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ORIGINAL RESEARCH PAPER

Implementation STEAM project-based learning to improve the students' critical thinking skills

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Abstract
The lack of students' critical thinking skills has been widely reported, particularly in biology learning, which often emphasizes memorization rather than higher-order thinking processes. Although various instructional approaches have been proposed, limited studies have specifically examined the integration of STEAM-based project-based learning (PjBL) to address this issue. This gap indicates the need for empirical evidence on how such an approach can effectively enhance students' critical thinking skills. The purpose of this study was to describe the implementation of STEAM-based PjBL to improve students' critical thinking skills on the topic of environmental pollution. It also aimed to capture the significant difference in students' critical thinking skills before and after the application of STEAM-based PjBL, and the ignificant difference in students' critical thinking skills between students who learn using STEAM-based PjBL and students who learn using conventional learning. It was an experiment with the population was all 10th-grade students at SMA Negeri Peusangan, a public senior high school in Aceh, Indonesia. From the population, we purposively selected 140 students as the sample. The differences in critical thinking skills of the experimental class and the control class were analyzed using the independent sample t-test. The results show that the average N-gain for the experimental class of 72.03. The critical thinking skill gain was 0.93. of the paired sample t-test analysis in the experimental class showed a significance value of $\rho < .001$, indicating that Ha was accepted. This result demonstrates that there was a significant difference in students' critical thinking skills before and after the implementation of the STEAM-based PjBL in the 10th-grade of SMA Negeri Peusangan on the topic of environmental pollution, which means the students' critical thinking was significantly improved.

Keywords: critical thinking skills, project-based learning, STEAM

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INTRODUCTION

The condition of thinking skills in Indonesia are still in the low category. Higher-order thinking skills are not only required during examinations, but must also be developed throughout the learning process. These skills are important for students to connect concepts and materials so that they are able to understand and solve problems in the classroom (Beers, 2011). The development of these 21st-century skills can be carried out across all disciplines. Critical thinking was first developed by Edward Glatser in 1941 (Zulmaulida et al., 2018).

Research on students' thinking skills in Indonesia has been conducted by several researchers. The findings indicate that students' critical thinking skills are still in the low category and have not been optimally developed in the learning process (Basri, 2019). From the analysis of six critical thinking sub-skills (interpretation, analysis, evaluation, inference, explanation, and self-

regulation), the interpretation sub-skill falls into the low category, as more than 60% of students are not yet able to produce accurate interpretations. In addition, the evaluation, analysis, and self-regulation sub-skills are among the lowest critical thinking sub-skills mastered by students compared to the other sub-skills. Therefore, further research is needed to determine how to develop students' critical thinking skills so that they can positively influence learning outcomes (Basri, 2019).

The low level of critical thinking skills is caused by the learning process focusing solely on content and memorization of concepts. Students do not engage in practical activities optimally, so they are not given the opportunity to analyze problems, identify issues, draw conclusions, or generate new ideas or actions in response to a problem. In reality, research shows that the biology learning process in schools does not sufficiently encourage students to think critically. This is consistent with the findings of observations conducted on students and the learning process in Grade X at SMA Negeri 2 Peusangan, which showed that the results of observations and interviews with 12 students indicated that the implementation of learning has not been able to motivate all students to learn, due to the subject matter still being largely theoretical in nature.

Environmental pollution is still considered difficult by most students. This is because the material is still theoretical and the presentation has not maximized critical thinking skills and student learning motivation. Learning activities on environmental pollution show that students are not active in learning; they only listen to explanations and take notes from the teacher (Prihatini, 2017). Therefore, in the teaching and learning process, one solution offered is to implement a STEAM-based PjBL learning model. Several previous studies related to this research on the use of Project-Based Learning have been conducted. Oktaya & Panggabean (2022) explained that the use of the PjBL model can involve students in completing tasks based on complex problems derived from learning materials and connected to real-life contexts. Students are given opportunities to conduct observations, surveys, or analyze problems collaboratively in groups. In this learning process, students are encouraged to be more active and to participate actively in questioning, investigating, explaining, and interacting with the given problems.

Furthermore, the results of the investigations carried out by students are produced in the form of a product, which is then presented (Oktaya & Panggabean, 2022). In this form of PjBL, learning is designed so that students can solve problems through project activities, and in carrying out these projects, they gain real-world experience in project planning. In each activity they undertake, students obtain direct hands-on experience, which can enhance their creativity and learning outcomes (Made, 2022). Moreover, Project-Based Learning is one of the learning models that has been proven effective in improving students' critical thinking skills (Sholeh, 2024).

One learning model that can stimulate students' critical thinking, communication, creativity, and collaboration skills is STEAM, an integrated approach of science, technology, engineering, art, and mathematics (Motimona & Maryatun, 2023). Furthermore, STEAM-based learning serves as a means for student inquiry, developing communication and critical thinking during learning (Nasrah, 2021). The STEAM learning method provides important benefits, including teaching students critical thinking through a multidisciplinary approach. With STEAM, students are encouraged to solve problems and analyze using technology and engaging in creative collaborative learning strategies. STEAM learning creates an environment that supports the development of student creativity by encouraging independent thinking, exploration, observation, reflection, and unconventional questioning.

However, despite the growing body of research on PjBL and STEAM, several limitations remain. First, most previous studies have examined these approaches separately, with limited attention to their systematic integration in specific subject contexts. Second, existing studies tend to focus on general learning outcomes, with insufficient emphasis on the development of

specific critical thinking sub-skills. Third, there is a lack of empirical research that investigates the implementation of STEAM-based PjBL in the context of biology learning, particularly on topics that are conceptually complex and closely related to real-life issues, such as environmental pollution. These gaps indicate that further research is needed to explore how the integration of STEAM and PjBL can be designed and implemented to more effectively enhance students' critical thinking skills.

Therefore, this study offers a novel contribution by: (1) integrating STEAM and Project-Based Learning within a biology learning context on environmental pollution; (2) examining the improvement of students' critical thinking skills across specific sub-skills; and (3) providing empirical evidence from a real classroom setting in Indonesian secondary education. This study does not merely confirm the effectiveness of an established approach but seeks to extend previous research by addressing the identified gaps in context, integration, and analytical focus. Thus, this study is expected to contribute to the development of innovative and context-based learning strategies that can effectively enhance students' critical thinking skills in biology education. Based on the background described above, the research questions of this study are formulated as follows.

(1) Does the implementation of STEAM-based Project-Based Learning (PjBL) improve students' critical thinking skills on the topic of environmental pollution?
(2) Is there a significant difference in students' critical thinking skills before and after the implementation of STEAM-based Project Based Learning?
(3) Is there a significant difference in the improvement of students' critical thinking skills between students who learn using STEAM-based Project Based Learning and those who learn using conventional learning?

The purpose of this study is to determine the implementation of STEAM-based Project Based Learning (PjBL) to improve students' critical thinking skills on the topic of environmental pollution; (2) to determine significant differences in students' critical thinking skills before and after the application of STEAM-based Project Based Learning; and (3) to determine significant differences in improving students' critical thinking skills between students who learn using STEAM-based Project Based Learning and students who learn using conventional learning.

RESEARCH METHOD

This research approach uses a quantitative approach with experimental methods. This method is used to determine the effects of a deliberately administered treatment. The variables used are experimental variables. This research design uses a quasi-experimental design, as shown in Table 1.

Table 1. Pretest-posttest non-equivalent control group design

Sample	Group	Pretest	Treatment	Posttest
Non-randomized	Experiment	O1[a]	X1[b]	O2[c]
Non-randomized	Control	O3[d]	X2[e]	O4[f]

[a] pretest in the experiment class
[b] STEAM-based PjBL model
[c] posttest in the experiment class
[d] pretest in the control class
[e] scientific approach
[f] posttest in the control class

This study employed a quasi-experimental design involving an experimental group and a control group without random assignment. This design was selected due to practical constraints in controlling external variables within the school setting. Specifically, the study applied a pretest–posttest non-equivalent control group design, in which both groups were administered

a pretest prior to the intervention to establish baseline equivalence, followed by a posttest after the intervention to measure changes in students' critical thinking skills.

The research was conducted at SMA Negeri Peusangan, involving all 10th-grade students as the population. A total of 140 students were selected as the sample using a purposive sampling technique, based on the consideration of class characteristics and comparability between groups in terms of prior academic ability. The experimental group received instruction using the STEAM-based PjBL, while the control group was taught using conventional instructional methods.

The instrument used to measure students' critical thinking skills was a reasoned multiple-choice test. Each item required students not only to select an answer but also to provide justification for their choice, which was assessed using a structured scoring rubric. The instrument was developed based on indicators of critical thinking skills, and prior to its use, it underwent validation by experts to ensure content validity. Additionally, reliability testing was conducted to confirm the consistency of the instrument.

Data analysis was conducted using both descriptive and inferential statistics. The improvement in students' critical thinking skills was calculated using the normalized gain (N-gain) formula. A paired sample t-test was employed to analyze differences in pretest and posttest scores within each group, while an independent sample t-test was used to examine differences between the experimental and control groups. Prior to hypothesis testing, assumptions of normality and homogeneity were assessed to ensure the appropriateness of the statistical analyses.

RESULTS AND DISCUSSION

Critical thinking skills at experiment class

The implementation of the STEAM-based Project Based Learning assisted by LKPD was carried out through project activities related to environmental pollution concepts. The learning activities followed the syntax of the Project Based Learning, consisting of several stages: (1) starting with essential questions, (2) designing a project plan, (3) creating a project schedule, (4) monitoring the project development process, (5) assessing the project results, and (6) evaluating the learning experience. In the initial stage, students were presented with environmental pollution problems related to real-life phenomena. Students then identified problems and formulated solutions through project activities guided by the STEAM-based LKPD.

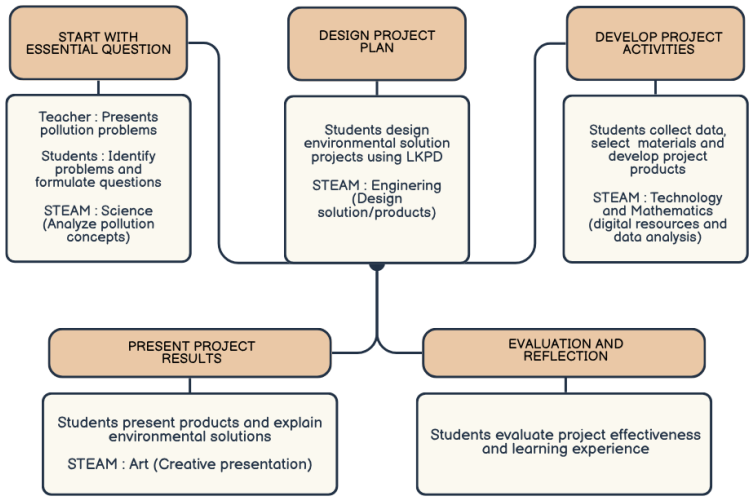

Figure 1. The implementation process of STEAM-based PjBL assisted by worksheet at the experiment class

The STEAM integration was implemented through activities that combined science, technology, engineering, art, and mathematics aspects (Figure 1). For example, students analyzed the causes and impacts of environmental pollution (science), searched for supporting information using digital resources (technology), designed and developed solutions or prototypes related to environmental problems (engineering), presented their project ideas creatively (art), and analyzed data or measurement results related to environmental conditions (mathematics). These activities encouraged students to analyze problems, evaluate information, develop solutions, and communicate their ideas, which are indicators of critical thinking skills.

The learning activities were designed to engage students in identifying problems, designing solutions, developing projects, and evaluating outcomes, thereby supporting the development of critical thinking skills. After the implementation of the STEAM-based project based learning assisted by worksheet, the improvement of students' critical thinking skills was analyzed using the paired sample t-test. The paired sample t-test was used to see the differences in students' critical thinking skills before and after learning with the application of the STEAM-based project based learning asisted worksheet in class X of SMA N Peusangan on environmental pollution concept. The results of the paired sample t-test of critical thinking skills in the experimental class are presented in Table 2.

Table 2. Paired sample t-test of critical thinking skills of experimental class

Value	N	Mean	Std. Deviation	Paired sample t-test[a]
Pretest	71	29.15	4.23	ρ<.001
Posttest	71	75.28	5.51	ρ<.001

[a] paired sample t-test (Ha accepted, $\rho < \alpha = 0.05$)

Based on Table 2, it can be explained that the total sample size of the study was 71 respondents. The mean pretest score was 29.15 with a standard deviation of 4.23, while the mean posttest score increased to 75.28 with a standard deviation of 5.51. The results of the paired sample t-test showed a significance value of $\rho < 0.001$, indicating that there is a significant difference between the pretest and posttest scores. Therefore, it can be concluded that there was a significant improvement in learning outcomes after the treatment was administered. The average indicator of students' critical thinking skills with the implementation of the STEAM-based project-based learning on environmental pollution concept in the experimental class is presented in Figure 2.

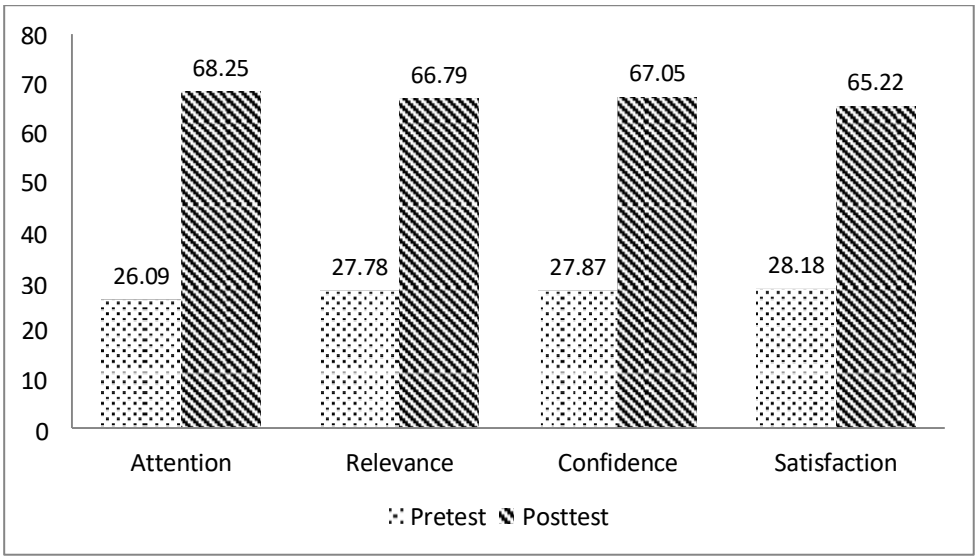

Figure 2. The average score of critical thinking ability indicator of students in experimental class based on pretest and posttest scores.

The implementation of the STEAM project-based learning to students at the focus stage, students are given the opportunity to identify problems according to the facts of environmental pollution clearly. So that students are able to be trained to focus their attention to identify problems regarding environmental pollution. Fidela and Fadilah (2024), the PjBL is a learning model that pays attention to student understanding from various aspects, including theoretical understanding, deepening, evaluation and application of these understandings concretely through learning projects. STEAM learning involves students actively in understanding and exploring learning concepts through various integrated activities, so that the learning process becomes more meaningful (Nurhasanah, et. al, 2023). There are differences in critical thinking skills of students who use the project-based learning at the beginning of the measurement (pretest) and the final measurement (posttest), encouraging students to solve problems with critical thinking (Pebriana & Disman, 2017). Furthermore, by using the STEAM-based PjBL, students are able to provide and explain the reasons for their conclusions. When drawing conclusions (inferences), students are also able to draw appropriate and relevant conclusions. At the situation stage, students are able to utilize all important information.

At the crarity stage, students are able to provide further explanations (justifying or clarifying) regarding the final conclusions based on experiments conducted on environmental pollution. At the overview stage, students are able to check the validity of the solutions obtained by linking them to the context of the given problem situation. This is in accordance with previous research which stated that all indicators of critical thinking skills are categorized as sufficient. When compared, previous critical thinking skills with the provision of worksheet based on the STEAM approach, several indicators showed an increase. Integrating STEM aspects can have a positive impact on student interest, especially in terms of improving students' critical thinking (Marshall & Jason, 2018).

Improvement of students' critical thinking skills in the experimental class

The improvement of critical thinking skills was analyzed using Meltzer's N-gain formula. The results of the critical thinking skills improvement test for the experimental class are presented in Table 3.

Table 3. Improvement of critical thinking skills of students in the experimental class

Value	N	N-Gain Mean	Std. Deviation
Pretest	71	29.15	4.23
Posttest	71	75.28	5.51
N-gain	71	72.03	9.22

Table 3 shows the average N-gain for the experimental class of 72.03. The critical thinking skill gain was 0.93. Therefore, the experimental class's critical thinking skill improvement was categorized as high. A study on STEAM was also conducted by Ulfa et al. (2019), which showed that STEAM combined with PjBL can increase student interest in learning, making learning more meaningful. Furthermore, STEAM can challenge students, motivate active involvement, and encourage creativity, contributing to improved problem-solving abilities.

The implementation of the project-based learning can improve students' critical thinking skills. Students are able to solve a problem by conducting appropriate analysis and providing alternative solutions. Students find the learning process more engaging and challenging, and they can express their opinions effectively in front of the class (Kardoyo et al., 2020).

The implementation of STEAM-based PjBL on critical thinking skills resulted in an n-gain increase of 0.5 in pretest and posttest scores, which falls within the moderate criteria. This means that the implementation of the PjBL developed with the STEAM approach can make a positive contribution to students' critical thinking skills (Daniel, 2017).

Differences in critical thinking skills between experimental and control classes

The results of the independent sample t-test post-test of critical thinking skills of students at SMA Negeri Peusangan can be seen in Table 4.

Table 4. Results of the independent sample t-test of students' critical thinking skills

Class	Posttest Mean	Independent Sample T-test[a]
Experimental	75.28	ρ<.001
Control	63.72	ρ<.001

[a] Independen sample t-test (Accept Ha, ρ < α 0.05)

Based on Table 4, the results of the independent sample t-test obtained ρ<.001, thus Ha is accepted. Therefore, it is concluded that there is a difference in students' critical thinking skills between the experimental class and the control class on environmental pollution concept in grade X of SMA Negeri Peusangan. Learning using the STEAM-based project based learning is more effective in improving students' critical thinking skills compared to conventional learning on environmental pollution material.

The average results of the pretest and posttest of critical thinking skills of students in the experimental and control classes to see the difference in the average improvement in students' critical thinking skills can be seen in Figure 3.

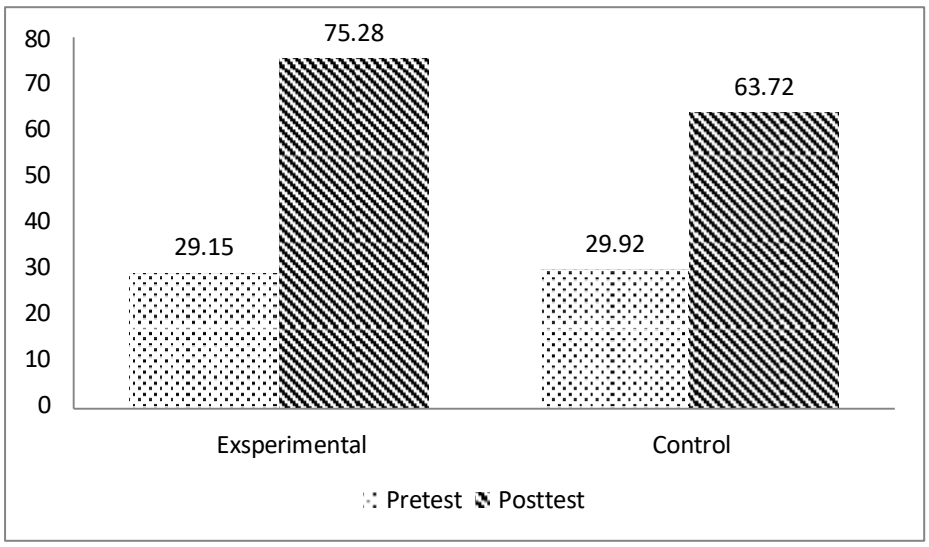

Figure 3. Average pretest and posttest of critical thinking skills of students in the experimental and control classes

Figure 3 shows the difference in the average critical thinking skills of students between the experimental and control classes. The pretest mean for critical thinking skills in the experimental class was 29.15 and the posttest mean was 75.28. The pretest mean for critical thinking skills in the control class was 29.92 and the posttest mean was 63.72. Based on the averages obtained in the experimental and control groups, it can be seen that the average critical thinking skills of students in the experimental group were higher than those in the control group. It suggests that the use of STEAM-based PjBL can improve critical thinking in learning environmental pollution.

The difference in critical thinking skills of students in the two classes is due to the different learning methods used in each class. In the experimental class, taught using the STEAM-based project based learning, students' thinking processes were focused during the focus stage. Students were given the opportunity to identify problems based on clear facts about environmental pollution. This trained them to focus their attention on identifying environmental pollution issues.

The use of the STEM-based PjBL encourages students' enthusiasm for problem-solving through product creation. This encourages active learning. Learning using the STEAM approach allows students to observe everyday phenomena and helps them design products related to environmental pollution. Students are guided and instructed to observe and view worksheets. The problem-solving process is demonstrated through the product they create on the environmental pollution topic: a water filter for filtering cloudy water.

Furthermore, learning with STEAM allows students to discuss and share their ideas and thoughts to answer questions on the worksheets, following the learning steps. During the learning process, students gain new information or insights from their observations and elaborate on new ideas by understanding experiments and answering questions based on their abilities and knowledge. Furthermore, students apply their understanding to concepts by collecting experimental data. Students are also asked to design tools and build water filters to filter cloudy water.

The use of an integrated STEAM approach can help students acquire knowledge by discovering and conducting experiments to prove their hypotheses. The STEAM-based PjBL enhances students' creativity and critical thinking because it is a learning process that encourages students to understand concepts by exploring their abilities. This is supported by the results of research by Ananda (2018). Previous research related to the use of project-based learning was conducted by Fidela and Fadilah (2024). One learning model that can support active student learning and improve students' creative and critical thinking skills is the Project-Based Learning. This model focuses on student understanding from various aspects, including theoretical understanding, deepening, evaluation, and concrete application of these understandings through learning projects. In fact, the PjBL is effective in developing students' critical and collaborative thinking skills (Sholeh et al., 2024).

Furthermore, STEAM-based project based learning can be used as an alternative learning model because it can enhance student creativity (Fatmah, 2021). The implementation of the STEAM-based project based learning enables students to develop real-world skills, such as collaboration, decision-making, initiative, communication, problem-solving, and self-management, thereby enhancing critical thinking skills (Diana & Saputri, 2021).

The STEM-based project based learning encourages students to engage in meaningful learning by understanding a concept and exploring it through project activities, actively engaging them in the process (Jauhariyyah, 2017). This fosters critical, creative, and analytical thinking in students, and enhances higher-order thinking skills. Jauhariyyah's research analysis shows that PjBL-STEM can improve scientific literacy, motivation, material comprehension, creative thinking skills, effectiveness, meaningful learning, and support future careers.

CONCLUSION

Based on the research results, the implementation of STEAM-based Project-Based Learning was found to significantly improve students' critical thinking skills, as indicated by substantial increases between pretest and posttest scores. There was a significant difference in students' critical thinking skills before and after the implementation of STEAM-based Projects. These findings indicate that integrating an interdisciplinary STEAM approach with project-based activities effectively facilitates higher-order thinking processes, particularly in learning the concept of environmental pollution.

These results imply that STEAM-based Project-Based Learning can serve as an effective teaching strategy to encourage active learning and critical engagement among students. Therefore, it is recommended that teachers consider adopting this approach in science classes to foster students' critical thinking skills. Future research is recommended to explore its application across different subjects, educational levels, and longer intervention periods to further validate and expand these findings.

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DECLARATION

Author contribution

All authors contribute in the research and/or writing the paper, and approved the final manuscript.

Zainatul Hasanah	Conceptualizing the research idea, leading the investigation, and setting up the methodology and writing the original draft.
Erlia Hanum	Assisting the investigation, reviewing the validity of the methodology, analyzing the data, and translating the paper into English.
Cut Roswita	Assisting the investigation and reviewing the paper.
Rahmawati	Assisting the investigation and enriching the data analysis.

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Conflict of interest

All authors declare that they have no competing interests.

Ethics declaration

We as authors acknowledge that this work has been written based on ethical research that conforms with the regulations of our institutions and that we have obtained the permission from the relevant institutes when collecting data. We support the International Journal on Education Insight (IJEI) in maintaining the high standards of personal conduct, practicing honesty in all our professional practices and endeavors.

The use of artificial intelligence

We do not use any generative AI tools to write any part of this paper.

Additional information

Not available.

REFERENCES

Ananda, U. (2018). Penerapan model project based learning untuk meningkatkan kreativitas siswa pada pembelajaran IPA Kelas IV MIN 6 Aceh Selatan. *Skripsi*. UIN Ar-Raniry Banda Aceh.

Basri, H. (2019). Investigating critical thinking skill of junior high school in solving mathematical problem. *International Journal of Instruction*, *12*(3), 745-758. https://doi.org/10.29333/iji.2019.12345a

Beers, S. Z. (2011). *21st Century Skills: Preparing for Their Future*. ASD Author.

Daniel, F. (2017). Kemampuan berpikir kritis siswa pada implementasi project based learning (PJBL) berpendekatan saintifik. *JPMI (Jurnal Pendidikan Matematika Indonesia), 1*(1), 7-13. http://dx.doi.org/10.26737/jpmi.v1i1.76

Diana, H. A., & Saputri, V. (2021). Model project based learning terintegrasi STEAM terhadap kecerdasan emosional dan kemampuan berpikir kritis siswa berbasis soal numerasi. *Numeracy*, *8*(2), 113-127. https://doi.org/10.46244/numeracy.v8i2.1609

Fatmah, H. (2021). Kreativitas peserta didik dalam pembelajaran bioteknologi dengan pjbl berbasis steam. *Pedagonal: Jurnal Ilmiah Pendidikan*, *5*(1), 7–14. https://doi.org/10.33751/pedagonal.v5i1.2574

Fidela, W., & Fadilah, M. (2024). Literature review: penerapan model project based learning (PjBL) untuk meningkatkan hasil belajar dan kemampuan berpikir kreatif siswa SMA. *Jurnal Pendidikan dan Pembelajaran Indonesia (JPPI), 4*(4), 1498-1511. https://doi.org/10.53299/jppi.v4i4.745

Jauhariyyah, F. R., Suwono, H., & Ibrohim. (2017). Science, technology, engineering and mathematics project based learning (STEM-PjBL) pada pembelajaran sains. *Prosiding Seminar Pendidikan IPA Pascasarjana UM* (vol. 2). Universitas Negeri Malang.

Kardoyo, Nurkhin, A., Muhsin, & Pramusinto, H. (2020). Problem based learning strategy: its impact on students' critical and creative thinking skills. *European Journal of Educational Research*, *9*(3), 1141-1150. https://doi.org/10.12973/eu-jer.9.3.1141

Made, A. M., Ambiyar, A., Riyanda, A. R., Sagala, M. K., & Adi, N. H. (2022). Implementasi model project based learning (PjBL) dalam upaya meningkatkan hasil belajar mahasiswa teknik mesin. *Edukatif: Jurnal Ilmu Pendidikan*, *4*(4), 5162-5169. https://doi.org/10.31004/edukatif.v4i4.3128

Marshall, J. A & Jason R. H. (2018). Making learners: a framework for evaluating making in STEM education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(2), 1-13. https://doi.org/10.7771/1541-5015.1749

Motimona, P. D., & Maryatun, I. B. (2023). Implementasi metode pembelajaran STEAM pada kurikulum merdeka pada PAUD. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *7*(6), 6493-6504. https://doi.org/10.31004/obsesi.v7i6.4682

Nasrah, N. (2021). Efektivitas model pembelajaran STEAM (Science, Technology, Engineering, Art, and Mathematics) pada siswa kelas IV SD. *JKPD (Jurnal Kajian Pendidikan Dasar)*, *6*(1), 1-13. https://journal.unismuh.ac.id/index.php/jkpd/id/article/view/4166

Nurhasanah, A., Hermawan, W., Mandang, T., Unadi, A., Budiharti, U., Suparlan, Susanto, H., Amalia, A. F., Widodo, T. W., Budiastuti, M. J. T., Nitamiwati, N. P. D., Sagita, D., Hidayat, M., & Samudiantono, A. (2023). Engineering properties of sorghum bioguma-variety for designing appropriate thresher and chopper machine. *AIMS Agriculture & Food*, *8*(3), 720-735. https://doi.org/10.3934/agrfood.2023039

Oktaya, I., & Panggabean, E. M. (2022). Ketepatan dan efektivitas penggunaan teori belajar dalam pembelajaran matematika dengan model project based learning pada kurikulum merdeka belajar. *Journal of Mathematics in Teaching and Learning*, *1*(1), 10–14. https://jurnal.stain-madina.ac.id/index.php/matematika/article/view/1044

Pebriana, R., & Disman. (2017). Effect of problem based learning to critical thinking skills. *Journal of Elementary Education*, *1*(1), 109-118. https://doi.org/10.22460/pej.v1i1.487

Permanasari, A. (2016). STEM Education: Inovasi dalam Pembelajaran Sains. *Prosiding Seminar Nasional Pendidikan Sains*, 23-34.

Prihatini, E. (2017). Pengaruh model problem based learning (PBL) dan project based learning (PjBL) terhadap hasil belajar biologi pada materi pencemaran lingkungan peserta didik sekolah menengah atas. *Jurnal Pendidikan Biologi*, *6*(2), 304-311. https://doi.org/10.24114/jpb.v6i2.6550

Sholeh, M. I., Tasya, D. A., Syafi'i, A., Rosyidi, H., Arifin, Z., & Abd Rahman, S. F. (2024). Penerapan pembelajaran berbasis proyek (PjBL) dalam meningkatkan kemampuan berpikir kritis siswa. *Jurnal Tinta, 6*(2), 158-176. https://doi.org/10.35897/jurnaltinta.v6i2.1484

Ulfa, M. F., Asikin, M., & Dwidayati, N. K. (2019). Membangun kemampuan berpikir kreatif matematis siswa dengan pembelajaran PjBL terintegrasi pendekatan STEM. *Prosiding Seminar Nasional Pascasarjana*, 2(1), 612-617. https://garuda.kemdiktisaintek.go.id/documents/detail/3492758

Zulmaulida, R., Wahyudin, & Jarnawi, A. D. (2018). Watson-Glaser's critical thinking skills. *Journal of Physics: Conference Series*, *1028* (2018) 012094. https://doi.org/10.1088/1742-6596/1028/1/012094