



Implementation of Science Literacy-Oriented STEAM-Based Biology Learning to Enhance Students' Creative Thinking Skills

Nurliah¹

¹State Senior High School 4 Parepare, Indonesia

Article Info

Article history:

Received August 15, 2025

Revised August 20, 2025

Accepted August 20, 2025

Online First August 24, 2025

Keywords:

STEAM-based learning
science literacy
creative thinking skills
senior high school students
biology education

ABSTRACT

Purpose of the study: This study aims to examine the effect of implementing Biology learning based on Science, Technology, Engineering, Arts, and Mathematics (STEAM) integrated with scientific literacy on students' creative thinking skills in high school biology learning.

Methodology: The research employed a quasi-experimental method with a non-equivalent control group design. Participants were divided into an experimental class using STEAM-based learning integrated with scientific literacy and a control class using conventional learning. Creative thinking tests were administered, and data were analyzed using Microsoft Excel 2010.

Main Findings: The experimental class achieved a higher average creative thinking score (81 very creative) compared to the control class (73 creative). The most significant improvement was observed in originality, followed by fluency, flexibility, and elaboration. This suggests that STEAM-based learning integrated with scientific literacy can foster higher-level thinking and idea generation in biology learning.

Novelty/Originality of this study: This study combines STEAM learning with scientific literacy orientation in biology, offering a comprehensive approach to improving creative thinking skills. The integration bridges conceptual understanding and higher-order thinking, advancing knowledge on how interdisciplinary methods can be applied effectively in science education.

This is an open access article under the [CC BY](#) license



Corresponding Author:

Name of Corresponding Author,

Matematics Education Departement, Faculty of Teacher Training and Education, Universitas Muhammadiyah Makassar

Email: nurliah.smapat@gmail.com

1. INTRODUCTION

Learning processes in the 21st century require teachers to constantly adapt methods and strategies in line with the development of science, technology, and students' needs [1]. However, science learning at the senior high school level is still often dominated by conventional paradigms, in which science is perceived merely as a collection of facts to be memorized and the teacher serves as the sole source of knowledge [2]. In fact, science learning should ideally not only focus on conceptual mastery but also on the development of science process skills and the ability to apply knowledge in real-world projects [3]. Through activities involving exploration, experimentation, and collaboration, students can actively engage, think critically, and develop creativity in problem-solving.

In practice, biology learning in senior high schools is still often monotonous, dominated by lectures, and lacking innovation. Learning models that are less varied have the potential to reduce students' motivation, hinder the optimal development of thinking skills, and focus the learning process solely on theoretical aspects [4]. One alternative relevant to the demands of 21st-century learning is the application of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) learning model. This approach integrates various disciplines in a cohesive manner, encouraging students to think creatively, solve problems, and produce original products or

works. The integration of the arts component in STEAM also helps students express ideas creatively while reinforcing their understanding of scientific concepts [5][6].

Within the context of the *Kurikulum Merdeka* (Independent Curriculum) currently implemented in Indonesia, students are required to become active subjects in the learning process, one of which is through the strengthening of scientific literacy. Scientific literacy not only encompasses an understanding of scientific concepts but also the skills to seek, evaluate, and apply information from various sources, including books, the internet, and digital media [7][8]. When scientific literacy is integrated with STEAM-based learning, students not only gain a deeper understanding of biology but are also able to connect it to real-world phenomena and develop innovative solutions to various problems.

One of the essential skills that needs to be nurtured through the integration of STEAM and scientific literacy is creative thinking. Creative thinking reflects the ability to generate original, flexible, and useful ideas in problem-solving [9]. Munandar identifies four indicators of creative thinking: fluency, flexibility, originality, and elaboration [10]. These four indicators can be cultivated through learning experiences that provide opportunities for students to explore ideas, work collaboratively, and produce tangible products.

Preliminary observations in several senior high schools indicate that the implementation of STEAM-based learning is still limited. Teachers tend not to integrate this approach with scientific literacy, partly due to constraints in time, resources, and students' readiness. As a result, students are less motivated to develop their creativity and remain dependent on teachers' explanations. Based on these conditions, it is necessary to implement STEAM-based biology learning oriented toward scientific literacy to enhance senior high school students' creative thinking skills.

2. RESEARCH METHOD

This research employed a quantitative approach with a quasi-experimental design using a posttest-only control design model. According to Sugiyono, a quasi-experimental design involves a control group but is not fully capable of controlling external variables that may influence the experiment's implementation [11]. This design was chosen to examine the effect of implementing science literacy-oriented STEAM-based biology instruction on the creative thinking skills of senior high school students.

The study was conducted at SMA Negeri 4 Parepare during the odd semester of the 2024–2025 academic year. The research subjects were Grade XI science stream students selected using a simple random sampling technique, namely, the random selection of sample members without considering specific strata within the population (Sugiyono, 2018). The randomization process yielded two classes as the research sample: one experimental class, which received STEAM-based biology instruction integrated with science literacy, and one control class, which received conventional instruction. Prior to implementation, the researcher prepared instructional materials, including teaching modules, essay-type creative thinking skill test instruments, test blueprints, learning materials, and tools and materials for biology projects relevant to the lesson content, such as creating models or prototypes of simple ecosystems.

Instruction in the experimental class was carried out in three sessions, during which students were assigned a STEAM-based project integrating science, technology, engineering, arts, and mathematics with a focus on science literacy. The learning activities comprised the stages of engage, explore, explain, engineer/create, and evaluate. Meanwhile, the control class underwent two sessions of conventional learning using lecture and question–answer methods. After the learning activities, both groups were given a posttest consisting of seven essay questions to measure students' creative thinking skills. The test instruments referred to the indicators of fluency, flexibility, originality, and elaboration as proposed by Munandar [10]. The test results were then categorized into five levels of creative thinking ability [12], namely:

Table 1. Creative Thinking Criteria

Creative Thinking Criteria	Class Interval
Not Creative	10 – 20
Less Creative	21 – 40
Fairly Creative	41 – 60
Creative	61 – 80
Very Creative	81 - 100

Posttest data were analyzed using normality and homogeneity tests as prerequisites, followed by hypothesis testing with an independent t-test to determine the difference in creative thinking skills between the experimental and control classes. All analyses were carried out using Microsoft Excel software.

3. RESULTS AND DISCUSSION

3.1 Results

Based on the research findings, the average scores for each aspect of students' creative thinking skills in the experimental and control classes are presented in Table 2.

Table 2. Average Scores of Creative Thinking Ability Aspects

Creative Thinking Aspect	Experimental Class	Control Class
<i>Fluency</i>	8,30	7,52
<i>Flexibility</i>	8,10	8,00
<i>Originality</i>	8,35	6,95
<i>Elaboration</i>	3,45	3,05

Based on the table, it is evident that the experimental class achieved higher average scores across all aspects compared to the control class. The most notable improvement was observed in the originality aspect, where the experimental class obtained a score of 8.35, while the control class achieved only 6.95. This finding indicates that the implementation of STEAM-based learning integrated with scientific literacy can effectively encourage students to generate more original ideas.

After combining the scores from all aspects of creative thinking, the overall average score for each class was obtained, as shown in Table 3.

Table 3. Nilai Rata-rata Kemampuan Berpikir Kreatif

Class	Average Score	Category
Experimental	81	Very Creative
Control	73	Creative

The results in Table 3 show that the average creative thinking ability score of students in the experimental class falls into the "very creative" category, while the control class is in the "creative" category. This difference indicates that the implementation of STEAM-based biology learning oriented toward scientific literacy has a positive contribution to enhancing students' creative thinking abilities compared to conventional learning.

3.2. Discussion

The results of the study indicate that the implementation of science literacy-oriented STEAM-based biology learning has a positive effect on the creative thinking skills of senior high school students. This is evident from the higher average score of the experimental class compared to the control class, both in each aspect of creative thinking (fluency, flexibility, originality, and elaboration) and in the overall score. The average score of the experimental class reached 81 (very creative category), while the control class only obtained a score of 73 (creative category). These findings align with the research objective, namely to examine the effectiveness of implementing STEAM-based learning in enhancing students' creativity through the reinforcement of science literacy.

The significant difference between the experimental and control classes can be explained by the characteristics of STEAM-based learning, which is integrative, contextual, and student-centered. This model combines elements of science, technology, engineering, arts, and mathematics, thereby providing rich and diverse learning experiences. In the context of this study, student engagement in biology projects that required conceptual exploration, solution design, and the creation of tangible products facilitated the development of creative thinking indicators. The largest improvement in the originality aspect shows that students were able to generate new and unique ideas when given the freedom to create with guided direction.

These findings are consistent with the results of research by Razi and Zhou, who stated that STEAM learning fosters creative thinking skills through the integration of the arts into science and technology processes, enabling students to express ideas in innovative ways [4]. In addition, research by Herro and Quigley showed that the STEAM approach can increase student engagement and the ability to solve complex problems because students are accustomed to working collaboratively and in a multidisciplinary manner [5].

The integration of science literacy into STEAM learning also plays an important role in supporting these results. Science literacy helps students understand concepts deeply, connect knowledge to real-world phenomena, and search for and evaluate information from various sources [13]. Thus, students do not rely solely on materials from the teacher but also develop independent learning skills. This finding is supported by research by Fives et al., which stated that science literacy contributes to the improvement of higher-order thinking skills, including creativity [8].

The research method used in this study, namely the posttest-only control design with different treatments between the experimental and control classes, provides a clear picture of the treatment's effectiveness. The

treatment in the form of STEAM-based projects implemented over three meetings allowed students to experience the learning cycle from problem exploration, solution design, to the evaluation of their work. This is consistent with the opinion of Perignat and Katz-Buonincontro that learning processes requiring students to create and reflect on their work can enhance fluency, flexibility, and originality [6].

Thus, the findings of this study reinforce empirical evidence that the implementation of science literacy-oriented STEAM-based biology learning is effective in improving the creative thinking skills of senior high school students. This learning model is not only relevant to the demands of the Merdeka Curriculum, which emphasizes student-centered learning, but also aligns with the needs of 21st-century education, which requires higher-order thinking skills[14][15]. Therefore, biology teachers are advised to adopt this approach continuously, accompanied by the development of teaching materials and assessment strategies that support creative learning and science literacy.

Although this study provides strong evidence of the effectiveness of science literacy-oriented STEAM-based biology learning in enhancing the creative thinking skills of senior high school students, there are several limitations that need to be considered. First, the relatively short treatment duration of three meetings in the experimental class may limit the maximum development of students' creativity. Second, the implementation of STEAM-based projects requires more resources, time, and coordination compared to conventional learning, which can be a challenge in schools with limited facilities. Third, the measurement of creative thinking skills in this study was only carried out through essay tests and product assessments, and thus has not fully captured the process aspects of students' creative thinking during the learning activities.

Based on these limitations, future research is recommended to implement science literacy-integrated STEAM learning over a longer period of time and across various biology topics. In addition, it is necessary to develop authentic assessment instruments, such as portfolios or learning journals, that can provide a more comprehensive picture of students' creativity development. Collaboration between biology teachers and teachers from the fields of arts, technology, and mathematics is also recommended to enrich project activities so that the integration of STEAM can be optimized.

4. CONCLUSION

Based on the objectives formulated in the Introduction, this study aimed to demonstrate that the implementation of science literacy-oriented STEAM-based biology learning can enhance the creative thinking skills of senior high school students. The findings presented in the Results and Discussion section indicate a significant difference between the experimental and control classes, both in the overall scores and across each aspect of creative thinking (fluency, flexibility, originality, and elaboration). The experimental class, which received STEAM-based learning integrated with science literacy, achieved the "very creative" category with an average score of 81, while the control class fell into the "creative" category with an average score of 73. These findings confirm that the expectations stated in the Introduction are consistent with the results obtained, thus demonstrating alignment between the study's objectives, methods, and outcomes.

The prospects for developing the findings of this study are considerable. In the short term, the STEAM-based biology learning model oriented toward science literacy can be adapted and applied to other biology topics in senior high schools, particularly those relevant to real-world problem-based projects. In the long term, this approach has the potential to be sustainably integrated into the school curriculum to strengthen 21st-century skills, especially creativity, collaboration, and science literacy. Further research could develop more comprehensive authentic assessment instruments, broaden the scope of subject matter, and involve cross-disciplinary collaboration more intensively to produce more meaningful and applicable learning experiences.

REFERENCES

- [1] S. Hasmyati, Andi, and A. Arafah, *Effective Learning Models In Physical Education Teaching*, 1st ed. Yogyakarta, Indonesia: CV Budi Utama, 2018.
- [2] Nuriani and W. Muliawan, "Development of science learning with project-based learning on science process skill: A needs analysis study," *Int. J. Sci. Learn.*
- [3] R. R. Setiawan, Suwondo, and W. Syafii, "Implementation of project-based learning student worksheets to improve students' science process skills on environmental pollution in high schools," *J. Educ. Sci.*, vol. 5, no. 1, pp. 130–140, 2021, doi: 10.31258/jes.5.1.p.130-140.
- [4] A. Razi and G. Zhou, "STEM, iSTEM, and STEAM: What is next?," *Int. J. Technol. Educ.*, vol. 5, no. 1, pp. 1–29, 2022, doi: 10.46328/ijte.231.
- [5] D. Herro and C. F. Quigley, "Exploring teachers' perceptions of STEAM teaching through professional development: Implications for teacher educators," *Prof. Dev. Educ.*, vol. 43, no. 3, pp. 416–438, 2017, doi: 10.1080/19415257.2016.1205507.
- [6] L. B. Perignat and J. Katz-Buonincontro, "STEAM in practice and research: An integrative literature review," *Think. Skills Creat.*, vol. 31, pp. 31–43, 2019, doi: 10.1016/j.tsc.2018.10.002.

-
- [7] OECD, *PISA 2018 Assessment and Analytical Framework*. Paris, France: OECD Publishing, 2019.
- [8] H. Fives, W. Huebner, and D. Birnbaum, "Developing a measure of teachers' knowledge of student engagement," *J. Educ. Psychol.*, vol. 106, no. 3, pp. 1–16, 2014, doi: 10.1037/a0036652.
- [9] M. A. Runco and S. Acar, "Divergent thinking as an indicator of creative potential," *Creat. Res. J.*, vol. 24, no. 1, pp. 66–75, 2012, doi: 10.1080/10400419.2012.652929.
- [10] U. Munandar, *Pengembangan Kreativitas Anak Berbakat*. Jakarta, Indonesia: Rineka Cipta, 2017.
- [11] Sugiyono, *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R&D*. Bandung, Indonesia: Alfabeta, 2018.
- [12] K. Sari and A. Nurwahyunani, "Profil literasi sains siswa SMP Negeri se-Kota Semarang," *J. Pendidik. IPA Indones.*, vol. 6, no. 2, pp. 249–361, 2016, doi: 10.15294/jpii.v6i2.9616.
- [13] OECD, *PISA 2018 Assessment and Analytical Framework*. Paris, France: OECD Publishing, 2019.
- [14] M. Pérez Torres, D. Couso Lagarón, and C. Marquez Bargalló, "Evaluation of STEAM project-based learning (STEAM PBL) instructional designs from the STEM practices perspective," *Educ. Sci.*, vol. 14, no. 1, p. 53, 2023, doi: <https://doi.org/10.3390/educsci14010053>.
- [15] S. Pahmi, D. Juandi, and R. Sugiarni, "The effect of STEAM in mathematics learning on 21st century skills: A systematic literature reviews," *Prisma*, vol. 11, no. 1, pp. 93–104, 2022, doi: <https://doi.org/10.35194/jp.v11i1.2039>.