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MATHEMATICAL CRITICAL THINKING ABILITIES OF STUDENTS IN TERMS OF SELF-REGULATED LEARNING IN REALISTIC MATHEMATICS EDUCATION ASSISTED BY MOBILE LEARNING

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ABSTRACT

The students' mathematical critical thinking ability is categorized as still not good due to the teaching and lack of use of instructional media in the learning process. These factors also contribute to the students' low level of learning independence. Several studies have found that the mathematical critical thinking ability is still below average. One of the teaching methods that can help improve students' mathematical critical thinking ability is Realistic Mathematics Education (RME) assisted by mobile learning. This study aims to: (1) Test the effectiveness of RME assisted by mobile learning on students' mathematical critical thinking ability, and (2) Analyze and understand students' mathematical thinking ability in terms of their learning independence in RME assisted by mobile learning. The research method used is a mixed method with concurrent embedded research design. Quantitative research serves as the primary method, and qualitative research as the secondary method. The population in this study consists of seventh-grade students at MTs Al Wahdah Sumber in the academic year 2022/2023. The sample is determined using purposive sampling technique, selecting two classes as samples - Class VII A as the control group and Class VII B as the experimental group. Data collection techniques used in this study include tests, questionnaires, documentation, and interviews. Data analysis includes individual mastery test, classical mastery test, mean difference test, and proportion difference test. The results of this study indicate that: (1) RME assisted by mobile learning is effective in improving students' mathematical critical thinking ability, as evidenced by the average mathematical critical thinking ability of the experimental group reaching the actual mastery level, 75% mastery proportion in the experimental group, higher mean difference in the experimental group compared to the control group, and higher proportion in the experimental group compared to the control group, and (2) Diverse mathematical critical thinking abilities were found in the low, medium, and high learning independence groups.

Keywords: Mathematical Critical Thinking Skills, Self-Regulated Learning, Realistic Mathematics Education, Mobile Learning

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PRELIMINARY

Critical thinking is one of the higher-order thinking skills. According to (Liang et al., 2014), higher-order thinking is a combination of critical thinking, creative thinking, and foundational knowledge thinking. The ability to think critically in mathematics plays a crucial role for students in facing future changes (Muslimahayati, 2020). In line with this, several researchers (Kadir, 2017; Tiruneh et al., 2017; Widyatiningtyas et al., 2015) state that one of the skills that need to be developed is critical thinking ability.

Although it has been stated that critical thinking is one of the skills that needs to be developed, the reality is that the critical thinking ability of Indonesian students in mathematics is still very low and unsatisfactory. Based on the international study on mathematics achievement conducted by the Trends in International Mathematics and Science Study (TIMSS) in 2015, Indonesia ranked 44th out of 49 countries with an average score of 397 out of the international average score of 500 (Mullis et al., 2016). However, in 2019, based on the TIMSS study, Indonesia did not participate. Furthermore, data from the Programme for International Student Assessment (PISA) conducted by the Organization for Economic Co-operation and Development (OECD) in 2018 placed Indonesia at 73rd out of 79 countries with an average score of 386 out of the OECD average score of 489 (OECD, 2019). This indicates that the average scores in Indonesia are still below the international average, and Indonesia's ranking has not changed much over the years and is still lower than other countries.

Critical thinking skills are essential for students. Students with strong critical thinking abilities can solve mathematical problems better than those with low critical thinking abilities. Critical thinking ability in mathematics brings many benefits to students, including the ability to enhance and develop conceptual understanding and develop their thinking skills, enabling them to solve more complex problems easily (Ratnawati et al., 2020). A student's critical thinking ability can influence their ability, speed, and effectiveness in learning (Heong et al., 2011).

Research findings show that students' mathematical critical thinking abilities are still low (Putri et al., 2020; Warniasih et al., 2019). This was also highlighted by Maulidah et al., (2020), who found that students still lack critical thinking skills in mathematics. This greatly affects students' mathematics learning outcomes. Therefore, researchers believe that there is a need to improve students' mathematical critical thinking skills because it will affect the achievement of learning goals in schools.

Another fact is the low mathematical critical thinking ability observed from students' work when solving problems. The low mathematical critical thinking ability of students is due to their inability to understand the given problems, leading to (1) an inability to comprehend the meaning of the problems, (2) an inability to identify and infer relationships among statements, questions, concepts, descriptions, or other forms, (3) a lack of access to the credibility of statements/representations and the logical connection between statements, descriptions, questions, and concepts, and (4) an inability to identify and obtain the elements needed to draw conclusions. Because students do not understand mathematical concepts and the meaning of the problems, the indicators of mathematical critical thinking skills are not fulfilled by these students.

The low critical thinking ability is caused by several factors, one of which is the teaching methods employed by teachers. Teachers still have difficulty in selecting and using appropriate teaching models to deliver the content and learning objectives, which hinders the improvement of students' mathematical critical thinking abilities. Additionally, there is a lack of utilization of instructional media in the classroom learning process. These factors also contribute to the lack of development of students' self-regulated learning, which is crucial to support students' learning success. Individuals with high self-regulated learning tend to learn better, can monitor, evaluate, and organize their learning effectively, save time in completing tasks, and achieve higher scores (Sumarmo, 2002).

The need to develop self-regulated learning in individuals who study mathematics is supported by several research findings. Individuals with high self-regulated learning tend to learn better, can monitor, evaluate, and organize their learning effectively, save time in completing tasks, manage learning and time efficiently, and obtain higher scores in science subjects (Hargis, 2000). However, the current reality is that self-regulated learning has not been socialized and developed among students. They consider the teacher as the sole source of knowledge, leading to a dependency on others, especially teachers. However, knowledge can be acquired through various sources, places, facilities, and the surrounding environment, such as libraries, laboratories, and the internet (Yamin, 2008). This situation is also experienced by students at MTs Al Wahdah Sumber, where students tend to be passive and only receive information and instructions from teachers. They rarely ask questions about the presented material and often doubt their problem-solving abilities, leading to low self-regulated learning.

The higher the level of self-regulated learning of students, the better their learning independence, which in turn impacts their abilities and learning outcomes (Mulyono, 2021).

From these statements, it can be understood that self-regulated learning contributes to students' learning outcomes. Self-regulated learning is seen as any form of learning in which individuals have primary responsibility for planning, implementing, and even evaluating their efforts (Nagpal, 2013). Self-regulated learning has a significant influence on learning outcomes in all subjects, including primary school mathematics. Students' self-regulated learning enables them to take the initiative in solving problems without the help of others, thereby maximizing their learning scores or achievements.

To address these issues, an instructional model can be implemented to improve students' critical thinking skills. One model that can be used is Realistic Mathematics Education (RME). Realistic Mathematics Education (RME) is an alternative for teachers to support teaching and learning activities. RME fundamentally utilizes the reality and environment understood by students to facilitate the mathematics learning process, thereby achieving better mathematical education goals compared to before. Reality refers to tangible or concrete things that students can observe or understand through imagination, while the environment refers to the surroundings where students are, including the school, family, and community environments that students can understand. The environment, in this case, is also referred to as daily life. RME provides extensive opportunities for students to construct their knowledge through problem-solving processes (Warsito et al., 2018).

The learning model applied by educators in teaching and learning activities has its own respective steps or procedures according to the model used. The steps of a learning model are stages that must be executed accurately, as they can determine the success of the applied model. The syntax of implementing the RME learning model in this research refers to the opinion of Hobri (2009) as follows: (1) understanding contextual problems, (2) explaining contextual problems, (3) solving contextual problems, (4) comparing and discussing answers, and (5) drawing conclusions from the answers.

To support the Realistic Mathematics Education (RME) instructional approach, instructional media can be utilized. The role of instructional media is crucial as it aids the learning process for students. With instructional media, it is hoped that students' interest in learning can be enhanced (West, 2018). One suitable media that aligns with the current technological advancements is technology-based media. With the advancement of technology, various tools and resources have emerged, such as smartphones. This has led to innovations in media usage, particularly in the form of mobile learning.

Based on the description, it is necessary to conduct a study on whether Realistic Mathematics Education (RME) with the assistance of mobile learning is effective in improving students' mathematical critical thinking abilities. Additionally, it is important to investigate the students' mathematical critical thinking abilities in the context of RME with mobile learning, considering their level of self-regulated learning. The objective of this research is to examine the effectiveness of Realistic Mathematics Education (RME) with mobile learning in enhancing students' mathematical critical thinking abilities and to analyze students' mathematical critical thinking abilities in relation to their level of self-regulated learning in the context of RME with mobile learning.

This study will focus on analyzing students' mathematical critical thinking abilities in relation to their level of self-regulated learning in the context of Realistic Mathematics Education (RME) with mobile learning. The study will be conducted at MTs Al-Wahdah Sumber in the academic year 2022/2023. The researcher will administer a pretest to the experimental group and then teach them using the Realistic Mathematics Education (RME) model with mobile learning. Subsequently, the researcher will analyze the students' mathematical critical thinking abilities, taking into account their level of self-regulated learning, which will be classified into three levels.

METHODS

The research used a mixed-method approach with a sequential explanatory research design. The sequential explanatory design is characterized by a researcher combining quantitative and qualitative research gradually in the study. Quantitative data is collected and analyzed in the first stage, and then qualitative data is collected and analyzed in the second stage to strengthen the findings of the quantitative research conducted in the first stage. The population in this study consisted of 68 students from class VII of Al Wahdah Sumber Islamic Junior High School in the 2022/2023 academic year. The research sample consisted of Class VII A with 25 students as the control group and Class VII B with 25 students as the experimental group. The sample was determined using purposive sampling technique, considering the observation results that identified issues related to the low mathematical critical thinking skills of students, which resulted in low creativity in learning a subject, low self-regulated learning in mathematics affecting students' mathematical critical thinking skills, the use of an inappropriate learning model for students to improve their mathematical critical thinking skills, and the lack of use of instructional media for students in the mathematics learning process in the classroom.

The data collection techniques used in this study consisted of tests, questionnaires, documentation, and interviews. In this study, the researcher combined both quantitative and qualitative data. The data analysis used in this research was divided into two parts, namely qualitative and quantitative analysis. The types of data obtained in the study included pretest-posttest, questionnaires, observations, and interviews. The quantitative data analysis included tests for normality, homogeneity, individual achievement, class achievement, independent samples t-test, and proportion difference test. The qualitative data analysis consisted of four steps, namely data validity, data reduction, data presentation, and drawing conclusions.

The critical thinking indicators developed by Facione (2015) are widely used in research, indicating that these indicators can be used to measure critical thinking skills. Additionally, Facione's critical thinking indicators align with the definition of critical thinking skills in this study. The six critical thinking indicators developed by Facione are further elaborated by the researcher into several sub-indicators in the following table.

Table 1. Critical Thinking Skill Indicators

Indicator	Description
Interpretation	a. Students can accurately understand the meaning of the problem b. Students can clearly and accurately write down the information provided in the problem
Analysis	Students can clearly and accurately identify what the problem is asking for
Inference	a. Students can formulate methods or strategies to solve the problem b. Students can use appropriate concepts to solve the problem accurately
Evalution	a. Students can solve the problem based on the information provided b. Students can draw logical conclusions from the question asked.
Explanation	Students can provide answers with appropriate explanations
Self Regulation	Students can document step-by-step problem-solving processes thoroughly and accurately

The indicators of self-regulated learning used in this study are based on Mudjiman (2006) opinion. The indicators of self-regulated learning are explained in the following table.

Tabel 2. Self-Regulated Learning Indicators

Indicator	Description
Self-Confidence	Responsibility motivates individuals to do their best and take ownership of their assigned tasks with ease. Students who take responsibility for their learning can more easily achieve the desired accomplishments.

Indicator	Description
Activeness	Being actively involved in learning is crucial in the learning process. One form of student activity in the learning process is actively asking and answering questions posed by the teacher. Students who actively engage in learning generally find it easier to achieve success.
Discipline	Discipline involves training the ability to enhance self-control and adhere to certain rules or values. Discipline in learning can be demonstrated by establishing study periods and adhering to them, as it will facilitate students in achieving the desired outcomes.
Responsibility	Responsibility motivates individuals to do their best and take ownership of their assigned tasks with ease. Students who take responsibility for their learning can more easily achieve the desired accomplishments.
Motivation	Motivation is an effort that drives individuals or a group of people to pursue an expected goal or feel satisfaction with their actions. When someone receives appropriate motivation, they can maximize their learning outcomes.

Realistic Mathematics Education (RME) with the assistance of mobile learning is a learning model that combines RME with mobile applications as an innovative approach. In this study, the mobile application used is an Android software related to the learning materials.

The RME process supported by mobile learning can assist teachers and students in conducting teaching and learning activities. Teachers can provide learning materials without having to explain everything and write them on the whiteboard. Through the mobile application, teachers can simply provide students with the facility to use mobile devices in the learning process, both inside and outside the classroom.

This learning approach encourages students to discuss and express their opinions by following the instructions provided in the mobile application. Teachers play a role in facilitating and confirming students' understanding to prevent any misconceptions. The syntax of RME supported by mobile learning is presented in the following table.

Table 3. Syntax of RME Supported By Mobile Learning

Phase 1 The teacher provides contextual problems available in the mobile application, and students understand the problem accessed through the mobile application.
Phase 2 The teacher explains the situation and conditions of the problems presented in the mobile application, giving limited guidance or suggestions as necessary to

clarify specific parts that students haven't understood yet. The explanation is given until students understand the purpose of the problem.
Phase 3 Students individually solve the contextual problems presented in the mobile application in their own way, following the written solution instructions provided in the mobile application. The teacher motivates students to solve the problems using their own methods by asking questions or providing guidance and suggestions.
Phase 4 The teacher allocates time and opportunities for students to compare and discuss their answers to the problems presented in the mobile application in groups. Later, the answers are compared and discussed in a classroom discussion.
Phase 5 Based on the discussion, the teacher guides students to draw conclusions about procedures or concepts, with the teacher acting as a facilitator.

RESULTS AND DISCUSSION

Results In this section, the research results regarding the effectiveness of realistic mathematics education (RME) assisted by mobile learning on mathematical critical thinking abilities will be presented, including: (1) the average mathematical critical thinking ability of students in RME assisted by mobile learning reaching the Actual Mastery Criterion; (2) the proportion of students' mastery of mathematical critical thinking abilities in RME assisted by mobile learning exceeding 75% of the Actual Mastery Criterion; (3) the average mathematical critical thinking ability of students in RME assisted by mobile learning being higher than the average mathematical critical thinking ability of students in conventional learning; and (4) the proportion of students' mathematical critical thinking abilities in RME assisted by mobile learning being higher than the proportion of students' mastery of mathematical critical thinking abilities in conventional learning.

The research sample was divided into two classes: the experimental class, which used RME assisted by mobile learning, and the control class, which used conventional learning. The research sample consisted of 25 students in the experimental class and 25 students in the control class from Grade VII of MTs Al Wahdah Sumber. Before conducting the testing to determine the effectiveness of RME assisted by mobile learning, prerequisite tests were performed. The researcher used the post-test scores to verify whether the classes used had a normal distribution, equal variances (homogeneity), and similar mathematical critical thinking abilities. After conducting the prerequisite tests, the final data obtained are presented in Table 3 as follows:

Table 4. Results of Normality Test and Homogeneity Test

Test	Sig.	Criteria
Normality test	0.200	H_0 accepted
Homogeneity Test	0.264	H_0 accepted

Based on Table 4, it can be seen that the data are normally distributed and homogenous as the significance values (sig) are greater than 0.05. Based on the results of the normality test in Table 4, it can be concluded that H_0 is accepted because the sig value is greater than 0.05. Therefore, the final test data are normally distributed. Based on the results of the homogeneity test in Table 4, it is known that the significance value of the final test data is 0.264. It can be concluded that H_0 is accepted, indicating that the variances of the control and experimental classes are homogeneous. After conducting the normality and homogeneity tests, the next step is to perform hypothesis testing for the final data.

Hypothesis testing is conducted to determine the effectiveness of realistic mathematics education with mobile learning on mathematical critical thinking abilities using the criteria of individual mastery, classical mastery, mean difference, and proportion difference tests. The individual mastery test is used to determine whether the average score of mathematical critical thinking abilities in realistic mathematics education with mobile learning reaches the expected level. The criteria for student mastery are set at 63, based on the Actual Mastery Criterion. The results of the test conducted using the z-test with the help of Microsoft Excel can be seen in Table 5.

Table 5. Individual Mastery Test

	t test	
Final score	t_{table}	t_{value}
	2.064	6.627

Based on Table54, the calculated t_{value} is 6.627. Since the t_{value} is greater than the t_{table} value (6.627 > 2.064), H_0 is rejected and H_1 is accepted. This means that the average score of students' mathematical critical thinking abilities in the experimental class using realistic mathematics education with mobile learning has reached the minimum mastery criterion. The minimum mastery criterion for classical mastery is set at 75%.

The classical mastery test is used to determine whether realistic mathematics education with mobile learning helps students surpass the classical mastery criterion in mathematical critical thinking abilities for Grade VII. The minimum mastery criterion for classical mastery is set at 75%. The results of the test conducted using the z-test with the help of Microsoft Excel can be seen in Table 6.

Table 6. Classical Mastery Test

x	n	π_0	z_{table}	z_{value}
23	25	0.75	1.64	1.96

Based on Table 6, it is known that out of 25 students, 23 have achieved mastery, resulting in a z-value of 1.96 > 1.64 (z_{table}) at a 5% confidence level. Therefore, H_0 is rejected, and it can be concluded that the classical mastery of the experimental class exceeds 75%.

The mean difference test is used to determine the difference in mean between the class using realistic mathematics education with mobile learning and the class using conventional learning. Among these two classes, which one has a higher average. The results of the mean difference test conducted using the t-test with the help of Microsoft Excel can be seen in Table 7.

Table 7. Mean Difference Test

Final score	t test	
	t_{table}	t_{value}
	2.01	3,28

Based on Table 7, the t_{value} is 3.28, and the t_{table} value is 2.01. Since the t_{value} is greater than the t_{table} value, H_0 is rejected. Therefore, it can be concluded that the average score of mathematical critical thinking abilities in realistic mathematics education with mobile learning is higher than that of students in conventional learning.

The difference in the proportion of students who achieve mastery in mathematical critical thinking abilities between the class using realistic mathematics education with mobile learning and the class using conventional learning can be determined through the proportion difference test. The results of the test conducted using the z-test with the help of Microsoft Excel are presented in Table 8.

Table 8. Proportion Difference Test Results

Final Data	z test	
	z_{table}	z_{value}
	1.65	4,43

Based on the calculation results presented in Table 7, z = 4.43 > z_{value} > $z_{0,5-\alpha}$ = 1.64. Therefore, H_0 is rejected. It can be concluded that the proportion of students' mathematical critical thinking abilities in realistic mathematics education with mobile learning is higher than that in conventional learning.

Qualitative research was conducted to describe the mathematical critical thinking abilities in terms of self-regulated learning. The research subjects were selected based on Grade VII students at MTs Al Wahdah Sumber who exhibited self-regulated learning. Data on students' self-regulated learning were obtained through questionnaires distributed during the research process. The questionnaire consisted of 20 questions. The responses from the questionnaire were then categorized into three groups: low, medium, and high. The descriptive statistics are presented in Table 9.

Table 9. Results of Student's Self-Regulated Learning Percentage

Self-Regulated Learning	Number Of Students	Percentage
High	11	44%
Medium	8	32%
Low	6	24%

Based on Table 9, it is known that there are 25 students in Grade VII at MTs Al Wahdah Sumber. There are 6 students in the low self-regulated learning category, 8 students in the medium self-regulated learning category, and 11 students in the high self-regulated learning category. The grouping of self-regulated learning resulted in 6 students as research subjects. The research subjects were determined through purposive sampling in each category. The selection of students in the high self-regulated learning category included 2 subjects with criteria of high and low critical thinking abilities. The medium self-regulated learning category included 2 subjects with criteria of high and low critical thinking abilities. The low self-regulated learning category included 2 subjects with criteria of high and low critical thinking abilities. The selected students as research subjects are shown in Table 10.

Table 10. List of Research Subjects Based on Self-Regulated Learning

Category	Subject	Score of Mathematical Critical Thinking Test
High	E-3	100,00
	E-9	85,00
Medium	E-12	90,00
	E-20	45,00
Low	E-1	76,67
	E-13	43,33

This study presents the analysis of mathematical critical thinking ability of six research subjects with different levels of self-regulated learning. High self-regulated learning comprises subjects E-3 and E-9, moderate self-regulated learning comprises subjects E-12 and E-20, and low self-regulated learning comprises subjects E-1 and E-13. The research subjects were given a set of 5 items for the mathematical critical thinking test, and item number 1 was selected for analysis.

Based on the qualitative analysis of data, for the high self-regulated learning category with subjects E-3 and E-9, they were able to solve the mathematical critical thinking test items in accordance with all indicators of critical thinking ability and achieved scores above the actual mastery level. These subjects were able to solve the items using each indicator of critical thinking ability and could explain their problem-solving process fluently.

In the moderate self-regulated learning category with subjects E-12 and E-20, some subjects achieved scores above the actual mastery level, while others obtained scores below the proficiency threshold. Some subjects in this category were able to solve the items using each indicator of critical thinking ability, while others did not meet the indicators of critical thinking ability. These students showed weaknesses in the analysis, evaluation, explanation, and self-regulation indicators.

In the low self-regulated learning category with subjects E-1 and E-13, there were differences in the problem-solving approaches. Subject E-1 successfully solved the items and achieved a satisfactory score. The problem-solving process of subject E-1 fulfilled the interpretation, inference, evaluation, and explanation indicators, although there were errors in providing the required information and a lack of self-regulation. On the other hand, subject E-13 only fulfilled the interpretation and analysis indicators. They were unable to meet the indicators of inference, evaluation, explanation, and self-regulation.

The research subjects with high self-regulated learning were E-3 and E-9, both of whom displayed excellent mathematical critical thinking ability. Subject E-3 obtained a score of 100 on the mathematical critical thinking test, while subject E-9 achieved a score of 85. The results of the study indicate that the mathematical critical thinking ability of subjects E-3 and E-9 only showed slight differences across each indicator of critical thinking ability.

For the subjects at the moderate self-regulated learning level, they were E-12 and E-20. Subject E-12 obtained a score of 90, while subject E-20 achieved a score of 45. Based on the scores on the mathematical critical thinking test, it is evident that the two subjects possess different levels of mathematical critical thinking ability.

Lastly, for the subjects at the low self-regulated learning level, they were E-1 and E-13. Subject E-1 obtained a mathematical critical thinking ability score of 76.67, while subject E-13 received a score of 43.33 on the test. The distinct scores obtained by these two subjects indicate differences in their mathematical critical thinking ability at the low self-regulated learning level.

In conclusion, the study suggests that realistic mathematics education supported by mobile learning is effective in enhancing students' mathematical critical thinking ability. The research findings provide insights into the varying levels of critical thinking ability among students with different levels of self-regulated learning.

DISCUSSION

Based on the analysis of research data, the effectiveness of realistic mathematics education supported by mobile learning in enhancing students' mathematical critical thinking ability includes the following: (1) the average mathematical critical thinking ability of students in realistic mathematics education with mobile learning reaches the actual mastery level; (2) the proportion of students who achieve proficiency in mathematical critical thinking ability in realistic mathematics education with mobile learning exceeds 75%; (3) the average mathematical critical thinking ability of students in realistic mathematics education with mobile learning is higher than the average mathematical critical thinking ability of students in conventional learning; and (4) the proportion of students' mathematical critical thinking ability in realistic mathematics education with mobile learning is higher than the proportion of proficiency in mathematical critical thinking ability in conventional learning.

The analysis of the effectiveness of realistic mathematics education supported by mobile learning in enhancing students' mathematical critical thinking ability yielded the following results: the average mathematical critical thinking ability of the experimental class was 80.30, indicating that it has reached the actual mastery level. Out of 25 students in the experimental class, 23 students achieved proficiency, which means the proportion of proficiency in the experimental class has reached 75%. This can be attributed to the fact that with realistic mathematics education supported by mobile learning, students become more active, interactive, and interested in learning. Furthermore, the analysis also revealed that the average mathematical critical thinking ability of the experimental class (80.30) was higher than that of the control class (70.23), indicating that the achievement of mathematical critical thinking ability in the experimental class is better than that in the control class. Similar findings were reported in the studies by Rani et al. (2018), which found that students who received realistic mathematics education had higher critical thinking abilities compared to those who did not. These findings are also supported by research on mobile learning conducted by Elmi et al. (2023) and Yulianti et al. (2021), which concluded that students in classes that used mobile learning achieved higher learning outcomes compared to those in classes that did not use mobile learning. The use of mobile learning supports the development of students' mathematical abilities as it engages students in activities such as discussions, understanding concepts, and solving problems in an interesting manner, aligning with Setyadi (2017) assertion that mobile learning can motivate students in learning.

Furthermore, it was found that the proportion of students who achieved proficiency in mathematical critical thinking ability in realistic mathematics education with mobile learning was higher than the proportion of proficiency in mathematical critical thinking ability in conventional learning.

The research subjects with high self-regulated learning were E-3 and E-9, both of whom demonstrated excellent critical thinking abilities. Subject E-3 obtained a score of 100 on the mathematical critical thinking test, while subject E-9 scored 85. The research results indicate that the mathematical critical thinking abilities of subjects E-3 and E-9 only exhibited slight differences across each critical thinking indicator.

In terms of interpretation, subjects E-3 and E-9 were able to comprehend the information in the mathematical critical thinking items. They were able to write and explain the information from the items succinctly and clearly. In the analysis indicator, subjects E-3 and E-9 demonstrated an understanding of the problems presented in the items that needed to be solved. After understanding the information and the problems, subjects E-3 and E-9 also formulated a plan for solving the problems. In the inference indicator, subjects E-3 and E-9 were able to draw conclusions from the given problems and information. Both subjects utilized their problem-solving plans and combined them with the available information, organizing the information according to the sequence of problem-solving steps.

Furthermore, both subjects showed proficiency in the evaluation indicator. In this stage, the students were able to solve the problems accurately using the identified concepts. However, subject E-3 outperformed subject E-9 as they wrote and explained each step of the problem-solving process accurately according to the relevant mathematical concepts, while subject E-9 skipped one step in the problem-solving process. Although both subjects obtained the same final result, this difference affected their scores. In the explanation indicator, subject E-3 provided clear explanations of the problem-solving steps and made statements based on the mathematical concepts. However, subject E-9 struggled to explain their problem-solving process, particularly in explaining a previously made mistake. In terms of self-regulation, subject E-3 demonstrated an understanding of the problem and its connection to the created problem-solving steps, supported by a correct understanding of the relevant mathematical concepts. On the other hand, subject E-9 understood the problem but could not explain it based on the correct concepts. Therefore, students with high self-regulated learning exhibited better mathematical critical thinking abilities. This finding aligns with Siagian et al. (2021) study, which stated that self-regulated learning has a strong influence on students' mathematical critical thinking abilities. Additionally, Farliana et al. (2021), Asmar & Delyana (2020), and Yanwar et al. (2019) also found a significant relationship between self-regulated learning and learning outcomes, indicating that students with high self-regulated learning tend to achieve better learning outcomes.

For subjects at the moderate self-regulated learning level, they were E-12 and E-20. Subject E-12 obtained a score of 90, while subject E-20 achieved a score of 45. Based on the scores on the mathematical critical thinking test, it is evident that the two subjects possess different levels of mathematical critical thinking ability.

Subjects E-12 and E-20 at the moderate self-regulated learning level mastered the interpretation indicator. Both subjects were able to interpret the information presented in the problem and describe the known information accurately. Subject E-12 demonstrated proficiency in the analysis indicator, as they understood the information related to the problem and were able to plan the problem-solving process based on the available information. However, subject E-20 struggled with the analysis indicator as they could not accurately state the problem based on the given information. In the inference indicator, the two subjects employed different problem-solving approaches. Subject E-12 organized the information and made appropriate inferences based on the problem-solving sequence, while subject E-20 used a different problem-solving approach. In the evaluation indicator, subject E-12 successfully used the relevant concepts to solve the problems, although they missed one part of the problem-solving process. Subject E-20 exhibited limited proficiency in using the chosen problem-solving concept, as they made errors in solving the problems. In the explanation indicator, subject E-12 was fluent in explaining the problem-solving process, while subject E-20 struggled to explain their previous mistakes in the problem-solving process. In terms of self-regulation, subject E-12 demonstrated an understanding of the problem and its relationship to the created problem-solving steps, while subject E-20 understood the problem but could not explain it based on the correct concepts. Therefore, at the moderate self-regulated learning level, students' mathematical critical thinking abilities differ, with some meeting the proficiency criteria for all critical thinking indicators while others exhibit limited proficiency in some indicators. This finding is in line with the research by Asmar & Delyana (2020), which states that self-regulated learning has a positive influence on students' mathematical critical thinking abilities.

For subjects at the low self-regulated learning level, they were E-1 and E-13. Subject E-1 obtained a score of 76.67 on the mathematical critical thinking test, while subject E-13 scored 43.33. These differing scores indicate differences in the mathematical critical thinking abilities of students at the low self-regulated learning level.

Subjects E-1 and E-13 demonstrated proficiency in the interpretation and analysis indicators. Both subjects were able to comprehend the problems and describe the known information accurately. Additionally, they could identify the problems that needed to be solved based on the provided information. In the inference indicator, both subjects faced challenges in organizing the information to solve the problems. In the evaluation indicator, both subjects were unable to use the problem-solving concepts and the available information to solve the problems. In the explanation indicator, both subjects struggled to explain the problem-solving steps accurately due to a lack of understanding of the underlying concepts. In terms of self-regulation, the subjects' knowledge of the information and the problems was limited, resulting in an inability to provide accurate explanations based on the correct concepts. This illustrates that students' mathematical critical thinking abilities differ at the low self-regulated learning level. This finding is consistent with Siagian et al. (2021) study, which found that students with low self-regulated learning have lower mathematical critical thinking abilities compared to those with high self-regulated learning.

Overall, realistic mathematics education supported by mobile learning can enhance students' mathematical critical thinking abilities. This approach provides students with opportunities to explore mathematical concepts and places reality and the environment at the forefront of problem-based learning through mobile learning applications. The problems presented are authentic and well understood by the students, eliminating difficulties in envisioning the given problems. The exploration activities encourage students to acquire knowledge through observation, questioning, and investigation of the developed concepts based on the provided materials. Students interpret the results of their observations, engage in in-depth analysis of the materials during the investigation process, and make hypotheses or predictions. They then confirm their hypotheses through further inquiry or by collecting the necessary evidence to find answers. Some students may not experience an improvement in their mathematical critical thinking abilities due to a lack of motivation, which hinders the learning process.

CONCLUSION

The conclusion of this research is that realistic mathematics education supported by mobile learning is effective in enhancing students' mathematical critical thinking abilities. This is demonstrated by: (1) the average mathematical critical thinking ability of students in realistic mathematics education with mobile learning reaching the actual mastery level; (2) the proportion of students who achieve proficiency in mathematical critical thinking ability in realistic mathematics education with mobile learning exceeding 75%; (3) the average mathematical critical thinking ability of students in realistic mathematics education with mobile learning being higher than the average mathematical critical thinking ability of students in conventional learning; and (4) the proportion of students' mathematical critical thinking ability in realistic mathematics education with mobile learning being higher than the proportion of proficiency in mathematical critical thinking ability in conventional learning.

Based on the analysis of the mathematical critical thinking abilities of Grade VII students in terms of self-regulated learning, the following results were obtained: (1) Students with high self-regulated learning are proficient in all aspects. In the interpretation, analysis, and inference stages, the students understand the problems, the problem-solving approaches used, and can model them. They are skilled in using formulas to solve problems, making the evaluation and explanation stages easier. This also facilitates self-regulation as they are proficient in the problem-solving process, enabling them to better understand the final results. (2) Students with moderate self-regulated learning do not all achieve proficiency in all aspects of critical thinking. In the interpretation, analysis, and inference stages, the subjects tend to be proficient. In the evaluation and explanation stages, the subjects are capable of solving problems and providing clear explanations, indicating good self-regulation. However, subjects with low scores are only proficient in the interpretation and inference stages, understanding and writing the information from the problems and formulating problem-solving approaches, but there are errors in determining the results. They are still not proficient in the evaluation stage, as they can only determine the total sales and percentage, but their calculations are not accurate. They struggle with explanation as they do not fully understand the purpose of the solution. Their self-regulation is still at the level of not being able to inadequate, which is caused by their lack of proficiency in the previous stages. (3) Students with low self-regulated learning are not yet proficient in all aspects of mathematical critical thinking. In the interpretation and analysis stages, they tend to be proficient. In the inference stage, the subjects struggle to translate and model the given problems. In the evaluation and explanation stages, the subjects are unable to use formulas to solve problems, resulting in difficulties in explanation. Their self-regulation is still at a level of not being able to inadequate because they do not obtain the results from the problem-solving process, thus being unable to understand the final results.

Based on the conclusions that have been presented, several recommendations were found as follows: Realistic mathematics education assisted by mobile learning is effective in enhancing students' mathematical critical thinking abilities. This approach can be considered an alternative teaching method to improve students' mathematical critical thinking skills. Based on the research results, the following findings were obtained regarding students' self-regulated learning levels: (1) Students with low self-regulated learning have relatively lower scores in mathematical critical thinking abilities. Therefore, these students should be provided with sufficient practice exercises, abundant motivation, reinforcement, and appreciation for their achievements, in order to improve their mathematical critical thinking abilities if they are still insufficient. (2) Students with moderate self-regulated learning have fairly good scores in mathematical critical thinking abilities. Therefore, students in this group should be assisted differently. For students who achieve low scores, they should be helped with adequate practice exercises, guided when working on problems, and still be given motivation. As for students who achieve high scores, they should be helped by continuing to provide sufficient practice exercises and be trained to gain confidence when working on problems. (2) Students with high self-regulated learning have good scores in mathematical critical thinking abilities. For students who achieve high scores, they should still be assisted by being given sufficient exercises and motivation to maintain their achievements.

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We hope that the findings of this research will bring long-term benefits to the development of more effective mathematics curriculum and teaching practices. May our efforts contribute positively to nurturing a generation of students who think critically, are self-regulated in their learning, and are prepared to face challenges in the future.

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