Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

The Influence of STEM-Based Project Learning Models on Science Literacy and Creative Thinking Skills of Junior High School Students

Desy Akyuni*, Ida Bagus Putu Arnyana, I Nyoman Tika

Universitas Pendidikan Ganesha, Singaraja, Indonesia
Corresponding Email: desybwi1@gmail.com

Abstract. This study aims to assess the effectiveness of the STEM-based project learning model on the scientific literacy and creative thinking skills of eighth-grade junior high school students. Using a quasi-experimental approach, the study compared the results between the group using the STEM model and the group with direct learning. The instruments used included a PISA-based scientific literacy test and a creative thinking test based on the Torrance indicators. The analysis results showed significant differences between the two groups, where students who participated in STEM-based learning showed higher improvements in both aspects. These findings confirm that the project-based and STEM-based learning models are effective in developing student competencies, especially in the context of 21st-century learning. Therefore, it is important for educators to apply innovative, contextual and cross-disciplinary approaches to optimize student potential.

Keywords: Project Learning Model, STEM, Science Literacy, Creative Thinking Ability

1 Introduction

Literacy in the world of education is a very important skill for students, not only including reading and writing skills, but also critical and creative thinking skills (Siregar et al., 2025). Literacy serves as the main foundation for students to understand the subject matter and actively participate in the learning process. Without good literacy skills, students will struggle to learn and face academic challenges. In addition, literacy helps students develop analytical and creative thinking skills, which are indispensable in today's information age. Literacy is not just the ability to read and write, but also includes the ability to think critically, analyze information, and use knowledge in the context of daily life (Holm, 2024; Siregar et al., 2025). In the context of science learning, science literacy is so important to pay attention to.

Literacy in education is defined as a set of skills that includes the ability to read, write, think critically, and process information reflectively. In an operational context, literacy is understood as the ability to use language and symbols to understand and participate in academic and social life. Science literacy is a special form of literacy, which emphasizes understanding the concepts, processes, and implications of science in real life. Operationally, science literacy can be measured through indicators of the ability to connect science knowledge with personal, social, and global issues. On the other hand, creative thinking is the ability to generate original, flexible, and useful ideas in solving problems. Creative thinking in education can be operationalized through indicators such as fluency, flexibility, novelty, and elaboration. Although these three constructions are different, they are interconnected in equipping students to face the challenges of the 21st century. General literacy provides a cognitive foundation, science literacy expands its application in scientific contexts, while creative thinking enriches the problem-solving process. Thus, the three are positioned as separate competencies that complement each other and need to be measured systematically in education.

However, the main problem in the implementation of science literacy is confusion in educational policies and practices related to the competencies taught in literacy achievement (Osborne & Allchin, 2024). The learning process that is carried out emphasizes more on mastering scientific knowledge, while the implications of science on daily life are neglected even though not all students will work as scientists (Rudolph, 2024). In addition, the concept of science literacy is often vague, not translated into concrete and measurable competencies in educational standards. As a result, students do not have the resources to distinguish between legitimate science and the disinformation that is widely circulated on social media. This is due to low attention to local environmental issues (Kumar et al., 2024). In addition, many teachers are still not trained to effectively integrate science literacy into the curriculum, particularly in the context of local culture and values that are often at odds with modern science. The current science learning process is considered to still need reform, including in the provision of teaching materials, assessment methods, and learning processes that are able to educate students to become science-literate citizens while being responsible for the environment.

In addition to science literacy, creative thinking skills are an important part of society 5.0. Creative thinking skills are the capacity to generate diverse, flexible, and original ideas in solving problems (Babalola & Keku, 2024). Meanwhile, according to Samaniego et al. (2024) Creative thinking ability is defined as a complex mental process that allows individuals to think, imagine, and act differently to create new ideas, solve problems, and give new meaning to a situation or task. In the context of education, creative thinking reflects an original and innovative way of understanding and facing reality. Creative activities involve unusual but still practical and rewarding solutions. Wilkie (2024) more emphasis on the ability in the process to produce new, unusual, and valuable ideas or solutions, both for the person himself and in the context of his group. Creative thinking is shown through students' ability to solve problems (problem solving) and design new problems (problem posing). The importance of this ability for students lies in its benefits in increasing metacognitive awareness, confidence, and readiness to face creative challenges in education and the world of work. Samaniego et al. (2024) Emphasizing the importance of this ability for students lies in its role in preparing them for the complex and ever-changing challenges of the 21st century. Creative thinking skills not only enrich academic learning, but also support personal growth, innovative decision-making, and active engagement in the social, cultural, and technological worlds.

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

Based on the identification of obstacles in efforts to build science literacy and creative thinking skills in students, the root of the problem is in the design of the curriculum that is not optimal in realizing these skills. Curriculum design in schools cannot be separated from the implementation of the learning process, one of which is the use of learning innovations. Learning innovations can be carried out using innovative learning models such as project learning models (MPP).

The project learning model is an inquiry-based learning approach that actively engages students in building knowledge through real project work and the creation of authentic products (Guo et al., 2020). In this process, students not only learn theory, but also apply it in real-life contexts (Abidin et al., 2020; Guo et al., 2020; Rahmania, 2021). Teachers and outsiders act as facilitators who provide support and feedback during the learning process. According to Rahmania (2021), The project learning model is a learning approach that emphasizes contextual and meaningful learning experiences for students through engagement in complex project activities. This learning places students as student-centered, where they not only learn theory, but also apply it in real-world activities (Fiteriani et al., 2021; Guo et al., 2020; Rahmania, 2021). Project learning encourages students to make decisions, design solutions, solve problems, and produce products as a result of learning.

The main characteristics of project learning are the presence of challenging trigger questions, focus on learning objectives, involvement in educational activities, collaboration between students, the use of technology as scaffolding, and the creation of real artifacts (Guo et al., 2020). This process requires students to work together, integrate knowledge, and create solutions to complex problems. According to Rahmania (2021) Problems or challenges are the main drivers of students in designing collaborative problem-solving processes and continuous evaluations. In addition, this learning is flexible to mistakes, mistakes found in the learning process are steps to make improvements and refine the next learning process (Adriyawati et al., 2020; Chen et al., 2022).

The main problem of science literacy in educational practice is the confusion in policies regarding competency standards that must be achieved. Education policies often emphasize the mastery of scientific knowledge alone, while aspects of its application in daily life are neglected. This gap persists because evaluation standards are still based on memorizing concepts, not applying knowledge. The curriculum also rarely integrates the ability to distinguish valid scientific information from disinformation that is widely circulated on social media. This is exacerbated by the lack of training for teachers in integrating science literacy contextually. Project-based learning can be a solution because it emphasizes real-world experiences, application of concepts, and student involvement in problem-solving. In this model, students not only understand the theory, but also use it to design practical solutions. Thus, project learning provides space to reduce policy gaps by connecting science, life skills, and community needs. This solution emphasizes that science literacy is not just knowledge, but a competence that is relevant to social and technological life.

The framework proposed by this study emphasizes the integration of local cultures, values, and environmental issues in science literacy education. This integration is important because there are tensions between modern science and local traditions that are often considered to be at odds. A project-based approach allows students to bridge those tensions through activities rooted in local contexts. For example, students can study

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

their local environmental problems, then design solutions that combine scientific knowledge with local wisdom. This process makes science literacy not only relevant, but also more accepted by the public. Thus, students are trained to become citizens who are sensitive to culture, values, and environmental issues. The framework also emphasizes the importance of collaboration between teachers, students, and communities in building solutions. Technology serves as a tool to broaden students' horizons while documenting locally-based innovations. Ultimately, this integration results in science literacy that is not only academic, but also contextual, culturally rooted, and oriented towards environmental sustainability.

2 Method

Quasi-experimental research design is essential in evaluating the effects of treatment when full individual randomization is not possible (Kenny & Kenny, 1994). A commonly used quasi-experimental design is the Nonequivalent Control Group Design, in which samples are not randomly assigned to the treatment and control groups. Instead, groups are formed based on pre-existing characteristics or conditions. This design typically involves pre-test and post-test measurements of dependent variables, which allows researchers to assess the effects of the treatment. So in this study the Pretest-Posttest Nonequivalent Control Group Design presented in Figure 3.1 was used.

O_1	X_1	O_2
O_3	X_2	O_4

Bryk & Weisberg (1977)

Figure 1. Research Design

The population in this study is grade 8 students at SMP Negeri 3 Singojuruh which consists of two classes, namely class 8A and class 8B. This study required two groups so that the entire population was used as a sample in the study. The instruments prepared in this study are science literacy tests and creative thinking ability tests. The science literacy test that is compiled refers to the indicators issued by the OECD (2022) which consists of: 1) Science Context; 2) Scientific knowledge; and 3) Science Competence. The creative thinking ability test refers to Torrance's theory which consists of a number of indicators, namely: fluency, flexibility, originality, and elaboration. The materials used are the same as the science literacy tests, namely vibration, waves, and light. The data collected in this study are primary data collected directly by the researcher during the research period. The test is given at the beginning to find out the initial ability and the final test to find out the student's learning achievements. The value of the reliability coefficient of the science literacy test was 0.716 with a high category. The value of the reliability coefficient of the creative thinking ability test was 0.767 with a high category. Data analysis techniques in this study include: 1) descriptive

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

analysis; 2) Assumption testing; and 3) hypothesis testing. The statistics used in this study are parametric statistics. Science literacy data and critical thinking skills must meet the criteria as a parameter which includes: normality test, multivariate normality, homogeneity, multivariate homogeneity, linearity, and collinearity test. Hypothesis testing using the MANCOVA multivariate statistical test. These statistics test the main influence of the learning model on both bound variables at once. This hypothesis test pays attention to multivariate statistical values, namely Pillae Trace, Wilk Lambda, Hotelling Trace, Roy's Largest Root (Candiasa, 2010). If the value of the multivariate statistical significance is less than 0.05, then the null hypothesis is rejected and the alternative hypothesis is accepted. All statistical tests use SPSS version 25.0.

3 Result and Discussion

3.1 Result

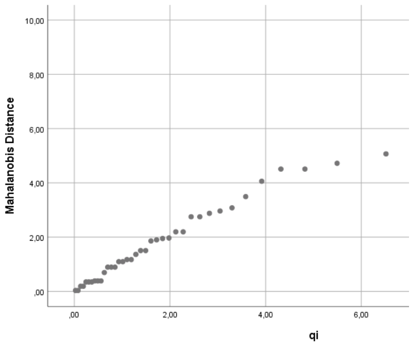
This study shows that the STEM-BASED PROJECT LEARNING (MPP-STEM) model is superior to the direct learning model (MPL) in improving students' science literacy and creative thinking skills. In science literacy, the MPP-STEM group achieved an average score of 17.26 (SD = 1.60), higher than the MPL group with an average of 15.90 (SD = 1.71). As many as 85% of MPP-STEM students are in the Very Good category, while only 59% of MPL students are in that category. For creative thinking skills, all MPP-STEM students (100%) were in the Good category, with an average score of 32.77 (SD = 1.84), while the MPL group had an average of 30.69 (SD = 1.66) with 90% in the Good category and 10% in the Fairly Good category. No participants from the MPP-STEM group were under the Good category. In general, MPP-STEM showed a more even distribution of outcomes, higher average achievements, and no participants with low achievements, indicating the effectiveness of this model in encouraging academic achievement and equitable distribution of learning outcomes.

Table 1. Comparison of MPP-STEM and MPL Data Descriptions

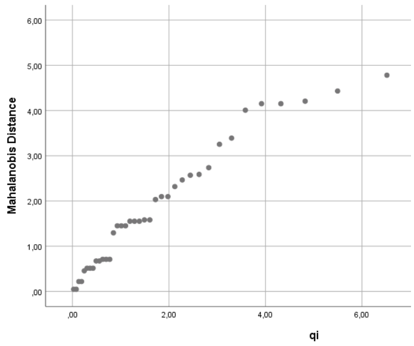
Aspects	Category	MPP-STEM (%)	MPL (%)	Average	Standard Deviation
Science Literacy	Excellent	85%	59%	17,26	1,60
	Good	15%	41%	15,90	1,71
Creative Thinking	Excellent	0%	0%	32,77	1,84
	Good	100%	90%	30,69	1,66
	Enough/ < Enough	0%	10%		

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

Before further statistical analysis is carried out, a series of assumption tests are first carried out to ensure the feasibility of the data. The normality test was carried out on the pretest and posttest scores of science literacy (LS) and creative thinking skills (KBK) in both groups, namely MPP-STEM and MPL, using the Kolmogorov-Smirnov and Shapiro-Wilk methods. The results showed that the overall significance value was above 0.05, in both univariate and multivariate tests, indicating that the data was distributed normally. Multivariate normality is also supported by scatterplot results between the Mahalanobis distance and chi-squared values which show that the distribution of data mostly follows a linear line, both in the control group (Figure 2a) and the experiment (Figure 2b). Deviant points can be ignored because they are very few in number and are considered multivariate biases that do not affect the overall pattern. See figure 2.



(a)



(b)

Figure 2. Scatterplots of distance mahalanobis and chi-squares

Furthermore, a variance homogeneity test was carried out with Levene's Test on the KBK and LS posttest scores. The results showed that all significance values were well above 0.05, either based on the mean, median, median with adjusted df, or trimmed mean. This shows that the variance between groups is homogeneous. The homogeneity test of the variance-covariance matrix with Box's M yielded a significance value of 0.895 which is also greater than 0.05, indicating that there is no significant difference between the variance-covariance matrix of the two groups, so this assumption is also met. The linearity test is carried out to ensure that there is a linear relationship between the initial score (pretest) and the final score (posttest) in science literacy and creative thinking ability. The results showed that the significance value for linearity was 0.000 ($p < 0.05$) and the significance value for deviation from linearity was above 0.05, namely 0.927 for science literacy and 0.580 for creative thinking ability. This means that the relationship between pretest and posttest is linear and there is no deviation from linearity, so the pretest score can be used as a covariate in the follow-up analysis. Finally, the collinearity test was carried out through the Pearson correlation between the final score of science literacy and the ability to think creatively. The results showed a correlation value of 0.320 with a significance of 0.004. Although this relationship is significant, the relatively low correlation value and far from the limit of collinearity (0.80) indicates that there is no problem of collinearity between dependent variables. Based on the results of all these tests, it can be concluded that all the data in this study meet the basic assumptions of parametric analysis, both univariate and multivariate. Therefore, the data is worth further analysis using the MANCOVA statistical technique.

Simultaneous hypothesis testing showed that there were differences in science literacy and creative thinking skills simultaneously between students who followed the MPP-STEM and MPL models.

Table 2. Summary of the First Hypothesis Testing

Variable	Wilks' Lambda	F	Sig.	Conclusion
pre_ls (kovariat)	0,249	109,884	0,000	Significant effect
pre_kbk (kovariat)	0,820	8,032	0,001	Significant effect
model	0,296	86,852	0,000	Significant effect

Since the significance value < 0.05, H_0 is rejected. This means that there are simultaneous differences between the MPP-STEM and MPL groups regarding science literacy and students' creative thinking skills.

Furthermore, the second hypothesis test showed that there was a difference in science literacy between the MPP-STEM and MPL student groups through the results of the Between-Subjects Effects Test (science literacy posttest) as shown in Table 3. Students who took MPP-STEM showed significantly higher average science literacy compared to students with the MPL model. The difference of 2.909 is stated to be significant at the level of 0.000.

Table 3. Significance of the difference in the average of science literacy data between the two groups

Model	Average	Difference	Sig.
MPP-STEM	17,26	2,909	0,000
MPL	15,90		

Furthermore, the third hypothesis test showed that there was a difference in creative thinking ability between the MPP-STEM and MPL student groups through the Between-Subjects Effects Test Results (posttest of creative thinking ability) as shown in Table 4. The students' creative thinking abilities in the MPP-STEM model are significantly higher than those of MPL. The difference of 1.875 with a significance of 0.000 shows the advantages of project-based and STEM models.

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

Table 4. Significance of the difference in the average of science literacy data between the two groups

Model	Average	Difference	Sig.
MPP-STEM	32,77	1,875	0,000
MPL	30,69		

3.2 Discussion

MPP-STEM is designed to place students at the center of learning through authentic problem-solving activities, demands active involvement, and emphasizes the integration of concepts from the fields of science, technology, engineering, and mathematics (Afriana et al., 2016; H. Lestari & Rahmawati, 2020; T. P. Lestari et al., 2018). The five operational stages in MPP-STEM: defining problems, analyzing and gathering information, designing solutions, executing plans, and communicating results directly train students to develop science literacy through the interconnectedness between scientific knowledge and real-world contexts. This activity requires students to use science knowledge in identifying and analyzing problems, as well as draw conclusions based on evidence, as emphasized in the definition of science literacy (Alabbasi et al., 2022; Domenici, 2022). In addition, the process of designing and implementing solutions encourages students to think originally, flexibly, and elaboratively, which is an indicator of creative thinking ability. A comparison of the steps between the STEM-based Project Learning Model (MPP-STEM) and the Direct Learning Model (MPL) shows that the simultaneous advantages of science literacy and creative thinking skills in the MPP-STEM group are strongly influenced by their more complex, contextual, and problem-solving oriented learning stages (Huang et al., 2020; Ritter et al., 2020; Zhou, 2021). In MPP-STEM, the initial stage is to determine and analyze the problem directly involving students in the process of identifying contextual issues and collecting relevant scientific information, which is in line with the indicators of the science context and science knowledge. The stages of designing solutions and implementing plans provide opportunities for students to develop science competencies through experimental activities and practical application of concepts. Simultaneously, this stage also stimulates fluency and flexibility of thinking, as students are encouraged to come up with various solution ideas and choose the most effective strategies. The final stage, which is to communicate the results, encourages elaboration and originality, as students must present their products and reasoning in a clear, creative, and scientifically evidence-based manner (Ritter et al., 2020).

The root of the problem identified in this study is the design of the national curriculum that has not fully aligned the goals of literacy with the development of creativity. The curriculum still tends to emphasize mastery of factual content rather than critical, analytical, and creative thinking skills. This imbalance makes the achievement of science literacy limited to memorizing concepts, not applying them to real-life contexts.

Critical evaluation shows the need for a paradigm shift from outcome-oriented learning towards process-based, experiential learning, and student active engagement. Concrete recommendations include the integration of science literacy and creative thinking indicators into core competency standards, as well as the development of contextual project-based teaching tools. With this step, the curriculum can be more aligned with the needs of the 21st century society that demands high literacy and sustainable creativity.

The simultaneous process of increasing science literacy and creative thinking skills in MPP-STEM learning can be explained more strongly through the fundamental relationship between the two variables. Science literacy not only requires an understanding of scientific concepts, but also the ability to identify problems, evaluate information, and draw conclusions based on evidence, all of which require a high-level creative thinking process (Aristeidou & Herodotou, 2020; Fortus et al., 2022; Queiruga-Dios et al., 2020). In this context, the ability to think creatively is an important element in developing science literacy, because a deep understanding of science often arises from the ability to look at problems from multiple perspectives (flexibility), come up with various alternative solutions (fluency), and find unique and effective approaches (originality and elaboration). MPP-STEM, through stages such as designing solutions and executing plans, creates space for these two abilities to develop simultaneously as students use science knowledge to solve real problems, they are also trained to think imaginatively, openly, and innovatively. Thus, the reciprocal relationship between science literacy and creative thinking in STEM-based project learning explains why this model is able to provide simultaneous advantages, in contrast to MPL which separates the process of mastering concepts from developing students' creative potential.

Within a conceptual framework, STEM-based project learning is aligned with a cross-disciplinary approach that demands the integration of science, technology, engineering, and mathematics in authentic problem-solving (Chang & Chen, 2022; Crawford et al., 2024), While in-person learning is fragmented and less contextual. Operationally in the field, STEM-based project learning provides a more challenging learning experience and involves the active participation of students in all stages of activities, from planning to presentation of results, which encourages the development of science literacy more comprehensively. Meanwhile, hands-on learning is often limited to lectures and practice questions, which while efficient for factual knowledge transfer, are less able to foster deep understanding and scientific thinking skills. Therefore, the advantages of STEM-based project learning in improving science literacy can be understood as a result of the integrity of the pedagogical approach, contextual relevance, and active involvement of students in the learning process.

This study provides strong empirical evidence regarding the effectiveness of PjBL-STEM in improving students' science literacy and creative thinking. The data showed significant differences in average scores between the experimental and control groups, both in science literacy and creative thinking skills. In addition, the distribution of learning outcomes in the PjBL-STEM group is more even, without students in the low category, which reinforces the claim of superiority of this model. These findings go beyond mere citations of the literature, as statistical analyses such as MANCOVA, homogeneity tests, and intervariable correlations are used to reinforce the validity of conclusions. Thus, this study confirms that PjBL is not only theoretically relevant, but also measurably proven in improving two important competencies. This empirical evidence

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

provides a foundation for wider adoption of project learning models in formal education systems.

Regarding the assessment strategy, this study uses a quantitative approach through a science literacy test and creativity measurement instruments based on fluency, flexibility, originality, and elaboration indicators. However, the manuscript has not explicitly mentioned the use of rubrics or performance-based assessments in more detail. This is important because science literacy and creativity are multidimensional, so they require more holistic measurement tools. Project-based assessments with descriptive rubrics can help assess the quality of ideas, collaborative processes, and relevance of solutions to real-world contexts. Likewise, performance-based tasks such as experimental products or presentations can showcase students' abilities more authentically. Therefore, the development of a comprehensive assessment strategy is a follow-up recommendation so that the excellence of PjBL can be measured validly and reliably.

A recognized limitation is that many teachers have not been trained in literacy integration and the implementation of PjBL. This research emphasizes the importance of professional development programs that focus on innovative pedagogy, STEM integration, and authentic assessments. Teachers need to be trained on how to design contextual projects, manage student collaboration, and utilize technology as a learning support. In addition, support in the form of modules, rubric guides, and learning communities between teachers can increase implementation capacity. This study also shows that the success of PjBL-STEM is highly determined by the readiness of teachers to act as facilitators, not just material presenters. Thus, improving teacher competence is an absolute requirement so that PjBL can be implemented effectively and sustainably in schools.

Although STEM-based Project Learning has been shown to improve science literacy, there are some challenges that can make it difficult to fully understand this improvement. First, integrating STEM concepts into projects can be tricky. Students may have trouble seeing the connections between different STEM fields and how they apply to real-world problems. This complexity can hinder their ability to understand science concepts effectively, making it difficult to measure literacy improvement. Second, some students find it difficult to visualize engineering concepts in a framework. These difficulties can lead to misunderstandings and a lack of confidence in their science abilities, which can obscure the actual literacy gains that occur through the MPP-STEM approach. Third, the successful implementation of MPP-STEM requires teachers to be ready and knowledgeable about the content and pedagogical strategies involved. If teachers do not have the necessary training or resources, it can hinder the effectiveness of the approach and make it difficult to achieve the desired increase in science literacy.

Operationally, MPP-STEM integrates the four main areas of science, technology, engineering, and mathematics in a complex and challenging series of projects. Each stage in this model, such as designing solutions and executing plans, provides space for students to explore ideas extensively, strategize, develop prototypes, and revise ideas, which directly activates creative thinking indicators such as fluency, flexibility, originality, and elaboration (T. P. Lestari et al., 2018; Rahmawati et al., 2021). On the other hand, MPL emphasizes more on the delivery of material by teachers, drill exercises, and evaluations that focus on the final result, not the process. In practice in the field, MPLs often limit student initiative due to rigid learning time and structure, while MPP-

STEM instead opens up space for student exploration and initiative in creating new solutions. Thus, MPP-STEM's excellence in encouraging creative thinking skills is not only due to its challenging learning design, but also because of its theoretical foundation that places students as active subjects in the learning process. This model gives students the freedom and responsibility to think, create, and make decisions, which is in stark contrast to MPL's more instructional and one-way approach.

4 Conclusion

The results showed that there were significant differences in science literacy and creative thinking skills between students who participated in learning using the STEM-based project model and students who participated in hands-on learning. Simultaneously, both abilities improved better in the group that used the STEM approach. Separately, students who learn with a STEM-based project model show higher levels of science literacy compared to students who learn through hands-on learning. Similarly, students' creative thinking abilities are also more developed in STEM project-based learning. These findings suggest that STEM-based project learning models are more effective in developing students' science literacy and creative thinking skills compared to hands-on learning approaches.

References

1. Abidin, Z., Utomo, A. C., Pratiwi, V., & Farokhah, L. (2020). Project-Based Learning - Literacy in Improving Students' Mathematical Reasoning Abilities in Elementary Schools. *JMIE (Journal of Madrasah Ibtidaiyah Education)*, *4*(1), 39. https://doi.org/10.32934/jmie.v4i1.170
2. Adriyawati, Utomo, E., Rahmawati, Y., & Mardiah, A. (2020). Steam-project-based learning integration to improve elementary school students' scientific literacy on alternative energy learning. *Universal Journal of Educational Research*, *8*(5), 1863–1873. https://doi.org/10.13189/ujer.2020.080523
3. Afriana, J., Permanasari, A., & Fitriani, A. (2016). Project based learning integrated to stem to enhance elementary school's students scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 261–267. https://doi.org/10.15294/jpii.v5i2.5493
4. Alabbasi, A. M. A., Paek, S. H., Kim, D., & Cramond, B. (2022). What do educators need to know about the Torrance Tests of Creative Thinking: A comprehensive review. *Frontiers in Psychology*, *13*(October), 1–14. https://doi.org/10.3389/fpsyg.2022.1000385
5. Aristeidou, M., & Herodotou, C. (2020). Online citizen science: A systematic review of effects on learning and scientific literacy. *Citizen Science: Theory and Practice*, *5*(1), 1–12. https://doi.org/10.5334/cstp.224
6. Babalola, E. O., & Keku, E. (2024). Ethno-STEM Integrated Project-Based Learning to Improve Students' Creative Thinking Skills. *International Journal of Ethnoscience and Technology in Education*, *1*(2), 116. https://doi.org/10.33394/ijete.v1i2.11308
7. Bryk, A. S., & Weisberg, H. I. (1977). Use of the nonequivalent control group design when subjects are growing. *Psychological Bulletin*, *84*(5), 950–962. https://doi.org/10.1037/0033-2909.84.5.950

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

8. Candiasa, I. M. (2010). *Pengujian Instrumen Penelitian Disertai Aplikasi ITEMAN dan BIGSTEPS*. Unit Penerbitan Universitas Pendidikan Ganesha.
9. Chang, C. C., & Chen, Y. K. (2022). Educational values and challenges of i-STEM project-based learning: A mixed-methods study with data-transformation design. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.976724
10. Chen, S. Y., Lai, C. F., Lai, Y. H., & Su, Y. S. (2022). Effect of project-based learning on development of students' creative thinking. *International Journal of Electrical Engineering and Education*, *59*(3), 232–250. https://doi.org/10.1177/0020720919846808
11. Crawford, L. K., Arellano Carmona, K., & Kumar, R. (2024). Examining the Impact of Project-Based Learning on Students' Self-Reported and Actual Learning Outcomes. *Pedagogy in Health Promotion*. https://doi.org/10.1177/23733799241234065
12. Domenici, V. (2022). STEAM Project-Based Learning Activities at the Science Museum as an Effective Training for Future Chemistry Teachers. *Education Sciences*, *12*(1). https://doi.org/10.3390/educsci12010030
13. Fiteriani, I., Diani, R., Hamidah, A., & Anwar, C. (2021). Project-based learning through STEM approach: Is it effective to improve students' creative problem-solving ability and metacognitive skills in physics learning? *IOP Conference Series: Earth and Environmental Science*, *1796*(1). https://doi.org/10.1088/1742-6596/1796/1/012058
14. Fortus, D., Lin, J., Neumann, K., & Sadler, T. D. (2022). The role of affect in science literacy for all. *International Journal of Science Education*, *44*(4), 535–555. https://doi.org/10.1080/09500693.2022.2036384
15. Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*(April), 101586. https://doi.org/10.1016/j.ijer.2020.101586
16. Holm, P. (2024). Impact of digital literacy on academic achievement: Evidence from an online anatomy and physiology course. *E-Learning and Digital Media*, *22*(2), 139–155. https://doi.org/10.1177/20427530241232489
17. Huang, N. tang, Chang, Y. shan, & Chou, C. hui. (2020). Effects of creative thinking, psychomotor skills, and creative self-efficacy on engineering design creativity. *Thinking Skills and Creativity*, *37*(April), 100695. https://doi.org/10.1016/j.tsc.2020.100695
18. Kenny, D. A., & Kenny, D. A. (1994). A Quasi-Experimental Approach to Assessing Treatment Effects in Nonequivalent Control Group Designs A Quasi-Experimental Approach to Assessing Treatment Effects in the Nonequivalent Control Group Design. *Psychological Bulletin*, *82*(3), 345–362.
19. Kumar, V., Choudhary, S. K., & Singh, R. (2024). Environmental socio-scientific issues as contexts in developing scientific literacy in science education: A systematic literature review. *Social Sciences and Humanities Open*, *9*(May 2023), 100765. https://doi.org/10.1016/j.ssaho.2023.100765
20. Lestari, H., & Rahmawati, I. (2020). Integrated STEM through Project Based Learning and Guided Inquiry on Scientific Literacy Abilities in Terms of Self-Efficacy Levels. *Al Ibtida: Jurnal Pendidikan Guru MI*, *7*(1), 19. https://doi.org/10.24235/al.ibtida.snj.v7i1.5883
21. Lestari, T. P., Sarwi, S., & Sumarti, S. S. (2018). STEM-Based Project Based Learning Model to Increase Science Process and Creative Thinking Skills of 5th Grade. *Journal of Primary Education*, *7*(1), 18–24.
22. OECD. (2022). Are Students Ready to Take on Environmental Challenges? In *PISA, OECD Publishing*. https://www.oecd-ilibrary.org/education/are-students-ready-to-take-on-environmental-challenges_8abe655c-en

Journal of Science and Education (JSE)
Vol 6, Issue 1, September 2025, Pages 1006-1018
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v6i1.629

23. Osborne, J., & Allchin, D. (2024). Science literacy in the twenty-first century: informed trust and the competent outsider. *International Journal of Science Education*, 1–22. https://doi.org/10.1080/09500693.2024.2331980
24. Queiruga-Dios, M. Á., López-Iñesta, E., Diez-Ojeda, M., Sáiz-Manzanares, M. C., & Dorrío, J. B. V. (2020). Citizen science for scientific literacy and the attainment of sustainable development goals in formal education. *Sustainability (Switzerland)*, *12*(10). https://doi.org/10.3390/su12104283
25. Rahmania, I. (2021). Project Based Learning (PjBL) Learning Model with STEM Approach in Natural Science Learning for the 21st Century. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*, *4*(1), 1161–1167. https://doi.org/10.33258/birci.v4i1.1727
26. Rahmawati, Y., Hadinugrahaningsih, T., Ridwan, A., Palimbunga, U. S., & Mardiah, A. (2021). Developing the critical thinking skills of vocational school students in electrochemistry through STEM - Project-based learning (STEM-PjBL). *AIP Conference Proceedings*, *2331*. https://doi.org/10.1063/5.0041915
27. Ritter, S. M., Gu, X., Crijns, M., & Biekens, P. (2020). Fostering students' creative thinking skills by means of a one-year creativity training program. *PLoS ONE*, *15*(3), 1–18. https://doi.org/10.1371/journal.pone.0229773
28. Rudolph, J. L. (2024). Scientific literacy: Its real origin story and functional role in American education. *Journal of Research in Science Teaching*, *61*(3), 519–532. https://doi.org/10.1002/tea.21890
29. Samaniego, M., Usca, N., Salguero, J., & Quevedo, W. (2024). Creative Thinking in Art and Design Education: A Systematic Review. *Education Sciences*, *14*(2). https://doi.org/10.3390/educsci14020192
30. Siregar, M. M., Joharis, M., Nasution, N. M., Vera, Y., & Sitinjak, N. (2025). *International Journal of Educational The Importance of Literacy in the World of Education : " How Important is Literacy Really "*. 2–4.
31. Wilkie, K. J. (2024). Creative thinking for learning algebra: Year 10 students' problem solving and problem posing with quadratic figural patterns. *Thinking Skills and Creativity*, *52*(May), 101550. https://doi.org/10.1016/j.tsc.2024.101550
32. Zhou, Q. (2021). Development of creative thinking skills through aesthetic creativity in middle school educational music course. *Thinking Skills and Creativity*, *40*, 100825. https://doi.org/10.1016/j.tsc.2021.100825

