Research Article

The Influence of STEM: Integrated PjBL Learning Models on Students' Mathematical Creative Thinking Abilities Examined from a Metacognitive Perspective

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Abstract.
The STEM-integrated PjBL learning model is one solution to enhance students' creative mathematical thinking skills. Efforts to maximize students' mathematical creative thinking abilities involve using a metacognitive approach. This research aims to (1) determine the effect of the STEM-integrated PjBL learning model on students' mathematical creative thinking abilities in terms of metacognition and (2) investigate the interaction between the learning models and students' metacognition levels (high, medium, and low) on students' mathematical creative thinking abilities between the experimental and control classes. The population in this study consisted of all eighth-grade students at SMP Negeri 6 Jepara for the 2022/2023 academic year. The samples for this research were selected from class VIII-E and class VIII-G using a cluster random sampling technique. The research design employed was the posttest-only control group design. Data collection in the research included metacognitive questionnaires, written creative thinking tests, and documentation. Data were analyzed using a two-way ANOVA test followed by the Scheffe test. The results of the research indicate that (1) there is an influence of the STEM-integrated PjBL learning model on students' mathematical creative thinking abilities in terms of metacognition, and (2) there is an interaction between the learning model and students' metacognition levels on mathematical creative thinking abilities. Students who received STEM-integrated PjBL learning showed better results in terms of mathematical creative thinking abilities when compared to students who underwent conventional learning.

Keywords: STEM integrated PjBL, think creatively, metacognitive

1. Introduction

Mathematics is a fundamental science that should be pursued and studied by students at every level of education. Consequently, students are required to understand and comprehend the contents of mathematics to facilitate the learning process [1]. Learning mathematics is considered a process that necessitates profound comprehension. This is because learning does not solely require theoretical understanding but also emphasizes practical application in problem-solving [2]. Therefore, students must master various aspects of mathematics, including understanding fundamental concepts such as reading mathematical symbols, performing calculations and analyses, and applying them in everyday life.

Many students still perceive mathematics as a challenging subject [3]. Students' difficulties in mathematics include, among other things, struggles with grasping mathematical concepts and applying them to problem-solving [4]. The challenges in learning mathematics can be attributed to factors such as mathematics anxiety, prior knowledge, and the level of effort invested in learning mathematics [5]. Another factor contributing to students' incomplete understanding of mathematics is the traditional teaching method, which primarily involves information transmission. Therefore, it is essential to adopt teaching strategies that can stimulate student motivation, alleviate boredom, encourage active exploration and comprehension of mathematical concepts, and enhance problem-solving skills.

In solving a problem, every student must be capable of understanding the problem, planning a solution, and subsequently solving it. Creative thinking is the ability to address problems and develop a logically structured thought process related to the realm of knowledge [6]. Creative thinking skills can help students generate multiple ideas and arguments, pose questions, acknowledge the validity of an argument, and even enable students to be open and responsive to various perspectives [7]. Creative thinking comprises four primary components: fluency, flexibility, originality, and elaboration [8]. Each student possesses their own unique methods or even multiple creative and intriguing approaches to solving mathematical problems.Mathematical creative thinking is a crucial mathematical skill that students studying mathematics should possess and be capable of developing. The primary rationale behind this assertion is that creative mathematical thinking is one of the criteria for graduate competency qualifications, which motivates students to solve open-ended mathematical problems and encourages them to address real-life issues [9].

The process and stages of a person's thinking in solving learning problems, which contribute to their developmental maturity, are known as their metacognitive abilities. Metacognition refers to a person's awareness of their thought processes while undertaking specific tasks and their subsequent use of this awareness to control their actions [10]. Metacognition refers to what individuals know about cognition, their cognitive processes, and how a person utilizes metacognitive knowledge to adjust their information and behaviour [11]. Metacognition is a vital aspect of learning because a person's learning achievements are influenced by their metacognitive abilities. If every learning activity incorporates indicators of learning how to learn, optimal results can be achieved [12]. Metacognition is the ability that enables an individual to gain a broader understanding of their own thinking or comprehend how their thought processes work. It involves elements such as functional planning, self-monitoring, and self-evaluation [13]. In conclusion, metacognition is the process by which students think about what they think, discern what is known and what is unknown through planning, controlling, and evaluating their knowledge.

Based on the results of interviews with mathematics teachers at one of the junior high schools, it was found that students' creative thinking abilities in terms of metacognition in mathematics learning were still low. Many students still face difficulties when attempting questions with variations different from those provided by the teacher. The process of solving students' questions often involves imitating the steps given by the teacher. Students also struggle with comprehending questions thoroughly, seldom monitor the correctness of the formulas they use, and rarely double-check their answers when solving problems. Teachers continue to employ a direct learning model by using lecture methods and assigning tasks. Consequently, students have limited exposure to innovative learning approaches such as project-based learning, leading to a classroom environment where they mainly listen to the teacher. Given these reasons, there is a pressing need for a learning model capable of enhancing students' creative thinking abilities. One suitable student-centered learning model that can foster creativity is Project-Based Learning (PjBL).

Project-based learning is a systemic learning model that engages students in the transfer of knowledge and skills through a discovery process using a series of questions organized in assignments or projects [14]. PjBL is an innovative learning model that emphasizes contextual learning through complex activities [15]. In the literature, it is reported that the PjBL method is most effective in enhancing student success and has a positive influence on student participation [16]. PjBL is oriented toward developing students' learning abilities and skills through a series of planned activities, conducting research, and creating specific products organized within a single framework in the form of a learning project [17]. This model indirectly enhances student engagement by means of completed projects, fostering exploration through project activities to provide a meaningful learning experience for understanding a concept.

The PjBL model will be more meaningful for students when it is combined with a science, technology, engineering, and mathematics (STEM) approach. This entails planning and implementing learning using a STEM approach in conjunction with a project-based model. The integrated STEM PjBL model in learning can potentially enhance students' problem-solving skills [18]. The integrated STEM PjBL model begins with a scientific curriculum centred on life experiences, investigating solutions, actively engaging students in learning, and allowing them to master useful and in-depth knowledge and skills while working on projects [19]. In this context, students will be encouraged to explore through project activities, enabling them to actively participate.

Based on relevant research conducted by Ulya, it is shown that the PjBL-STEM learning model can enhance students' creative mathematical thinking abilities [20]. Other studies conducted by Jesika and Wulandari demonstrate that the metacognitive approach can help improve creative thinking abilities [21,22]. The research conducted by Hafiana indicates that the integrated STEM PjBL model influences students' creative mathematical thinking abilities when viewed from a metacognitive perspective [23]. Based on the explanations above, the objectives of this study are to determine 1) the influence of the integrated STEM PjBL learning model on students' creative mathematical thinking abilities in terms of metacognition and 2) the interaction between the learning model and students' metacognition on creative mathematical thinking abilities.

2. Method

This research falls under quantitative research. The research design employed is the Posttest-Only Control Group Design. The population used consists of all eighth-grade students at SMP Negeri 6 Jepara for the 2022/2023 academic year, totaling 203 students divided into 7 classes. The sampling technique utilized cluster random sampling, and from the 7 classes, 2 classes were selected as samples: class VIII G as the experimental group with 24 students and class VIII E as the control group with 26 students.

The data collection techniques for this research include using tests, questionnaires, and documentation. The test instrument is employed to measure students' creative mathematical thinking abilities through essay questions. The questionnaire instrument is used to categorize students into high, medium, and low metacognition levels using a Likert scale with four response options: strongly agree, agree, disagree, strongly disagree. The test and questionnaire instruments are validated by experts, and reliability is estimated using Cronbach's alpha. The required documentation for this research includes the names and the number of students in each class, students' midterm exam scores, photos taken during activities, scores from the creative thinking ability test, and questionnaire results to assess metacognitive abilities.

The data analysis for this research employs two-way ANOVA and Scheffe's test. Prior to the analysis, the data are tested for normality, homogeneity, and t-test. The two-way ANOVA is used to examine the interaction between the learning model and students' metacognition on creative mathematical thinking abilities. In the Scheffe's test, it is used to determine whether there is an influence of the integrated STEM PjBL learning model on students' creative mathematical thinking abilities in terms of metacognition between students taught with the integrated STEM PjBL setting and students taught with conventional learning.

3. Result and Discussion

3.1. Presenting thResults

The content validation results of the research instruments consist of 5 items for post-test of creative mathematical thinking ability and 25 statements for the metacognitive questionnaire, which were evaluated by 3 validators and assessed as valid based on Aiken's V. The reliability estimation of the creative thinking test and metacognitive questionnaire instruments falls within the high category. The results of the item and questionnaire reliability estimations are presented in Table 1.

Table 1: Results of Question and Questionnaire Reliability.

Instrument	Cronbach's Alpha	N	Reliability Category
Post Test Questions	0,786	5	Hight
Questionnaire	0,760	25	Hight

The study was conducted at SMP Negeri 6 Jepara, with a sample consisting of two classes: class VIII G, comprising 24 students, where the integrated STEM PjBL learning model was implemented as the experimental group, and class VIII E, comprising 26 students, where conventional learning was employed as the control group. Before applying treatment, initial data tests were conducted using students' midterm exam scores, which included normality tests using the Kolmogorov-Smirnov test, homogeneity tests using the F formula, and tests for the equality of means using the t-test. The results of the normality test for the initial data are presented in Figure 1.

Based on Figure 1, for both the experimental and control classes with $\alpha = 0.05$ and the significance level of both classes being $0.200 \geq 0.05$, H_0 is accepted, indicating

	Class	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
UTS scores	Experiment	.117	24	.200*
	Control	.105	26	.200*

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Figure 1: Results of Normality Test for Initial Data.

that both classes have a normal distribution. Subsequently, a homogeneity test was conducted for the initial data, with the calculation results presented in Figure 2.

Test of Homogeneity of Variances

UTS Scores

Levene Statistic	df1	df2	Sig.
.542	1	48	.465

Figure 2: Results of Homogeneity Test for Initial Data.

Based on Figure 2, with α = 0.05, the significance level obtained is 0.465 ≥ 0.05, so H_0 is accepted, indicating that the data groups have homogenous variances. The results of the equality of means test using the t-test are presented in Figure 3.

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai_UTS	Equal variances assumed	1.695	48	.097	2.558	1.509	-.477	5.592
	Equal variances not assumed	1.677	43.142	.101	2.558	1.525	-.518	5.633

Figure 3: Results of Independent Samples Test.

Based on Figure 3, with α = 0.05, the significance value obtained is 0.097 ≥ 0.05, so Ho is accepted. Thus, it can be concluded that the experimental class and the control class have the same mean.

They were administering a metacognitive questionnaire consisting of 25 statements to both the experimental and control classes. This questionnaire is used to categorize students based on their metacognition levels: high, medium, and low. Implementing learning activities in the control class (VIII E) using a conventional learning model and in the experimental class (VIII G) using the integrated STEM PjBL learning model. In the experimental class, students work on a project, specifically presenting data in the form of bar charts. The project development is structured based on the integrated STEM PjBL syntax, which involves (1) formulating fundamental questions, (2) designing project plans, (3) creating schedules, (4) monitoring student progress and project advancement, (5) testing outcomes, and (6) evaluation. After the learning activities are completed, both classes are given an individual post-test to assess students' creative thinking abilities after receiving the treatment. The collected data are then processed and analyzed.

The final data analysis is obtained from the post-test scores administered to the control and experimental classes. The data are analyzed using a two-way ANOVA test, followed by a Scheffe test, preceded by tests for normality and homogeneity. The results of the normality test can be seen in Figure 4.

Tests of Normality

		Kolmogorov-Smirnov[a]		
	Class	Statistic	df	Sig.
Posttest Scores	Experiment	.161	24	.110
	Control	.161	26	.080

a. Lilliefors Significance Correction

Figure 4: Results of Normality Test for Final Data.

Based on Figure 4, the significance value for the experimental class is 0.110 ≥ 0.05, so Ho is accepted, and for the control class, it is 0.080 ≥ 0.05, so Ho is accepted as well. Therefore, the post-test score data follow a normal distribution. The results of the homogeneity test are presented in Figure 5.

Test of Homogeneity of Variances

Posttest Scores

Levene Statistic	df1	df2	Sig.
.064	1	48	.801

Figure 5: Results of Homogeneity Test for Final Data.

Based on Figure 5, the significance value is 0.801 ≥ 0.05, so Ho is accepted, indicating that the data has homogenous variances. Next, a two-way ANOVA test was conducted, and the results are shown in Figure 6 below.

Based on Figure 6, by examining the significance values, (1) Based on the corrected model value, a significance value < 0.05 indicates that the application of the STEM

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Tests of Between-Subjects Effects

Dependent Variable: Posttest Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11217.502[a]	5	2243.500	10.686	.000
Intercept	202612.081	1	202612.081	965.093	.000
Kelas	2008.395	1	2008.395	9.567	.000
Metakognitif	8716.234	5	2179.059	10.379	.000
Kelas * Metakognitif	193.724	5	38.745	.185	.048
Error	9237.378	44	209.940		
Total	223212.000	50			
Corrected Total	20454.880	49			

a. R Squared = ,548 (Adjusted R Squared = ,497)

Figure 6: Results of Two-Way ANOVA Test.

integrated PjBL model has an effect on creative thinking abilities, (2) In the intercept line, a significance value < 0.05, which means changes in creative thinking ability values are not always caused by changes in metacognitive values, (3). In the "class" row, it can be seen that the significance value = 0.000 ≤ 0.05; therefore, Ho is rejected. Consequently, it can be concluded that there is an influence of the STEM integrated PjBL learning model in terms of metacognition on students' mathematical creative thinking abilities, (4) In the "metacognitive" row, it can be seen that the significance value = 0.000 ≤ 0.05; therefore, Ho is rejected. Consequently, it can be concluded that metacognition has a significant effect on students' creative thinking abilities. (5) In the "class*metacognitive" row, it can be seen that the significance value = 0.048 ≤ 0.05; therefore, Ho is rejected. Consequently, it can be concluded that there is an influence between metacognition and learning models on mathematical creative thinking abilities.

Based on the focus of the research discussion and the results of calculations using the two-way ANOVA test, it was determined that there is an interaction between the PjBL integrated STEM learning model concerning students' metacognitive abilities and their mathematical creative thinking abilities when compared to conventional classes. After conducting the two-way ANOVA test, a subsequent post-ANOVA test was performed using the Scheffe method. The results of the Scheffe test are presented in Figure 7.

Based on Table 8, the following findings are observed 1) there is no significant average difference between high metacognition in the experimental class and high metacognition in the control class, as indicated by the absence of an asterisk in the Mean Difference (I-J) value, 2) there is no significant average difference between moderate metacognition in the experimental class and moderate metacognition in the control class, as indicated by the absence of an asterisk in the Mean Difference (I-J) value, 3) there is no significant average difference between low metacognition in

Multiple Comparisons

Dependent Variable: Posttest Scores
Scheffe

(I) Metacognitive	(J) Metacognitive	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
High Experiment	Medium Experimenting	24.68	7.302	.062	-.75	50.12
	Low Experimentation	32.61*	7.041	.003	8.08	57.14
	Height Control	18.36	7.041	.048	-6.17	42.89
	Medium Control	27.99*	7.041	.016	3.46	52.51
	Low Control	46.71*	6.657	.000	23.52	69.90
Medium Eksperimen	Height Experiment	-24.68	7.302	.062	-50.12	.75
	Low Experiment	7.93	7.499	.950	-18.19	34.05
	Height Control	-6.32	7.499	.981	-32.44	19.80
	Medium Control	3.30	7.499	.039	-22.82	29.43
	Low Control	22.03	7.140	.113	-2.85	46.90
Low Experiment	Height Experiment	-32.61*	7.041	.003	-57.14	-8.08
	Medium Experiment	-7.93	7.499	.950	-34.05	18.19
	Height Control	-14.25	7.245	.574	-39.49	10.99
	Medium Control	-4.63	7.245	.995	-29.86	20.61
	Low Control	14.10	6.873	.049	-9.84	38.04

Based on observed means.
The error term is Mean Square (Error) = 209,940.
*. The mean difference is significant at the ,05 level.

Figure 7: Scheffe Test Results.

the experimental class and low metacognition in the control class, as indicated by the absence of an asterisk in the Mean Difference (I-J) value, 4) a significant average difference is found between high metacognition in the experimental class and low metacognition in the experimental class, as indicated by an asterisk in the Mean Difference (I-J) value of 32.61 and a significance value of 0.030 ($p < 0.05$), 5) a significant average difference is found between high metacognition in the experimental class and moderate metacognition in the control class, as indicated by an asterisk at the Mean Difference (I-J) value of 27.99 and a significance value of 0.016 ($p < 0.05$), 6) a significant average difference is found between high metacognition in the experimental class and low metacognition in the control class, as indicated by an asterisk at the Mean Difference (I-J) value of 46.71 and a significance value of 0.000 ($p < 0.05$). These findings are based on the analysis of the Scheffe test results in Table 8.

4. Discussion

Students' mathematical creative thinking abilities in terms of metacognition are divided into 3 categories, namely mathematical creative thinking abilities with high metacognitive, mathematical creative thinking abilities with moderate metacognitive, and mathematical creative thinking abilities with low metacognitive. Based on the research results, it was found that the PjBL integrated STEM learning model had an effect on students' mathematical creative thinking abilities from a metacognitive perspective. This is in line with what was said by Chalim that there is an influence of the STEM-integrated PjBL learning model on students' creative thinking abilities in terms of metacognition compared to other learning models [24].

The statistical data shows that classes with STEM-integrated PjBL learning settings yield better results compared to classes that receive conventional learning. This learning model encourages students to be active in learning activities, engage in discussions, and collaborate with their peers to complete a project, thereby enhancing students' activity and creativity. This aligns with the research conducted by Ulya and Fiteriani, whose findings indicate that the use of the PjBL STEM learning model can improve mathematical creative thinking abilities [20][25]. With the STEM-integrated PjBL model, students produce projects that involve science, technology, engineering, and mathematics. Students learn to plan projects, test the results, and evaluate the outcomes of the given mathematical project. This helps students utilize their abilities to solve mathematical problems with creative thinking skills. The PjBL integrated STEM learning model has an impact on students' mathematical creative thinking abilities from a metacognitive perspective. This is in line with previous research conducted by Hafiana, which demonstrates that the STEM-integrated PjBL model influences creative thinking abilities from a metacognitive standpoint [23].

Based on the research results, it is evident that the levels of high, moderate, and low metacognition do not significantly influence students' creative thinking abilities. In other words, students' awareness of their cognitive or self-capabilities does not strongly impact their creative thinking abilities even when applied in the STEM-integrated PjBL model.

5. Conclusion

The mathematical creative thinking abilities of students who receive the STEM-integrated [redacted] PjBL learning model yield better results compared to the mathematical creative thinking abilities of students with conventional learning. Based on the research results and analysis, it can be concluded that (1) There is an influence of the STEM-integrated PjBL learning model on students' mathematical creative thinking abilities from a metacognitive perspective. (2) There is an interaction between the learning model and students' metacognition on mathematical creative thinking abilities.

The STEM integrated PjBL learning model can be used as an alternative in teaching, making it more engaging. This is because using the STEM integrated PjBL learning model can result in better mathematical creative thinking abilities of students compared to conventional teaching, especially from a metacognitive perspective. Further studies with different variables and materials are needed to gain a better understanding and experience with the STEM integrated PjBL learning model, which can enhance creative thinking knowledge and improve the quality of teaching.

References

[1] H11endriana H, Rohaeti EE, Sumarmo U, Atif NF. Hard Skills dan Soft Skills Matematik Siswa. Bandung: PT Refika Aditama; 2018.

[2] Saidah I. Dwijanto, Iwan J. Kemampuan Berpikir Kreatif Siswa dalam Pembelajaran Matematika. In: Prosiding Seminar Nasional Pascasarjana UNNES. 2020. p. 1042–5.

[3] Hermawati H, Nurcahyono NA, Setiani A. Proses Pelaksanaan Remidial Teaching Terhadap Ketuntasan Belajar Matematika Peserta Didik. Sosiohumaniora. 2018 Aug;4(2):102–6.

[4] Eryanti I. Pengaruh Strategi Belajar Peta Konsep Terhadap Ketuntasan Belajar Matematika Siswa. Fibonacci, Jurnal Pendidikan Matematika dan Matematika. 2015 Dec;1(2):45–58.

[5] Raj Acharya B. Factors Affecting Difficulties in Learning Mathematics by Mathematics Learners. International Journal of Elementary Education. 2017;6(2):8–15.

[6] Madyani I, Yamtinah S, Utomo SB, Saputro S, Mahardiani L. Profile of Students' Creative Thinking Skills in Science Learning. In: Advances in Social Science, Education and Humanities Research, 3rd International Conference on Learning Innovation and Quality Education (ICLIQE 2019). Atlantis Press SARL; 2020. p. 957–64.

[7] Sumarni W, Kadarwati S. Ethno-STEM Project-Based Learning: Its Impact to Critical and Creative Thinking Skills. Jurnal Pendidikan IPA Indonesia. 2020;9(1):11–21.

[8] Kelen YP. Pembelajaran Matematika dengan Pendekatan Problem Posing untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa (Mathematics Learningwith Problem Posng Approach to Improve Creative Thinking Ability of Students). Jurnal Matematika dan Pendidikan Matematika [Internet]. 2016 Mar [cited 2023 Oct 6];I(1):55–64. Available from: https://journal.unipdu.ac.id/index.php/jmpm/article/view/513

[9] Utami RW, Endaryono BT, Djuhartono T. Meningkatkan Kemampuan berpikir Kreatif Matematis Siswa Melalui Pendekatan Open-Ended. Faktor Jurnal Ilmiah

Kependidikan. 2020 Mar;7(1):43–8.

[10] Fitri R. Metakognitif Pada Proses Belajar Anak Dalam Kajian Neurosains. Jurnal Pendidikan. 2017;2(1):44–52.

[11] Güner P, Erbay HN. Metacognitive Skills and Problem-Solving. International Journal of Research in Education and Science. 2021 May 21;715–34. https://doi.org/10.46328/ijres.1594.

[12] Widodo BS, Utaya S, Sholeh M, Nugraheni L. The Effectiveness of Integrating Learning Management to Online Project-Based Learning on Students' Metacognitive Abilities. Studies in Learning and Teaching. 2023 May;4(1):183–94.

[13] Zayyadi M, Hasanah SI, Muhaimin A. Pengembangan Lembar Kegiatan Siswa dalam Pemecahan Masalah Matematika dengan Pendekatan Metakognitif. BRILIANT:Jurnal Riset dan Konseptual. 2018 Nov;3(4):401–10. https://doi.org/10.28926/briliant.v3i4.227.

[14] Wahyu R. Implementasi Model Project Based Learning (PjBL) Ditinjau dari Penerapan Kurikulum 2013. TEKNOSCIENZA [Internet]. 2016 Oct [cited 2023 Oct 6];1(1):49–62. Available from: https://ejournal.kahuripan.ac.id/index.php/TECNOSCIENZA/article/view/18/12

[15] Kristiyanto D. Peningkatan Kemampuan Berpikir Kritis dan Hasil Belajar Matematika dengan Model Project Based Learning (PJBL). Jurnal Mimbar Ilmu [Internet]. 2020 [cited 2023 Oct 6];25(1):1–10. Available from: https://ejournal.undiksha.ac.id/index.php/MI/article/view/24468/15050

[16] Baran M, Baran M, Karakoyun F, Maskan A. The Influence of Project-Based STEM (PjbL-STEM) Applications on the Development of 21st-Century Skills. Journal of Turkish Science Education. 2021;18(4):798–815.

[17] Hartini A. Pengembangan Prangkat Pembelajaran Model Project Based Learning untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Sekolah Dasar. ELSE (Elementary School Education Journal [Internet]. 2017 Dec [cited 2023 Oct 6];1(2a):6–16. Available from: https://journal.um-surabaya.ac.id/index.php/pgsd/article/view/1038

[18] Purwaningsih E, Sari SP, Sari AM, Suryadi A. The Effect of STEM-PjBL and Discovery Learning on Improving Students' Problem-Solving Skills of the Impulse and Momentum Topic. Jurnal Pendidikan IPA Indonesia [Internet]. 2020 Dec 1 [cited 2023 Oct 6];9(4):465–76. Available from: https://journal.unnes.ac.id/nju/index.php/jpii/article/view/26432

[19] Lou SJ, Chou YC, Shih RC, Chung CC. A study of creativity in CaC 2 steamship-derived STEM project-based learning. Eurasia J Math Sci Technol Educ. 2017 Jun;13(6):2387–404.

[20] Ulya R. Kemampuan Berpikir Kreatif Matematis dan Entrepreneurship Siswa SMK Melalui Model PjBL STEM Berbantuan Fun Card [Semarang]UNNES; 2018.

[21] Jesika AF. Efektivitas Pendekatan Metakognitif Terhadap Peningkatan Kemampuan Berpikir Kritis Matematis Siswa Kelas VII DI MTS Negeri 2 Mataram Tahun Pelajaran 2019/2020 [Skripsi]Universitas Islam Negeri Mataram; 2020.[Mataram].

[22] Wulandari K. Pengaruh Penerapan Strategi Metakognitif Terhadap Kemampuan Berpikir Kritis Matematis Berdasarkan Kemandirian Belajar Siswa Sekolah Menengah Pertama Negeri 1 Siak Hulu [Skripsi]Universitas Islam Negeri Sultan Syarif Kasim Riau; 2019.[Pekanbaru].

[23] Hafiana H. Pengaruh Model Pembelajaran Project-Based Learning (PjBL) Terintegrasi STEM Terhadap Kemampuan Berpikir Kreatif Siswa pada Materi IPA Kelas 4 di SDI Surya Buana [Malang]Universits Islam Maulana Malik Ibrahim; 2022.

[24] Chalim. Muhammad Nur, Mariani S, Wijayanti K. Kemampuan Komunikasi Matematis Siswa SMK Ditinjau dari Self Efficacy pada Setting Pembelajaran Project Based Learning Terintegrasi STEM. PRISMA. Prosiding Seminar Nasional Matematika [Internet]. 2019;2:540–50. Available from: https://journal.unnes.ac.id/sju/index.php/prisma/

[25] Fiteriani I, Diani R, Hamidah A, Anwar C. Project-based learning through STEM approach: Is it effective to improve students' creative problem-solving ability and metacognitive skills in physics learning? In: IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd; 2021. https://doi.org/10.1088/1742-6596/1796/1/012058.