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STUDENTS' MATHEMATICAL CREATIVE THINKING ABILITY VIEWED FROM SELF-REGULATED LEARNING IN LAPS-HEURISTIC LEARNING MODEL

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Abstract

Students' Mathematical Creative Thinking Ability (MCTA) remains relatively low, particularly in generating original ideas and elaborated solutions, while the effect of Self-Regulated Learning (SRL) on MCTA has not been clearly identified in mathematics learning. This condition indicates the need for an instructional model that not only emphasizes problem-solving processes but also supports students' independence and creativity in learning. This research aims to assess the effectiveness of the LAPS-Heuristic learning model on students' MCTA and describe students' MCTA concerning their SRL. A mixed-methods approach utilizing a sequential explanatory design was employed in this study. Six subjects were selected from the eighth-grade class VIII A at State Junior High School 1 Tayu, chosen based on their SRL levels. The results indicate that (1) the LAPS-Heuristic learning model effectively on students' MCTA in the context of their SRL, and (2) students categorized with high SRL were able to meet all indicators of MCTA, including fluency, flexibility, originality, and elaboration. In contrast, students with average SRL levels achieved three indicators: fluency, flexibility, and elaboration. Meanwhile, those with low SRL levels met only two indicators: fluency and flexibility. For students identified with low SRL who have yet to reach proficiency in originality and elaboration, it is recommended that they engage in independent assignments and participate in peer teaching activities to foster their academic development.

Keywords: LAPS-Heuristic; Mathematical Creative Thinking Ability; Self-Regulated Learning.

Abstrak

Kemampuan Berpikir Kreatif Matematis (KBKM) siswa masih tergolong rendah, khususnya dalam menghasilkan ide-ide yang orisinal dan solusi yang terelaborasi, sementara pengaruh Self-Regulated Learning (SRL) terhadap KBKM dalam pembelajaran matematika belum teridentifikasi secara jelas. Kondisi ini menunjukkan perlunya model pembelajaran yang tidak hanya menekankan pada proses pemecahan masalah, tetapi juga mendukung kemandirian dan kreativitas siswa dalam belajar.Penelitian ini bertujuan untuk mengkaji keefektifan pembelajaran LAPS-Heuristik terhadap Kemampuan Berpikir Kreatif Matematis (KBKM) dan mendeskripsikan KBKM siswa ditinjau dari SRL. Metode yang digunakan adalah mixed method dengan sequential explanatory. Enam subjek dipilih dari kelas VIII A SMP Negeri 1 Tayu berdasarkan tingkat SRL siswa. Hasil penelitian menunjukkan bahwa (1) model pembelajaran LAPS-Heuristik efektif terhadap KBKM siswa ditinjau dari SRL, dan (2) siswa yang dikategorikan dengan SRL tinggi mampu memenuhi semua indikator KBKM: kelancaran, fleksibilitas, orisinalitas, dan elaborasi. Sebaliknya, siswa dengan tingkat SRL rata-rata mencapai tiga indikator: kelancaran, fleksibilitas, dan elaborasi. Sementara itu, siswa yang memiliki tingkat SRL rendah hanya memenuhi dua indikator: kelancaran dan fleksibilitas. Bagi siswa yang diidentifikasi memiliki SRL rendah yang belum mencapai indikator orisinalitas dan elaborasi, disarankan agar siswa terlibat dalam tugas mandiri dan berpartisipasi dalam kegiatan peer teaching untuk mendorong perkembangan akademis siswa.

***Kata kunci**: LAPS-Heuristik; Kemampuan Berpikir kreatif Matematis*; Self-Regulated Learning.

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INTRODUCTION

Teaching mathematics aims to develop students' creative, critical, logical, and collaborative thinking skills, which are essential in today's society (Sachdeva & Eggen, 2021). Creative thinking plays a crucial role in mathematical problem solving, as it enables students to generate original ideas, apply flexible strategies, and provide well-reasoned solutions (Sumartini, 2022). Previous studies emphasize that mathematical creative thinking significantly influences students' conceptual understanding and problem-solving processes (Tabach & Friedlander, 2017). Mathematical creative thinking is commonly characterized by four main indicators: fluency, flexibility, originality, and elaboration (Wang et al., 2011). These indicators reflect students' ability to produce multiple ideas, approach problems from various perspectives, generate novel solutions, and elaborate ideas in a detailed and coherent manner. However, despite its importance, students often struggle to demonstrate these abilities in mathematics learning, particularly when instruction empha-sizes procedural understanding rather than creative problem solving. This condition highlights the need for instructional approaches that can effectively facilitate the development of students' mathematical creative thinking abilities.

The creative thinking abilities of students in Indonesia remain a concern, as reflected in the Global Creativity Index score from 2015, which positioned Indonesia at 115th out of 139 countries in terms of creativity (Florida et al., 2015). This concern is further supported by the findings from the Programme for International Student Assessment (PISA), which evaluates students' mathematical literacy globally, encompassing their reading and writing skills. Research conducted Wang et al. (2011) by established a positive relation-ship between creative thinking and proficiency in reading and writing. In the most recent 2022 PISA results, Indonesia ranked 68th out of 81 countries, achieving a mathematics score of 379 (Setiawan et al., 2024). This data underscores the need for ongoing improvement in the educational strategies implemented within the country.

Recent interviews with a teacher from Junior High School 1 Tayu have highlighted the need for improvement in the creative thinking abilities of grade VIII students. Observations indicate that many students struggle with solving mathematical problems that differ from examples provided in class. Furthermore, teachers in teaching tend to be monotonous or less varied and have not been able to develop students' MCTA by giving non-routine questions.

In light of the current state of students' MCTA, it is imperative to enhance educational practices by developing effective learning models with well-defined objectives. This initiative aims to cultivate an environment where students can engage in and become accustomed to creative thinking. Numerous learning models exist that can strengthen students' creative thinking skills. One model that has proven to be particularly effective is the Logan Avenue Problem Solving (LAPS)-Heuristic model.

The LAPS-Heuristic learning model encompasses several essential steps: firstly, understanding the problem; secondly, planning an effective problem-solving strategy; thirdly, implementing the plan; and finally, re-evaluating the results obtained (Shoimin, 2014). As noted by Purba and Sirait (2017) this model emphasizes a

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student-centered approach, empowering learners to construct their understanding and conclusions. Furthermore, Ningsih et al. (2021) indicate that the LAPS-Heuristic model actively engages students in learning, promoting independent learning. This engagement fosters the development of creative problem-solving skills, enabling students to understand, formulate, discover, and reflect on their approaches to problem-solving. Consequently, the LAPS-Heuristic learning facilitates independent learning and enhances students' MCTA.

Creative and cognitive abilities are enhanced by integrating affective and psychomotor skills (Huang et al., 2020). Among the various components of effective student learning, self-regulated learning is paramount. According to Knowles (1975) self-regulated learning is a proactive process through which individuals identify their learning needs, establish goals, locate resources, choose suitable strategies, and assess their learning outcomes. Shoaa Kazemi & Mahamid (2024) further elaborate that SRL is significantly influenced by a student's thoughts, emotions, strategies, and behaviors, all directed toward achieving specific objectives. Moreover, Vaughans & Sy (2024) that deficiencies in self-regulated learning may give rise to behavioral challenges, including shyness, diminished moti-vation, and ineffective study habits in students. Research conducted by Eladl & Polpol (2020) also indicates that self-regulated learning is crucial in enhancing students' creative problem-solving abilities. Students with strong self-regulated learning skills will likely exhibit high-level mathematical creative thinking abilities. Furthermore, self-regulated learning can effectively mitigate the difficulties often encountered in the study of mathematics.

This study aims to assess the effectiveness of the LAPS-Heuristic model in improving students' MCTA, particularly in relation to self-regulated learning. Additionally, the study aims to describe the influence of SRL on students' MCTA within the framework of LAPS-Heuristic learning.

METHODS

The research method utilized in this study is a mixed methods approach incorporating a sequential explanatory design. The quantitative aspect is grounded in a true experimental framework, the Posttest-Only Control Design. A comprehensive description of the quantitative research design is provided in Table 1.

Table 1. Research Methods.

Group	Treatment	Posttest
A	X_1	O
B	X_2	O

Information:
A: experimental group
B: control group
X_1: LAPS-Heuristic model
X_2: Direct Instruction model
O: posttest for mathematical creative thinking ability

This research began with instrument preparation and validation, including a MCTA test, a SRL questionnaire, and interview guidelines. Instrument validation was conducted by one mathematics teacher and two university lecturers with expertise in mathematics education.

After that, the experimental and control classes were determined using cluster random sampling. The population for this study consists of 8th-grade students at Junior High School 1 Tayu during the second semester of the 2021/ 2022 academic year. The sample

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includes Grade VIII A students, the experimental group receiving LAPS-Heuristic learning, and Grade VIII B students, the control group receiving Direct Instruction. Additionally, the subjects in the study were selected based on a purposive sampling technique.

After the learning implementation, a posttest was administered to measure students' MCTA, and the SRL questionnaire was used to classify students in experimental class into high, moderate, and low SRL categories. Six students were then selected purposively for the qualitative phase. Quantitative data were analyzed using prerequisite tests, independent-samples t-tests, proportion tests, and regression analysis to test the criteria of effectiveness, while qualitative data were analyzed through data reduction, data display, and conclusion drawing. Finally, quantitative and qualitative findings were integrated to provide a comprehensive interpretation of the research results.

This study's data analysis comprises a prerequisite test analysis, an evaluation of the MCTA test results, and qualitative data analysis. The prerequisite test analysis incorporates three key components: 1) Normality Test to determine whether both sample groups are drawn from a normally distributed population, 2)Homogeneity Test to examine whether the variances within the sample groups are homogeneous, 3) Average Difference test too ascertain whether the sample groups share the same baseline abilities. The Kolmogorov-Smirnov test is employed for the normality test. The Levene test is used for the homogeneity test. At the same time, the Independent-Samples T-test is applied to average difference tests utilizing SPSS 25.0 for analysis. The findings indicate that both sample groups originate from a normally distributed population, exhibit homogeneity in variances, and demonstrate similar baseline abilities.

This report analyzes data from the MCTA test results and the SRL questionnaire. The primary objective is to evaluate the effectiveness of LAPS-Heuristic learning on students' MCTA, particularly in SRL. Following this quantitative analysis, a qualitative assessment will be conducted to comprehensively describe students' MCTA within the context of SRL as influenced by the LAPS-Heuristic Learning approach.

Qualitative data analysis techniques in this study are data reduction, data display, and conclusion drawing. The validity test for the study is obtained through a technique triangulation test.

RESULTS AND DISCUSSION

LAPS-Heuristic learning model is said to be effective on students' MCTA viewed from SRL if meets several criteria: (1) Hypothesis I: students' MCTA that use LAPS-Heuristic learning model achieve classical completeness of more than 75%; (2) Hypothesis II: the average of students' MCTA that use LAPS-Heuristic learning model is better than the average of students' MCTA that use Direct Instruction learning model; (3) Hypothesis III: the proportion of students who achieve mastery learning using the LAPS-Heuristic learning model is more than the proportion of students who use the Direct Instruction learning model; (4) Hypothesis IV: there is a positive influence between SRL on students' MCTA.

Before testing the hypothesis, it is necessary to do a prerequisite test, namely the normality test using the Kolmogorov Smirnov Test with SPSS

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25.0 assistance. In normality test was obtained that for experiment class sig = 0.200 > 0.05 and sig = 0.155 > 0.05 for controlled class, hence H_0 is accepted. Thus, the experiment and controlled class data are normally distributed.

The first hypothesis in this study is classical completeness test using one sample proportion test (one tail, right side). The classical completeness in this study is if more than 75% of students use LAPS-Heuristic learning to get a score with a minimum limit of 67. Based on the result, $Z_{count} = 2.026 > Z_{table} = 1.645$, then H_0 is rejected. Thus, the proportion number of students in LAPS-Heuristic learning who complete the test is more than 75%. This matter is in line with Larasanti and Prihatnani (2021) that the study result shows that the class taught with LAPS-Heuristic learning achieves the classical completeness. Applying the LAPS-Heuristic in mathematics learning positively contributes to the development or enhancement of MCTA.

The second hypothesis is the average difference test. Before testing the average difference test, it is necessary to do a prerequisite test, namely the variance difference test, using the Levene test with SPSS 25.0 assistance. In variance difference, the test was obtained that sig = 0.242 > 0.05, hence H_0 is accepted. Thus, the variance of the two classes is the same. The average difference test (one tail, right side) was conducted to test the average of students' MCTA that used the LAPS-Heuristic learning model higher than the average of students' MCTA that used the Direct Instruction learning, or not. Based on the result, $t_{count} = 5.57 > t_{table} = 1.670$, then H_0 is rejected. Thus, the average of students' MCTA that used the LAPS-Heuristic learning model is more than the average of students' MCTA that used the Direct Instruction learning model. This matter is in line with Ningsih et al. (2021) that the study results show that the LAPS-Heuristic class has better MCTA than a non-LAPS-Heuristic class.

The third hypothesis is the proportion difference test. The proportion difference test (one tail, right side) tests the proportion of students who achieved mastery learning using the LAPS-Heuristic learning model higher than those who achieved mastery learning that used Direct Instruction learning or not. Based on the result, $Z_{count} = 4.845 > Z_{table} = 1.645$, then H_0 is rejected. Thus, the proportion of students who achieve mastery learning with the LAPS-Heuristic learning model is more than the proportion of students who achieve learning mastery using the Direct Instruction learning model. This matter is in line with Ningsih et al. (2021) that the study result shows that the class that is taught with LAPS-Heuristic learning model has better MCTA than class that is not taught using the LAPS-Heuristic learning model.

The fourth hypothesis is simple linear regression test with SPSS 25.0 was used. The simple linear regression was conducted to test the effect of SRL on MCTA, where SRL as an independent variable is expressed by x and MCTA as the dependent variable is expressed by y. Then the results of regression equations can be seen through the Table 2.

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Table 2. Regression Equations

Model	Unstandardized Coefficients	Standardized Coefficients Beta	t	sig
	B	Std. Error		
(constant)	32,755	7,957	4,117	0,000
SRL	0,348	0,057	6,054	0,000

Based on the result, it is obtained that the value of constant $\alpha = 32.755$ and self-regulated learning (SRL) $\beta = 0.348$. Hence, the model regression equation which is formed is $\hat{Y} = 32.755 + 0.348x$. Next, the linearity test is carried out and can be seen through the Table 3.

Table 3. Linearity test result

Model	Sum of Squares	df	Mean Square	F	Sig
Regression	1701,115	1	1701,115	36,656	0,000
Residual	1392,232	30	46,408		
Total	3093,347	31			

Based on the result, it is obtained that the value of $sig = 0.000 < 0.05$, then H_0 is rejected. Thus, there is a positive linear relationship between the dependent variable (MCTA) and the independent variable (SRL). The number of effects of the SRL on MCTA can be seen through the Table 4.

Table 4. Independent Variable Effect

Model	R	R Square	Adjusted R Square	Std. Error of Estimate
1	0.742	0,550	0,535	6,81232

Based on the result, it is obtained that the value of $R\ square = 0.550 = 55\%$. This value indicates that SRL affects MCTA by 55%. There is still 45% of the variable of MCTA affected by other variables besides SRL. This matter is in line with (Munahefi et al., 2022)which shows that SRL has a positive influence on students' MCTA.

The analysis of the MCTA test and interview results revealed several key indicators of student performance. These indicators include: (1) fluency, which denotes the ability to solve mathematical problems accurately while demonstrating a coherent thought process that enhances the efficiency of problem-solving; (2) flexibility, which reflects the capacity to approach mathematics problems through a variety of strategies; (3) originality, characterized by the ability to respond to mathematics problems using one's own expressions, methods, or ideas; and (4) elaboration, which entails providing detailed answers to problems and the capability to generate new ideas or related problems. Below is a description of the student's performance in the MCTA, assessed through the lens of SRL.

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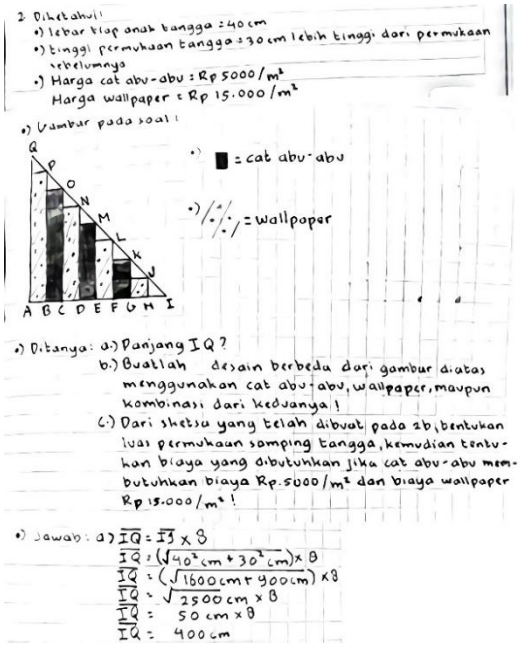

Figure 4. High SRL Student's Work

Based on the result of student work and analysis of interview result, it was obtained that students with high SRL able to answer the question well. In the fluency indicator, students with a high level of SRL can provide all answers in a relevant and precise manner, have a smooth flow of thought, do not find it difficult, and are confident in their answers. In the flexibility indicator, students with a high level of SRL can provide more than one solution strategy with the correct completion process, do not find it difficult to provide solutions using two different methods, and confident that the alternative answers given are the correct completion steps. best. In the originality indicator, students with a high level of SRL can provide unique answers, using methods obtained from their own ideas, and using methods, concepts, or procedures that are the result of their own development with the correct concept. In the elaboration indicator, students with a high level of SRL can develop the ideas they have, the steps in the completion are detailed and clear enough, understand the work process well, are sure that none of the steps taken have been missed, and are sure of the answers. it has been effective and systematic. Based on this, students with high SRL category can fulfil all indicators of mathematical creative thinking ability. The finding was also supported by Agustina et al. (2023) and Runisah & Ismunandar (2020) stating that high SRL students could achieve all MCTA indicators, fluency, flexibility, elaboration, and originality.

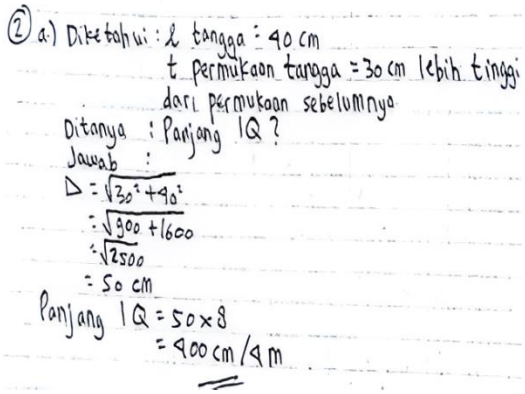

Figure 5. Average SRL Student's Work

Based on the result of student work and analysis of interview result, it was obtained that students with average SRL will find few difficulties when solving the problem. In the fluency indicator, students with average levels of SRL can provide all answers in a relevant and precise manner, have a smooth flow of thought, do not feel difficult, and are confident in their answers. On the flexibility indicator, students with average levels of SRL can provide more than one solution strategy with the correct completion process, do not find it difficult to provide solutions using two different methods, and are confident that the alternative answers given are the correct completion steps. best. In the originality indicator, students with average levels of SRL can use methods obtained from their own

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ideas. However, students with average levels of SRL are unable to provide unique or unusual answers and are unable to use methods, concepts, or procedures which are the result of their own development with the correct concepts. In the elaboration indicator, students with a average level of SRL can develop their ideas, the steps in the completion are detailed and clear enough, understand the work process well, are sure that none of the steps taken have been skipped, and are sure of the answers. it has been effective and systematic. Based on this, students in the average SRL category can only meet three indicators of MCTA, namely fluency, flexibility, and elaboration. The finding was also supported by Agustina et al. (2025) and Susanti & Waluya (2020) stating that average SRL students could achieve three MCTA indicators but could not achieve originality indicator.

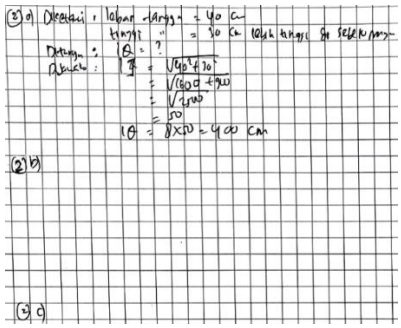

Figure 6. Low SRL Student's Work

Based on the result of student work and analysis of interview result, it was obtained that student with low SRL is unable to complete some MCTA problems. In the fluency indicator, students with low levels of SRL can provide all answers in a relevant and precise manner, have a smooth flow of thought, do not find it difficult, and are confident in their answers. In the flexibility indicator, students with low levels of SRL can provide more than one solution strategy with the correct completion process, do not find it difficult to provide solutions using two different methods, and are confident that the alternative answers given are the correct completion steps. best. On the originality indicator, students with low levels of SRL are unable to provide unique or unusual answers, use methods obtained from their own ideas, and use methods, concepts, or procedures which are the result of their own development with the correct concept. In the elaboration indicator, students with low levels of SRL are not able to develop their ideas, the steps in the completion are not yet detailed and clear, are unable to understand the work process well, are not sure that none of the steps taken have been skipped, and not sure that the answers he gave were effective and systematic. Based on this, students with low SRL categories can only meet two indicators of MCTA, namely fluency and flexibility. The finding was also supported by Susanti & Waluya (2020) stating that low SRL students could only achieve fluency and flexibility.

The recommendation given to students with low levels of SRL who have not been able to meet the originality and elaboration indicators is to provide special assistance for these students by giving additional assignments independently. With additional assignments to students with low SRL, these students can catch up in meeting the originality and elaboration indicators while increasing SRL. Apart from giving additional assignments independently, students with low levels of SRL who have not been able to meet the originality and elaboration indicators can also be given peer tutors. Peer tutoring can be done by grouping students heterogeneously, namely in one group there are students with low,

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average, and high levels of SRL. With peer tutors, it will help students with low SRL to be more active in discussions so that their SRL and MCTA increase. This is in line with the research of Larasanti & Prihatnani (2021) which states that peer tutors can increase students' MCTA. So, with additional assignments independently and peer tutors in mathematics learning, it is hoped that they can overcome the low SRL of students in meeting the indicators of originality and elaboration.

CONCLUSIONS

Based on the findings and discussions presented in the study, the following conclusions can be drawn: (1) The LAPS-Heuristic learning model has demonstrated effectiveness in enhancing students' MCTA as evaluated through the lens of SRL; (2) Students classified in the high SRL category successfully met all indicators of MCTA, while those in the average SRL category achieved indicators related to fluency, flexibility, and elaboration. In contrast, students categorized with low SRL were only able to meet the indicators of fluency and flexibility.

For future research, it is advisable to focus on students with low SRL who have not yet achieved the indicators of originality and elaboration. This could be addressed by assigning independent tasks and implementing peer teaching strategies to facilitate their development.

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