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The Effect of the Problem-Based Learning Model Based on the Science, Technology, Engineering, and Mathematics (STEM) Approach on Students' Creative Thinking Ability

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ABSTRACT

This research aims to analyze the effect of the Problem-Based Learning (PBL) model based on the STEM approach on students' creative thinking ability in the topic of the plant reproductive system. The design used was a quasi-experiment with a pretest-posttest control group model. The population consisted of all Grade IX students of MTS Laboratorium Jambi, totaling 120 students, while the sample comprised 48 students, consisting of Class IX-D and Class IX-E. The instruments used were an essay test of creative thinking ability and a student response questionnaire toward the Problem-Based Learning Model based on STEM. The initial data analysis techniques used the normality test, homogeneity test, and hypothesis test, while the final data analysis techniques used the N-Gain test and analysis of creative thinking ability data. The results of the analysis of creative thinking ability showed an N-Gain score of 0.57 in the experimental class, which is categorized as moderately effective, while the control class obtained an N-Gain score of 0.44, which is categorized as less effective. The PBL Model Based on STEM had a moderate effect on creative thinking ability. Based on the research findings, the dominant indicator of creative thinking was originality, which was moderately effective, while flexibility was found to be effective.

Keywords: PBL, STEM, creative thinking, students

INTRODUCTION

Twenty-first-century learning focuses on training creative thinking skills through student-centered learning processes, which include communication, collaboration, critical thinking, creativity, and innovation skills, commonly referred to as 4C skills [1]. Nowadays, creative thinking is a prioritized ability in facing the development of the Industrial Revolution 4.0, as having adequate 21st-century skills will foster and rapidly develop creative and innovative ideas to respond to various disruptive innovation challenges, especially in science learning[2].With creative thinking ability, numerous opportunities and potentials for student self-development can be created through various alternative, inspiring, and innovative learning activities [3].

Thinking creatively enables individuals to generate a variety of ideas in responding to challenges and obstacles in the learning process, for example, in science learning[4]. The complex and abstract subject matter of science requires analytical abilities and creative thinking processes[5]. In this context, the teacher plays an important role in fostering students' critical thinking skills so that various ideas and initiatives emerge in responding to science-related problems given by the teacher through participatory learning activities designed to be student-centered[6]. Science learning at the elementary and secondary education levels places greater emphasis on thematic issues in everyday life, such as the topic of the plant reproductive system. The plant reproductive system, which is closely related to students' daily environment, can serve as a specific learning topic to discuss various commonly encountered problems and the solutions to address them[7].

To date, the elements of creative thinking skills, such as fluency, flexibility, originality, and elaboration, have not been considered urgent in solving most science essay questions, resulting in students' creative thinking ability not being clearly measured. Through the Science, Technology, Engineering, and Mathematics (STEM) approach, various science topics can be taught using the Problem-Based Learning (PBL) model, which is closely related to students' creative thinking ability. For example, the topic of the plant reproductive system can train students' creativity in learning about processes related to plant reproduction, Angiosperms, Gymnosperms, and reproductive technology in plants, which require an implementable conceptual understanding of scientific processes. Therefore, a learning model is needed that can facilitate students' creative thinking skills to understand science material contextually and applicablywith their learning environment.

The PBL model is a contextual, problem-based learning model that is applicable in the field of science and aims to guide and motivate students to solve problems related to science[8].Problem orientation through the PBL model demands that the learning process of the plant reproductive system becomes more oriented toward innovation.

One of the learning approaches that is oriented toward innovation is the STEM approach. This approach makes it possible to train and sharpen creative thinking skills. STEM-integrated learning is an appropriate alternative approach to be applied in the science learning process as an effort to foster 4C skills[9]. With this approach, it is possible to integrate two or more fields of study related to the elements of science, technology, engineering, and mathematics[10]. In addition, various relevant studies related to the implementation of STEM can help generate new knowledge, answer research questions, and develop understanding[11].

Based on the results of the preliminary research, it was indicated that students were not yet able to identify scientific problems measurably, propose solution ideas, and perform scientific elaboration. Therefore, the proposed alternative is to implement a learning process using the PBL model based on the STEM approach; thus, the problem orientation becomes more focused and scientific by utilizing the elements of STEM throughout the science learning process.

In an effort to realize a more meaningful learning process that aligns with the challenges of the 21st century, PBL is integrated with the STEM approach, which enables students to understand the plant reproductive system not only from the biological aspect, but also from the perspective of agricultural technology (such as tissue culture), plant growth engineering, and mathematical data on plant population growth. Through this integration, students are encouraged to connect science concepts with real life, thereby promoting their creative thinking ability.

The novelty of this research lies in the implementation of the PBL model based on the STEM approach, which specifically enhances creative thinking skills in the topic of the plant reproductive system, a subject that has rarely been explored in depth within the context of science learning at the islamic junior secondary school (Indonesian: *Madrasah Tsanawiyah*; MTs) level. Up to this point,the Problem-Based Learning Model based on the STEM model has been implemented only partially and has not extensively addressed the scientific aspects of the discussed topics, such as the plant reproductive system, which is a fundamental concept in plant reproduction that enables students to apply it in plant cultivation. Therefore, the form of innovation in this research is designed to foster and develop students' creative thinking ability.

Based on the explanation above, the main focus of this research is to analyze the effect of learning experiences through the Problem-Based Learning Model based on STEM on students' creative thinking ability in the topic of the plant reproductive system.

RESEARCH METHOD

The research was conducted at MTS Laboratorium Jambi. Data collection was carried out over three meetings from November to December 2024. The research population consisted of 120 Grade IX students at MTs Laboratorium Kota Jambi. A total of 48 students were selected as the research sample using random sampling. The research design used was a pretest-posttest control group design. This design involved two groups selected randomly [12]. The experimental class (X_1), through pretest O_1 and posttest O3, received treatment using the Problem-Based Learning Model based on STEM, while the control class (Y_2), through pretest O_2 and posttest O_4, was taught using the PBL model without the STEM approach.

Table 1. Research Design

Pretest	Treatment	Posttest
O_1	X_1	O_2
O_3	Y_2	O_4

The instrument in this research used a creative thinking ability test that had been validated or declared valid through expert judgment. The data and information on students' learning experiences were obtained through written tests and questionnaires. Data normality analysis was conducted using the Shapiro-Wilk test with the Statistical Program for Social Science 29 (SPSS 29), while the Levene's test was used to assess data homogeneity, allowing for the evaluation of the effect of the Problem-Based Learning Model based on STEM on students' creative thinking ability. The N-Gain test was conducted to determine the improvement and effectiveness of the Problem-Based Learning Model based on STEM on students' creative thinking ability using the following formula;

$$g = \frac{posttest\ score\ -\ pretest\ score}{maximum\ score\ -\ pretest\ score} x100\%$$

The calculated N-Gain results were then categorized, as presented in Table 2 below;

Table 2. Interpretation Criteria of N-Gain Effectiveness

Percentage	Criteria
<40	Not Effective
40–55	Less Effective
56–75	Moderately Effective
>76	Effective

To assess the effect of learning experiences using the Problem-Based Learning Model based on STEM on creative thinking ability, the indicators used included fluency, flexibility, originality, and elaboration. In addition, students' learning activities in both the experimental and control classes were also observed throughout the learning process.

RESULTS AND DISCUSSION

The results of data analysis, as shown in Figure 1, indicate that both the experimental and control classes, after being assessed for pretest and posttest abilities, were normally distributed, as indicated by the Shapiro-Wilk significance value (Sig > 0.05).

Tests of Normality

			Kolmogorov-Smirnov[a]			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
Kemampuan Berpikir Kreatif	Kelas	Pre-test Eksperimen (PBL-STEM)	.192	24	.200*	.896	24	.118
		Post-Test Eksperimen (PBL-STEM)	.143	24	.200*	.957	24	.376
		Pre-Test Kontrol (PBL)	.142	24	.200*	.954	24	.326
		Post-Test Kontrol (PBL)	.116	24	.200*	.954	24	.325

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 1. Normality Test Results

The results of the normality test, as represented in Figure 1, show that both the experimental class and the control class had normally distributed learning ability modalities, with groups of students having low, moderate, and high abilities present in both classes. Therefore, the data met the requirements to evaluate the effect of different learning experiences in the experimental and control classes, both before and after being taught using the Problem-Based Learning Model based on the STEM approach and using only the PBL model [13].

Furthermore, to ensure that the variation in data distribution in both the experimental class and the control class is proportional and homogeneous, Levene's test was conducted, as shown in Figure 2. The data variation in both classes was found to be homogeneous, as indicated by a significance value >0.05 [14].

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Kemampuan Berpikir Kreatif	Based on Mean	.255	1	92	.857
	Based on Median	.218	1	92	.884
	Based on Median and with adjusted df	.218	1	84.492	.884
	Based on trimmed mean	.258	1	92	.856

Figure 2. Homogeneity Test Results

The results of the homogeneity test analysis presented in Figure 2 show that in both the experimental class and the control class, the groups of students with low, moderate, and high abilities were already balanced, thus meeting the requirements to evaluate the effect of different learning experiences experienced by the experimental and control classes.

To test the hypothesis proposed in this study, whether there is an effect of learning activities through the Problem-Based Learning Model Based on the STEM approach and the PBL model alone, as indicated by a clear difference in the average creative thinking ability of students before and after experiencing different learning approaches in the experimental and control classes, a paired samples t-test was conducted, as shown in Figure 3. It can be seen that there was an increase in students' creative thinking ability in the experimental class taught using the Problem-Based Learning Model Based on the STEM approach and in the control class using the PBL model alone, as evidenced by a significant difference between the pretest and posttest results, with a significance value of 0.01 < 0.05. Thus, H_0 is rejected and H_1 is accepted[15].

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	Preeksperimen - Posteksperimen	-29.083	18.004	3.675	-34.728	-23.439	-10.659	24	.010	.010
Pair 2	Prekontrol - Postkontrol	-20.833	13.367	2.729	-28.436	-13.231	-5.669	24	.070	.070

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Figure 3. Hypothesis Test Results

Based on the hypothesis test data in Figure 3, it was found that there was a significant effect of using the Problem-Based Learning Model based on the STEM approach on students' creative thinking ability in the topic of the plant reproductive system when compared to learning experiences without STEM. This finding is supported by the N-Gain analysis results, as shown in Table 3. The average N-Gain score in the experimental class was 0.57, which falls into the moderately effective category, while the average N-Gain score in the control class was 0.44, which falls into the less effective category. However, the data show that there was an increase in scores from pretest to posttest in the experimental class compared to the control class. Therefore, the use of the Problem-Based Learning Model based on STEM is moderately effective in improving students' creative thinking ability, particularly in learning about the plant reproductive system[16].

Table 3. Average Scores of Pretest, Posttest, and N-Gain of Students' Creative Thinking Ability

Variable	Class	Pretest	Posttest	Gain	Gain Index	N-Gain	Category
Creative Thinking Ability	Experimental	49	78	29	0.57	57	Moderately Effective
	Control	48	71	23	0.44	44	Less Effective

Furthermore, by referring to the criteria in Table 1, the depth and breadth of students' creative thinking ability taught using the Problem-Based Learning Model based on STEM can be evaluated. It was found that the indicators of fluency and elaboration were not effective, originality was moderately effective, while flexibility appeared to be more prominently effective. Meanwhile, the PBL model without STEM showed that the fluency indicator was not effective, whereas the indicators of flexibility, originality, and elaboration were all less effective[17].

Table 4. Percentage of Achievement on Indicators of Students' Creative Thinking Ability

Class	Indicator of Creative Thinking Ability	Pretest	Posttest	Gain	N-Gain	N-Gain Score (%)	Category
Experimental	Fluency	59	73	14	0.34	34	Not Effective
	Flexibility	63	91	28	0.76	76	Effective
	Originality	36	72	36	0.57	57	Moderately Effective
	Elaboration	62	77	15	0.35	35	Not Effective
Average		55	78	23	0.51	51	Less Effective
Control	Fluency	52	67	15	0.31	31	Not Effective
	Flexibility	48	75	27	0.52	52	Less Effective
	Originality	53	79	27	0.55	55	Less Effective
	Elaboration	45	68	23	0.41	41	Less Effective
Average		50	72	22	0.44	44	Less Effective

Students' creative thinking ability through the Problem-Based Learning Model based on the STEM approach showed dominant indicators in originality and flexibility. The supporting factors, based on a survey presented in Figure 4, indicated that in the "strongly agree" category, 71% of students found science more interesting, and 54% were able to guide their peers. In the "agree" category, the most prominent responses were the courage to express opinions (71%), increased creativity (67%), enhanced learning motivation (67%), and improved group collaboration (63%). Meanwhile, in the "disagree" category, 54% of students found it more effective, and 12% felt restricted in expressing opinions. Therefore, the Problem-Based Learning Model based on the STEM approach can enhance students' motivation, understanding, collaboration, creativity, and confidence in science learning, particularly in topics such as plant reproduction. This model is appropriate to be adopted as an effective and innovative learning strategy in 21st-century classrooms [18].

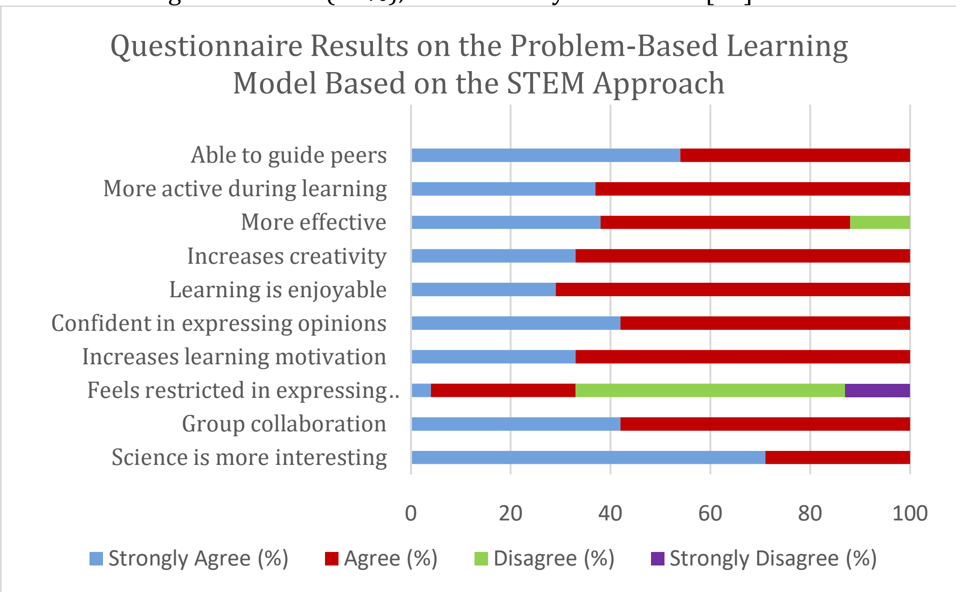

Figure 4. Questionnaire Results on the Problem-Based Learning Model Based on the STEM Approach

The survey results, as shown in Figure 4, indicate a positive student response toward the effect on creative thinking ability, which was the focus of this study. Students' learning ability was assessed based on four indicators that were internalized in each essay test item[19]. The ability to generate a variety of ideas or different approaches to solve a problem is essential. In the context of learning about the plant reproductive system, students' ability to view a concept from various perspectives and to formulate multiple problem-solving strategies is a crucial aspect in assessing students' performance and learning creativity [20]. The flexibility indicator was observed when students, during group discussions, were able to accept others' ideas. Originality was reflected in the ability to modify existing ideas and combine them into a new, more effective solution. Furthermore, elaborative and fluency abilities were identified through efforts to relate the material on the plant reproductive system with principles of science (generative and vegetative reproduction), technology (plant reproduction simulations or plant identification applications), engineering (cuttings and hydroponics), and mathematics (measurement and estimation). The dominance of the flexibility indicator in the effective category was due to students being more open to various possible solutions and able to adapt to changes in the context of the problem. This ability is highly relevant to be applied in real-life situations, where problems rarely have a single correct answer but instead require creative thinking. In the originality indicator, which fell into the moderately effective category, it was shown that some students were able to express original thoughts or generate uncommon ideas in solving problems related to the topic of the plant reproductive system[21]. The findings of this research indicate that the implementation of the Problem-Based Learning Model based on the STEM approach is moderately effective in encouraging students to think uniquely and creatively, although it has not yet reached its full potential. Students have begun to get accustomed to expressing opinions that differ from common answers; however, teacher guidance is still needed to further stimulate their confidence and courage in consistently presenting new ideas [22].

In addition, the relatively low indicators were fluency, with an N-Gain score of 0.34, and elaboration, with a score of 0.35. The fluency indicator reflects the students' limited ability to generate multiple ideas or alternative solutions when facing a problem. Meanwhile, the low elaboration ability was indicated by students not being optimal in developing or detailing their ideas and showing less capability of connecting concepts and ideas for problem-solving. This was caused by the students' lack of experience in integrating various disciplines within the STEM approach and the limited time available to explore solutions thoroughly[23]. This condition indicates that although the Problem-Based Learning Model based on STEM is capable of fostering creativity, there is still a need for the reinforcement of specific strategies to train students' fluency and depth of thinking. The significant improvement in creative thinking ability in the class taught using the Problem-Based Learning Model Based on STEM because of its syntactic structure, which directed students to think more focused and provided opportunities to become more practiced in solving problems using clear facts and focusing their attention on identifying problems through environmental phenomena, thereby encouraging students to be active and think creatively. In contrast, in the class taught using the PBL model without incorporating STEM, the learning atmosphere appeared less productive, as indicated by the fluency indicator falling into the not effective category. Furthermore, the indicators of flexibility, originality, and elaboration were all classified as less effective[24]. Based on the survey results as represented in Figure 4, students' responses were positive, including the perception that science learning materials were more interesting. In addition, peer participation and contribution had a positive effect on students' learning motivation, as demonstrated by their courage to express opinions and their collaborative and participatory group work[25]. The PBL model in science learning, facilitated by the STEM approach in the topic of the plant reproductive system, guides students to recognize a concept or knowledge (science) and apply that knowledge using the skills (technology) they have mastered to create or design a method (engineering) based on analysis and mathematical data calculations (math). The practice of science learning using the STEM approach has been shown to create an inspiring, enjoyable learning environment that focuses on directing students' skills in analyzing and solving real-life problems [26].

CONCLUSION

Science learning activities taught using the Problem-Based Learning Model based on the STEM approach have a positive effect on students' creative thinking ability in the topic of the plant reproductive system. The key finding shows that the dominant creative thinking abilities are in the indicator of originality, which is categorized as moderately effective, while flexibility is categorized as effective.

REFERENCES

[1] F. D. Herman, "Integrasi Problem Based Learning Dengan STEM Dalam Pembelajaran IPA," *J. Ilm. Wahana Pendidik.*, vol. 2023, no. 16, pp. 153–158, 2023, [Online]. Available: https://doi.org/10.5281/zenodo.8232552

[2] C. E. Rismorlita, F. Philiyanti, V. M. Prasetio, and L. P. Sari, "Relevansi Kebutuhan Stakeholder Terhadap Pengembangan Kurikulum Berbasis Keterampilan Abad 21," *KAGAMI J. Pendidik. dan Bhs. Jepang*, vol. 12, no. 2, pp. 12–20, 2021, [Online]. Available: https://journal.unj.ac.id/unj/index.php/kagami/article/view/23833

[3] B. I. G. Maulani, H. Hardiana, and J. Jamaluddin, "Upaya Peningkatan Hasil Belajar Biologi Melalui Penerapan Model Pembelajaran Problem-Based Learning dengan Pendekatan Pembelajaran Berdiferensiasi di Kelas X IPA 2 SMA Negeri 7 Mataram Tahun Ajaran 2022/2023," *J. Ilm. Profesi Pendidik.*, vol. 8, no. 4, pp. 2632–2637, 2023, doi: 10.29303/jipp.v8i4.1728.

[4] C.-Y. Lin, "Threshold Effects of Creative Problem-Solving Attributes on Creativity in the Math Abilities of Taiwanese Upper Elementary Students," *Educ. Res. Int.*, vol. 2017, no. 1, 2017, doi: 10.1155/2017/4571383.

[5] T. T. Wijaya, Y. Zhou, A. Were, and N. Hermita, " *Improving the Creative Thinking Skills of the Next Generation of Mathematics Teachers Using Dynamic Mathematics Software. International Journal of Emerging Technologies in Learning*, *16*(13), 212–226. https://doi.org/10.3991/ijet.v16i13.21535, 2021

[6] B. Santosa and D. Suryo, “Upaya Peningkatan Aktivitas dan Hasil Belajar IPS Peserta didik SD melalui Metode Tutor Sebaya,” *J. Sos.*, vol. 10, no. 2, pp. 223–232, 2018.

[7] A. Srirahmawati, T. Deviana, and S. Kusuma Wardani, “Peningkatan Keterampilan Abad 21 (6C) Peserta didik Kelas Iv SekolahDasar Melalui Model Project Based LearningPada Kurikulum Merdeka,” *Pendas J. Ilm. Pendidik. Dasar*, vol. 08, p. 5284, 2023.

[8] S. Hanif, A. F. C. Wijaya, and N. Winarno, “Enhancing Students’ Creativity through STEM Project-Based Learning,” *J. Sci. Learn.*, vol. 2, no. 2, p. 50, 2019, doi: 10.17509/jsl.v2i2.13271.

[9] S. N. Pratiwi, C. Cari, and N. S. Aminah, “Pembelajaran IPA abad 21 dengan literasi sains peserta didik,” *J. Mater. dan Pembelajaran …*, vol. 9, pp. 34–42, 2019, [Online]. Available: https://jurnal.uns.ac.id/jmpf/article/view/31612 %0Ahttps://jurnal.uns.ac.id/jmpf/article/download/31612/21184

[10] I. R. Yusup, “KESULITAN GURU PADA PEMBELARAN BIOLOGI TINGKAT MADRASAH/SEKOLAH DI PROVINSI JAWA BARAT (Studi Kasus wilayah Priangan Timur),” *J. BIOEDUIN*, vol. 8, no. 2, pp. 34–42, 2018, doi: 10.15575/bioeduin.v8i2.3187.

[11] A. Permanasari, STEM Education : I*novasi dalam Pembelajaran Sains.Seminar Nasional Pendidikan Sains : Peningkatan Kualitas Pembelajaran Sains dan Kompetensi Guru Melalui Penelitian dan Pengembangan dalam Menghadapi Tantangan Abad-21, Universitas Pendidikan Indonesia, Bandung,* 2016

[12] Sugiyono, Metode Penelitian Kuantitatif, Kualitatif, dan R&D, no. January. 2013..

[13] B.W. Yap, and C.H.Sim, “Comparisons of Various Types of Normality Tests,” vol. 81, no. 12, pp. 2141–2155,2011.https://doi.org/10.1080/00949655.2010.520163.

[14] A. N. Baitty and W. Sukmawati, “Pengaruh Praktikum Perubahan Wujud Materi Berbasis Video Terhadap Pemahaman Konsep Peserta didik Kelas V Sekolah Dasar,” *Ideas J. Pendidikan, Sos. dan Budaya*, vol. 8, no. 3, p. 944, 2022, doi: 10.32884/ideas.v8i3.859.

[15] B. Samosir, A. Mujid, and M. Noviyanti, “Improving Students ’ Problem-Solving Skills and Self-Confidence through Ratiolib-Assisted Problem-Based Learning,” vol. 3, no. 11, pp. 1709–1726, 2024.

[16] A. Handayani, Y. S. Rahayu, and R. Agustini, “Students’ creative thinking skills in biology learning: Fluency, flexibility, originality, and elaboration,” J. Phys. Conf. Ser., vol. 1747, no. 1, 2021, doi: 10.1088/1742-6596/1747/1/012040. “Critical thinking: Its nature, measurement, and improvement,” *Natl. Inst. Educ.*, vol. 11, no. 1, pp. 217–232, 1985, [Online]. Available: https://pdfs.semanticscholar.org/80a7/c7d4a98987590751df4b1bd9adf747fd7aaa.pdf

[17] R. Zakiah, “Application of STEM-Integrated Problem Based Learning Model to Improve Learners’ Creativity,” Wahana Pendidik. Fis., vol. 10, pp. 27–32, 2024.

[18] B. Samosir, A. Mujid, and M. Noviyanti, “Improving Students ’ Problem-Solving Skills and Self-Confidence through Ratiolib-Assisted Problem-Based Learning,” vol. 3, no. 11, pp. 1709–1726, 2024.

[19] M. Fuadiyah, B. I. Norra, and F. Astutik, “Biology learning model to improve critical thinking skills of ten grade students: A meta-analysis,” *Assim. Indones. J. Biol. Educ.*, vol. 5, no. 2, pp. 101–112, 2022, doi: 10.17509/aijbe.v5i2.46084.

[20] H. R. Putri, “Implementasi Model Pembelajaran Problem Based Learning (PBL) untuk Melatih Kemampuan Berpikir Kreatif Mahapeserta didik,” *BIO-CONS J. Biol. dan Konserv.*, vol. 3, no. 2, pp. 37–44, 2022, doi: 10.31537/biocons.v3i2.622

[21] A. A. Chistyakov, S. P. Zhdanov, E. L. Avdeeva, E. A. Dyadichenko, M. L. Kunitsyna, and R. I. Yagudina, “Exploring the characteristics and effectiveness of project-based learning for science and STEAM education,” Eurasia J. Math. Sci. Technol. Educ., vol. 19, no. 5, 2023, doi: 10.29333/EJMSTE/13128.

[22] S. Asokawati, A. Asrial, and A. H. Afreni Hamidah, “Pengaruh PBL Terhadap Kemampuan Berpikir Kritis Peserta Didik Pada Materi Sistem Perkembangbiakan Tumbuhan,” *Biodik*, vol. 9, no. 3, pp. 1–6, 2023, doi: 10.22437/biodik.v9i3.23400.

[23] R. Zakiah, “Application of STEM-Integrated Problem Based Learning Model to Improve Learners’ Creativity,” Wahana Pendidik. Fis., vol. 10, pp. 27–32, 2024.

[24] H. R. Putri, “Implementasi Model Pembelajaran Problem Based Learning (PBL) untuk Melatih Kemampuan Berpikir Kreatif Mahapeserta didik,” *BIO-CONS J. Biol. dan Konserv.*, vol. 3, no. 2, pp. 37–44, 2022, doi: 10.31537/biocons.v3i2.622.

[25] M. Fuadiyah, B. I. Norra, and F. Astutik, “Biology learning model to improve critical thinking skills of ten grade students: A meta-analysis,” *Assim. Indones. J. Biol. Educ.*, vol. 5, no. 2, pp. 101–112, 2022, doi: 10.17509/aijbe.v5i2.46084.

[26] C. D. Putri, I. D. Pursitasari*, and B. Rubini, “Problem Based Learning Terintegrasi STEM Di Era Pandemi Covid-19 Untuk Meningkatkan Keterampilan Berpikir Kritis Peserta didik,” J. IPA Pembelajaran IPA, vol. 4, no. 2, pp. 193–204, 2020, doi: 10.24815/jipi.v4i2.17859