributed to writing, reviewing, and revising the manuscript; all authors had approved the final version.

REFERENCES

[1] N. Agustina, "Improving realistic mathematics learning outcomes about spatial shapes with the project-based learning model in class 5 of SDN Punten 02 Batu," *Jurnal Pendidikan Taman Widya Humaniora (JPTWH)*, vol. 2, no. 3, pp. 1–23, 2023. (in Indonesian)

[2] I. J. Sugiarto, B. Usodo, and D. R. S. Saputro, "High school students' mathematic literacy performance in solving linear programming problem," *Journal of Physics: Conference Series*, vol. 1776, no. 1, 012014, 2021. doi: 10.1088/1742-6596/1776/1/012014.

[3] M. Chiasson and V. Freiman, "Rethinking the 21st-century school: New citizens' skills for the digital era and their interaction with mathematics teaching and learning," in *Mathematics and Its Connections to the Arts and Sciences (MACAS),* C. Michelsen, A. Beckmann, V. Freiman, U. T. Jankvist, and A. Savard, Eds., Cham: Springer, 2022, pp. 69–107. doi: 10.1007/978-3-031-10518-0_5

[4] S. Suciati, S. Munadi, S. Sugiman, and W. D. R. Febriyanti, "Design and validation of mathematical literacy instruments for assessment for learning in Indonesia," *European Journal of Educational Research*, vol. 9, no. 2, pp. 865–875, 2020. doi: 10.12973/eu-jer.9.2.865

[5] K. Stacey and R. Turner, "The evolution and key concepts of the PISA mathematics frameworks," in *Assessing Mathematical Literacy*, K. Stacey and R. Turner, Eds., Cham: Springer, 2015, pp. 5–33. doi: 10.1007/978-3-319-10121-7_1

[6] V. M. Kolar and T. Hodnik, "Mathematical literacy from the perspective of solving contextual problems," *European Journal of Educational Research*, vol. 10, no. 1, pp. 467–483, 2021. doi: 10.12973/EU-JER.10.1.467

[7] F. Jensen, A. Pettersen, T. S. Frønes, A. Eriksen, M. Løvgren, and E. K. Narvhus, *PISA 2022. Norske Elevers Kompetanse i Matematikk, Naturfag og Lesing*, Cappelen Damm Akademisk/NOASP, 2023. doi: 10.23865/noasp.205

[8] I. Makruf, A. A. Rifa'i, and Y. Triana, "Moodle-based online learning management in higher education," *International Journal of Instruction*, vol. 15, no. 1, pp. 135–152, 2022. doi: 10.29333/iji.2022.1518a

[9] A. Sibgatullina, R. Ivanova, and E. Yushchik, "Moodle learning system as an effective tool for implementing the innovation policy of the university," *International Journal of Web-Based Learning and Teaching Technologies*, vol. 17, no. 1, pp. 1–12, 2022. doi: 10.4018/IJWLTT.298683

[10] I. S. Utami, "Implementation of e-learning to improve student learning activities," *Jurnal Komputer Terapan*, vol. 2, no. 2, 169–178, 2016. (in Indonesian)

[11] I. Fitriyaningsih, R. Priyadi, and K. Ni'mah, "Development of moodle to enhance mathematical literacy on trigonometry topic," *Jurnal Kajian Pembelajaran Matematika*, vol. 7, no. 2, 112, 2023. doi: 10.17977/um076v7i22023p112-118 (in Indonesian)

[12] J. P. Widodo and J. Slamet, "Lecturers' perspectives through e-learning by using moodle for post-graduate students at STKIP PGRI Sidoarjo," in *Proc. the International Seminar on Language, Education, and Culture (ISoLEC)*, Atlantis Pres, 2021, pp. 167–171. doi: 10.2991/assehr.k.211212.031

[13] S. Ningsih, "Realistic mathematics education: An alternative model for school mathematics learning," *Jurnal Pendidikan Matematika*, vol. 1, no. 2, pp. 73–94, 2014. doi: 10.18592/jpm.v1i2.97 (in Indonesian)

[14] S. Y. Karaca and A. Özkaya, "The effects of realistic mathematics education on students' math self reports in fifth grades mathematics course," *International Journal of Curriculum and Instruction*, vol. 9, no. 1, pp. 81–103, 2017.

[15] Wardono and S. Mariani, "The realistic learning model with character education and PISA assessment to improve mathematics literacy," *International Journal of Education and Research*, vol. 2, no. 7, pp. 361–372, 2014.

[16] Wardono, S. Mariani, B. Waluya, Kartono, and Sukestiyarno, "The realistic scientifict humanist learning model with character education to improve mathematics literacy based on PISA," *International Journal of Education and Research*, vol. 3, no. 1, pp. 349–362, 2015.

[17] N. S. Widyastuti and P. Pujiastuti, "The influence of Indonesian realistic mathematics education (PMRI) on students' conceptual understanding and logical thinking," *Jurnal Prima Edukasia*, vol. 2, no. 2, pp. 183–193, 2014. doi: 10.21831/jpe.v2i2.2718 (in Indonesian)

[18] A. M. Hasibuan, S. Saragih, and Z. Amry, "Development of learning materials based on realistic mathematics education to improve problem solving ability and student learning independence," *International Electronic Journal of Mathematics Education*, vol. 14, no. 1, pp. 243–252, 2018. doi: 10.29333/iejme/4000

[19] M. S. Widodo, "The effectiveness of mathematics learning using the indonesian realistic mathematics education (PMRI) approach," *MATHEdunesa: Jurnal Ilmiah Pendidikan Matematika*, vol. 3, no. 2, pp. 42–48, 2014. (in Indonesian)

[20] H. A. Fauzia, "The implementation of the problem-based learning model to improve mathematics learning outcomes in elementary school," *Jurnal Primary Program Studi Pendidikan Guru Sekolah Dasar Fakultas Keguruan dan Ilmu Pendidikan Universitas Riau*, vol. 7, no. 1, pp. 40–47, 2018. (in Indonesian)

[21] A. Y. Yusri, "The effect of the problem-based learning model on the mathematical problem-solving ability of Grade VII students at Pangkajene State Middle School," *Mosharafa: Jurnal Pendidikan Matematika*, vol. 7, no. 1, pp. 51–62, 2018. doi: 10.31980/mosharafa.v7i1.474 (in Indonesian)

[22] S. A. Octavia, *Model-model pembelajaran*. Jakarta: Deepublish, 2020.

[23] Wardono, S. B. Waluya, Kartono, Mulyono, and S. Mariani, "Junior high school students' mathematical literacy in realistic problem-based learning using Edmodo and Schoology," *Prisma, Prosiding Seminar Nasional Matematika*, 2018, pp. 477–497. (in Indonesian)

[24] OECD. (2018). *PISA 2021 Mathematics Framework (Draft)*. [Online]. Available: https://pisa2022-maths.oecd.org/files/PISA%202022%20Mathematics%20Framework%20Draft.pdf

[25] OECD, *PISA 2018 Assessment and Analytical Framework*, Paris: OECD Publishing, 2019.

[26] H. Freudenthal, *Revisiting Mathematics Education: China Lectures*, Mathematics Education Library, vol. 9, Dordrecht: Kluwer Academic Publishers, 2002. doi: 10.1007/0-306-47202-3

[27] D. C. Webb, H. V. D. Kooij, and M. R. Geist, "Design research in the Netherlands: Introducing logarithms using realistic mathematics education," *Journal of Mathematics Education at Teachers College*, vol. 2, no. 1, pp. 47–52, 2011. doi: https://doi.org/10.7916/jmetc.v2i1.708

[28] J. De Lange, *Mathematics, Insight and Meaning: Teaching, Learning and Testing of Mathematics for the Life and Social Sciences*, Utrech, the Netherlands: OW & OC, Rijksuniversiteit Utrecht, 1987.

[29] I. Maryati, D. Fisher, S. A. M. Yatim, and R. Mauladaniyati, "Statistical literacy ability of students through virtual learning environment based on moodle-learning management system," *International Journal of Information and Education Technology*, vol. 14, no. 1, pp. 99–106, 2024. doi: 10.18178/ijiet.2024.14.1.2029

[30] M. Faisal, A. Dhoruri, and F. N. Mahmudah, "The effect of the problem-based learning model on improving mathematical literacy skills," *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, vol. 13, no. 2, pp. 577–585, 2024. doi: 10.24127/ajpm.v13i2.8663 (in Indonesian)

[31] D. Y. Madyaratri, Wardono, and A. P. B. Prasetyo, "Students' mathematical literacy ability in problem-based learning viewed from learning styles," *Prisma, Prosiding Seminar Nasional Matematika*, 2019, pp. 648–658. (in Indonesian)

[32] B. M. Larasaty, Mustiani, and H. S. Pratini, "Improving mathematical literacy of Grade VIII students at SMP Bopkri 3 Yogyakarta through a PMRI approach bas," *Prosiding Seminar Nasional Etnomatnesia*, 2018, pp. 622–633. (in Indonesian)

[33] W. A. Najwa, "The PMRI approach as a school literacy movement in mathematics learning," *PRISMA, Prosiding Seminar Nasional Matematika*, 2018, pp. 575–581. (in Indonesian)

[34] A. Rosita, Wardono, and Kartono, "Discovery learning-PMRI in improving mathematics literacy of junior high school students," *Unnes Journal of Mathematics Education Research*, vol. 7, no. 1, pp. 35–39, 2018.

[35] Wardono and S. Mariani, "The analysis of mathematics literacy on PMRI learning with media schoology of junior high school students," *Journal of Physics: Conference Series*, vol. 983, no. 1, 2018. doi: 10.1088/1742-6596/983/1/012107

[36] Wardono, S. B. Waluya, S. Mariani, and S. D. Candra, "Mathematics literacy on problem based learning with Indonesian realistic mathematics education approach assisted e-learning Edmodo," *Journal of Physics: Conference Series*, vol. 693, no. 1, 2016. doi: 10.1088/1742-6596/693/1/012014