



Integrating STEM education and socio-scientific issues: Impacts on student creativity



Nafa Navi'a Hayati, Setiono^{ID*}, Sistiana Windyariani

Biology Education, Faculty of Teacher Training and Education, Muhammadiyah University of Sukabumi, Indonesia

* Corresponding author: setionoase@gmail.com

Article Info

Article History:

Received 22 July 2025
Revised 16 August 2025
Accepted 27 August 2025
Published 30 November 2025

Keywords:

STEM
Creativity
Socio-scientific issues



ABSTRACT

Creativity is an essential 21st-century skill that students must develop to solve real-life scientific and environmental problems. This study aims to determine the effect of the STEM-Socio Scientific Issues learning model on students' creativity in the concept of organic waste management. Students' creativity is measured based on four indicators according to Torrance, namely fluency, flexibility, originality, and elaboration. This study uses a quasi-experimental method with a non-equivalent control group design. The research subjects consist of two classes at Muhammadiyah High School in Sukabumi City. Data were collected through creativity tests in the form of pretest and posttest essay questions that had been validated and reliability-tested. The results showed that the STEM-SSI learning model significantly improved students' creativity, particularly in the aspects of fluency (N-Gain 0.4031), flexibility (0.3029), and originality (0.3017), with a moderate category. However, on the elaboration indicator, the control class achieved a slightly higher N-Gain score (0.3574) compared to the experimental class (0.3396), indicating that this aspect has not developed optimally in STEM-SSI learning. Nevertheless, since three out of four creativity indicators showed significant improvement in the experimental class, it can be concluded that STEM-SSI learning can enhance students' creativity, particularly in terms of fluency, flexibility, and originality.

Copyright © 2025, Hayati et al

This is an open access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license



Citation: Hayati, N.N., Setiono, & Windyariani, S. (2025). Integrating STEM education and socio-scientific issues: Impacts on student creativity. *JPBIO (Jurnal Pendidikan Biologi)*, 10(2), 328-340. DOI: <https://doi.org/10.31932/jpbio.v10i2.5207>

INTRODUCTION

Creativity is an important element in shaping individuals who are adaptive, innovative, and capable of dealing with complex problems (Hasanah et al., 2023; Susanti et al., 2022). Not only

that, creativity is needed because it can encourage someone to think outside the box, develop new ideas, and deal with problems in unique ways so that innovative solutions can be produced.

Creativity is not a fixed ability but must be cultivated and developed. Therefore, education plays a crucial role in fostering creativity. Richardson & Mishra (2018) emphasize that creativity must be nurtured through school-based learning, as it will be a key skill in the future. Therefore, the Merdeka Curriculum has been implemented as an effort to emphasize the development of creativity, innovation, and independence in the learning process of students (A. Firdaus & Alfian Hadi, 2023). Not only that, the independent curriculum is also designed to equip students with skills relevant to the rapid development of information technology, including emphasizing other abilities such as problem-solving, critical thinking, literacy, communication, and social-emotional skills (Muliardi, 2023; Murdiyanto et al., 2022; Sri Hanipah, 2023). This aligns with the demands of the modern world, where students are not only expected to master theoretical knowledge but also to apply it in real-world contexts. Creativity is even recognized as one of the six dimensions of the Pancasila learner profile, aiming to cultivate individuals who are not only intellectually intelligent but also capable of making tangible contributions to sustainable development (Kemendikbudristek, 2022).

According to the results of a survey conducted by the Global Creativity Index 2023, Indonesia is one of the countries with low creativity levels, ranking 150th out of 160 countries (Florida, Richard & Mellander, 2023). This serves as evidence that creativity in Indonesia still requires serious attention, necessitating greater efforts to improve it. Low student creativity remains an issue in many schools, which generally have not implemented active learning that fosters creative thinking, particularly in biology education (Prasetyo et al., 2021; Sugiarto & Djukri, 2015). Research shows that nearly 80% of students, regardless of their cognitive abilities (high, moderate, or low), have low levels of creativity, particularly in biology lessons (Julianto & Nurhamidah, 2018). This condition is caused by students' lack of desire to demonstrate their creativity (Sukarso et al., 2023).

Based on observation results, through the Verbal Creativity Test (Torrance Test of Creative Thinking Verbal), it was found that creativity at one private high school in Sukabumi City remains low, with 70.59% of students in the low category, 23.53% in the moderate category, and only 5.88% in the high category. This situation indicates that students' creativity needs to be enhanced through the implementation of appropriate learning models.

Efforts to enhance creativity can be made through learning models that require students to actively think and create, one of which is the STEM (Science, Technology, Engineering, and Mathematics) model. This model emphasizes the Engineering Design Process (EDP), which stimulates creativity in designing solutions and products (Setiono et al., 2023). STEM learning encourages students to identify problems, find solutions, think creatively, innovatively, collaborate, and communicate effectively, and is relevant to the learning needs of the 21st century (Damayanti et al., 2024; Syarah et al., 2021). Thus, the application of STEM learning is assumed to be able to enhance students' creativity through exploration, problem-solving, and independent product development (Widodo, 2021).

As an effort to optimize the learning model used in this study, the researcher integrated STEM with Socio-Scientific Issues (SSI). This integration was chosen because SSI can contribute to developing creative thinking skills. This is because SSI involves interdisciplinary connections between science content and social issues such as environmental, political, and health issues, based on moral reasoning, thereby providing students with contextual, meaningful, and relevant learning experiences tied to real-life situations. Additionally, controversial socio-scientific issues encourage students to think more deeply, explore diverse ideas, and propose innovative solutions to problems that do not have a single definitive answer. The socio-scientific issues addressed, such as waste

management, energy crises, or climate change, are complex real-world problems that require creative, science-based solutions. Indriani & Jayanti (2022) state that SSI-based learning has been proven to enhance students' creative thinking abilities. In line with this, Rahmawati et al. (2018) add that the creative thinking skills taught to students will lead to the development of creativity as a result of the learning process. Furthermore, Suhartini et al. (2023) state that integrating SSI into the context of STEM problems opens up great opportunities for students to be actively involved in learning that is directly related to real, relevant, contextual issues that can be debated. Therefore, the integration of socio-scientific issues into STEM learning has the potential to foster and develop students' creativity because the learning process becomes more relevant, meaningful, and aligned with students' needs.

The selected material is the utilization of waste, focusing on organic waste, given the high amount of food waste in Indonesia, which is estimated to reach 54.32% in 2024, having a significant impact on the environment (SIPSN, 2024). Learning with a waste problem context is expected to encourage students to think creatively in finding sustainable solutions, in line with the objectives of science education, which is to shape students who can make creative decisions and take creative actions for their community and environment (Permanasari, 2022).

This study aims to analyze students' creativity through the application of a STEM learning model integrated with socio-scientific issues on the concept of waste utilization. Through the application of this model, it is hoped that students will be able to think creatively in seeking, designing, and finding solutions to problems related to socio-scientific issues, particularly those related to waste management and the environment.

RESEARCH METHODS

Research Design

This study used a quantitative approach, with a quasi-experimental method and a non-equivalent control group design. The sample was selected using purposive sampling. In this design, there were two groups of subjects: one experimental group that was given the STEM-SSI learning model treatment, and a control group that was given the discovery learning treatment. Both classes were given pre-tests and post-tests to measure the changes that occurred after the treatment was given. The STEM learning model used by the researcher in the experimental class followed the learning steps outlined by James Morgan (Setiono et al., 2023), which include: (1) identify problems and constraints, (2) research, (3) ideas, (4) research, (5) build, (6) test and refine, and (7) communicate and reflect. Meanwhile, in the discovery learning model, the researcher used the learning steps according to Marisyah & Sukma (2020), which consist of: 1) stimulation, 2) problem statement, 3) data collection, 4) data processing, 5) verification, and 6) generalization.

Population and Samples

The research was conducted at Muhammadiyah High School in Sukabumi City, located at Jalan R. Syamsudin, S.H. No. 59, Cikole District, Sukabumi City, West Java 43113. The research was conducted during the even semester of the 2024/2025 academic year, specifically from January to June 2025. The research sample consisted of 56 students from two 10th-grade classes. The experimental class received treatment using the STEM-SSI model, while the control class received instruction using the discovery learning model.

Instruments

The research instrument consists of an instrument to measure creativity, in the form of a verbal creativity test according to Torrance, which has four indicators of creativity, namely fluency, flexibility, originality, and elaboration. The verbal creativity test consists of several subtests, including: 1) Ask and guess, 2) Guessing causes and guessing consequences; 3) Unusual use activity; 4) Improvement activity; 5) Just suppose activity (The Alberta Teachers' Association,



2014, in Fauziah et al., 2021). Additionally, a questionnaire was administered to students to assess their responses to the implementation of the STEM-SSI learning model after the learning process using STEM-SSI was completed in the experimental class. The instrument has undergone expert validation and has been declared valid in terms of content. Reliability testing was conducted using Cronbach's alpha formula, with a result of 0.89, which falls into the high category.

Procedures

The procedure of this research is divided into four stages: the planning stage, the pre-research stage, the research implementation stage, and the final research stage. The planning stage involved initial observation at the school and literature review, as well as designing the STEM-Socio Scientific Issues approach and developing student worksheets (LKPD). The pre-research stage included the preparation of research instruments, such as the verbal creativity test, creative product assessment sheet, and student response questionnaire, followed by the validation and revision of these instruments. The research implementation stage was conducted by carrying out learning activities in the experimental and control classes, and collecting data through pretest, posttest, and student response questionnaires. The final research stage consisted of analyzing the data, presenting the research findings, and preparing scientific articles or journals.

Data Analysis

The research data were analyzed statistically using SPSS Version 25 and Microsoft Excel. The processing of pretest and posttest scores included parametric analysis, prerequisite tests (normality and homogeneity tests), and hypothesis testing analyzed using the t-test (Independent samples t-test). The analysis of verbal creativity test results was also conducted using the N-Gain calculation. Gain is the difference between the pretest and posttest scores to determine the criteria for scores or indicate improvements in students' creativity. The N-Gain calculation uses the following formula:

$$N - Gain = \frac{(Posttest\ Score - Pretest\ Score)}{(Ideal\ score - Pretest)}$$

After the calculation, the results were categorized according to the criteria in the following N-Gain score Table I.

Table I. N-Gain Improvement Categories

N-Gain Range	Criteria
$(\langle g \rangle) > 7$	High
$0,3 \leq g \leq 0,7$	Moderate
$G < 0,3$	Low

Meanwhile, the student response questionnaire data were analyzed using a Likert scale, with scores given for each positive and negative question (Table 2).

Table 2. Alternative Scoring of Questionnaire Response Statements

Answer	Value	
	Positive statement	Negative statement
Strongly disagree	1	4
Disagree	2	3
Agree	3	2
Strongly agree	4	1

(Source: Sugiyono, 2018)



The method for calculating data from the response questionnaire using the Likert scale is as Table 3:

Table 3. Questionnaire Criteria for Responses to STEM-SSI Learning

Score Percentage	Interpretation
0% - 24.99%	Not good
25% - 49.99%	Less than good
50% - 74.99%	Good
75% - 100%	Very good

(Source: Sugiyono, 2018)

RESULTS

The research data consists of student creativity ability data obtained from the test scores of students in the experimental class who used the STEM Socio Scientific Issues learning model and students in the control class who used the discovery learning model. The creativity test questions used were valid and reliable. A summary of the students' creativity ability results is presented in Table 4.

Table 4. Student Creativity Pretest-Posttest Score Data

Description	Experimental		control	
	Pretest	Posttest	Pretest	Posttest
N	28	28	28	28
Minimum	18	54	24	30
Maximum	81	90	70	85
Median	43.50	73.00	38.00	59.50
Standard Deviation	13.408	8.324	10.778	11.412
Mean	43.32	72.39	38.64	60.18

Based on Table 4, there is a difference in the mean creativity scores between students in the experimental class using the STEM Socio Scientific Issues learning model and the control class using the discovery learning model. Furthermore, to confirm whether the difference is significant, a series of statistical tests was conducted, including normality tests, homogeneity tests, and hypothesis tests using pretest and posttest data from both classes. The normality test aims to determine whether the data is normally distributed, while the homogeneity test is used to examine the similarity of variances between groups. Hypothesis testing was then conducted as the basis for deciding whether the proposed hypothesis was accepted or rejected. The entire testing process was carried out using SPSS version 25, utilizing the N-Gain values obtained from the pretest and posttest scores. The results of the three tests are presented in the following table.

Table 5. Summary of Normality Test, Homogeneity Test, and Hypothesis Test

Test	Description	Pretest		Posttest	
		Experimental	Control	Experimental	Control
Normality Test	Shapiro-Wilk	0.386	0.278	0.278	0.276
Homogeneity Test	Based on-mean	0.503		0.503	
Hypothesis Test		0.156		0.156	

Based on the results of the normality test and homogeneity test in Table 5, it can be concluded that the data in this study are normally distributed and have homogeneous variance, as



indicated by a significance value (sig.) > 0.05 . Following this, a hypothesis test was conducted using the parametric independent sample t-test. The results of the independent sample t-test on the pretest scores of the experimental and control groups showed a value > 0.05 , indicating that the initial abilities of students in the control and experimental groups were equivalent. Therefore, the hypothesis decision was made using the independent sample t-test on the posttest scores. Based on the hypothesis test using the independent sample t-test on the posttest scores, the significance value (Sig. 2-tailed) was less than 0.05, indicating that there was a significant difference in the posttest scores between the experimental and control classes. Thus, H_0 is rejected and H_1 is accepted, meaning that the STEM-SSI learning model has a significant effect on student creativity.

Student creativity based on N-Gain

The creativity skill test analysis also uses the N-Gain calculation. N-Gain is used to determine the extent of improvement in students' creativity skills before and after the treatment. The N-Gain calculations for students' creativity skills based on pretest-posttest data in the experimental and control classes were classified according to creativity indicators as defined by Torrance (1977). Figure 2 below shows the N-Gain values obtained by students in the experimental and control classes on the creativity test.

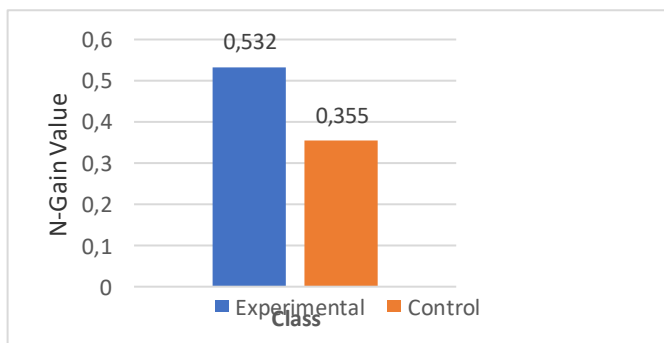


Figure 1. Students' N-Gain Creativity Scores

Student Creativity on Each Indicator in the Experimental Class and Control Class

Based on Table 6 above, the results of the N-Gain analysis for each creativity indicator in the experimental class and control class show that, in general, there was an increase in each indicator, although with varying categories. Based on the average scores, creativity in the experimental class was superior to that in the control class. This was because in the experimental class, the researcher used an integrated STEM learning model that incorporated socio-scientific issues.

Table 6. Student Creativity N-Gain Values per Indicator

No.	Creativity Indicator	Experimental		Control	
		N-Gain	Category	N-Gain	Category
1.	Fluency	0.4031	Moderate	0.3551	Moderate
2.	Flexibility	0.3029	Moderate	0.3011	Moderate
3.	Originality	0.3017	Moderate	0.2377	Low
4.	Elaboration	0.3396	Moderate	0.3574	Moderate

Student Creativity Based on the Engineering Design Process in the Experimental Class

In addition to creativity tests, creativity was also assessed in the experimental class based on the Engineering Design Process (EDP). This assessment aimed to observe the extent to which students' creative thinking skills were actively involved during learning. According to Windyariana

& Setiono (2024), to effectively assess creative thinking skills in STEM learning, a performance assessment method is needed that not only measures students' learning outcomes but also evaluates the learning process. The following figure shows students' creativity scores based on the EDP:

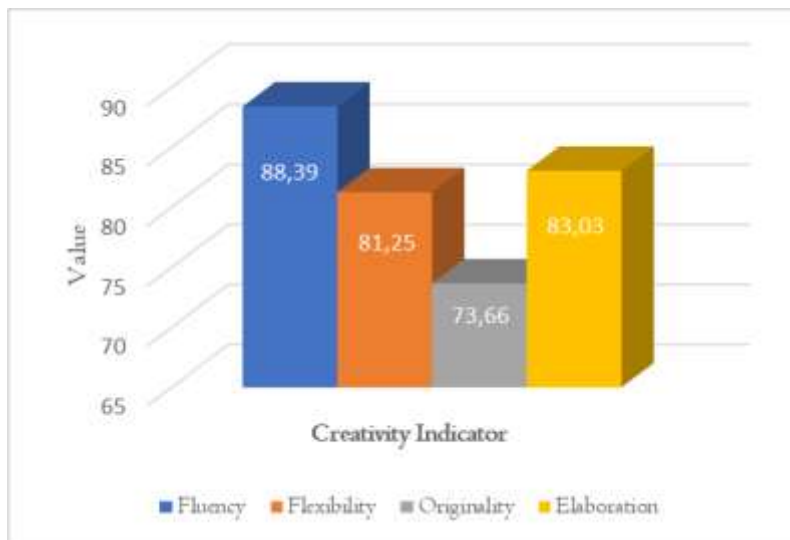


Figure 2. Graph of Average Student Creativity Scores Based on EDP

Based on the graph of the average value of student creativity based on the EDP, the fluency indicator has the highest score, 88.39, in the "very good" category, which indicates that students are very capable of generating many ideas at the problem identification stage and generating many ideas and solutions. The flexibility indicator is also in the "very good" category with an average score of 81.25, which reflects students' ability to explore various alternative solutions. For the originality indicator, the average score is 73.66, categorized as "good". Although categorized as good, this score is lower than fluency and flexibility, which indicates that students' ability to generate unique or different ideas still needs to be improved. The elaboration indicator has an average of 83.03, categorized as "very good". This indicates that students are quite good at developing ideas in detail, both when making prototypes and when redesigning.

Table 7. Student Creativity Scores in the Experimental Class

No.	Creativity Indicator	Average Score				
		Group 1	Group 2	Group 3	Group 4	Group 5
1	Fluency	81	81	88	81,25	81,25
2	Flexibility	83	75	67	67	75
3	Originality	75	88	63	69	69
4	Elaboration	75	81	75	87,5	69

Student creativity scores for the products produced indicate that fluency and elaboration are the indicators with the highest achievement, reflecting students' ability to generate many ideas and develop them in detail (Table 8). Meanwhile, flexibility and originality scores tended to vary more between groups, indicating that the dimensions of alternative thinking and unique ideas still require strengthening in the learning process.

Student Responses to the STEM-SSI Learning Model

Student responses to the STEM-SSI learning model consist of six indicators, including: 1) student interest in the use of the STEM-SSI learning model, 2) student assessment of the STEM-

SSI learning model, 3) student assessment of creativity, 4) student assessment of creativity after implementing the learning model, 5) students' interest in the STEM-SSI learning model with waste management, 6) students' evaluation of the STEM-SSI learning model with the concept of waste management.

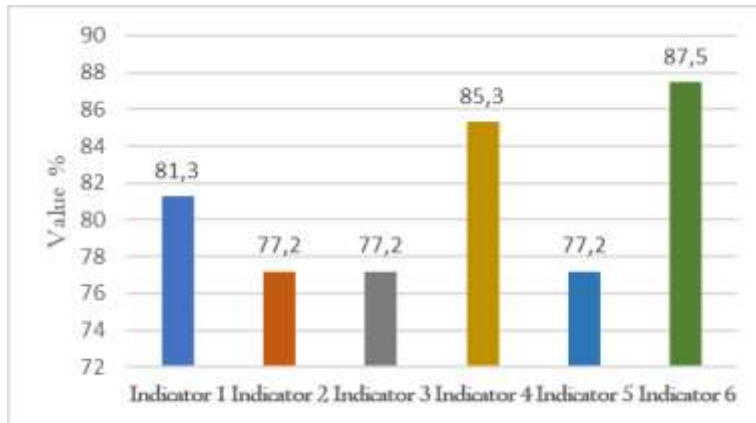


Figure 3. Percentage of Student Responses to the STEM-SSI Learning Model

Based on Figure 3, students' responses to the implementation of the STEM-SSI learning model showed very positive results. The overall average percentage reached 81% and was categorized as very good, indicating that students not only accepted the STEM-SSI model well but were also able to connect the material to real-world issues in their surroundings, thereby making learning more relevant, engaging, and impactful for the development of their creativity.

DISCUSSION

The impact of implementing the integration of STEM learning models with socioscientific issues

The data analysis results indicate that the STEM-Socio-Scientific Issues (STEM-SSI) learning model significantly increased student creativity. Based on Table 4, the average posttest creativity score for students in the experimental class was 73.00, higher than the 59.50 for the control class. Similarly, the N-Gain value for the experimental class was 0.513, categorized as moderate, while the control class only achieved 0.355, categorized as moderate (Figure 1). The validity of this difference is also supported by the t-test results in Table 5, which show a significance value <0.05 , thus rejecting H_0 and accepting H_1 . This means there is a significant difference in creativity between the experimental and control classes after being given different learning treatments.

This improvement is supported by the STEM-SSI learning process, which encourages students not only to understand concepts but also to explore solutions to real-world issues in their environment. This is reflected in the students' enthusiasm throughout the learning process, both during group discussions, designing prototypes, and testing their work. Student responses also indicate that implementing the STEM-SSI learning model can enhance student creativity. This can be seen in Figure 3, where indicator 4, namely students' assessment of creativity after participating in the lesson, achieved a percentage of 85.3%, categorized as very good. This finding indicates that students were not only actively engaged during the learning process but also felt that the activities they engaged in improved their creative thinking skills. This confirms that the increase in creativity in the experimental class was higher than that in the control class. This aligns with other studies showing that integrating STEM with Socio-Scientific Issues (SSI) can develop 21st-century skills, where creativity and innovation are the most developed aspects (Benek & Akcay, 2022). This improvement is supported by the characteristics of the STEM model, which provides contextual,

challenging, and relevant learning experiences, thereby fostering students' creativity (Benek & Akcay, 2022; Wahono et al., 2021).

Based on the data in Table 6, the N-Gain value for the fluency indicator in the experimental class was 0.4031, categorized as moderate, slightly higher than the control class, which obtained an N-Gain value of 0.3551, also categorized as moderate. The increase in the fluency indicator shows that students have found ideas and provided questions or statements with more than one answer. This is supported by the opinion that fluency is the ability to generate many ideas or solutions in a short time; the more ideas generated, the higher a person's fluency level (Damayanti et al., 2024; H. M. Firdaus et al., 2018). The measurement of fluency in this study can be seen when students ask as many questions or make as many statements as possible based on the problems or stimuli provided, without considering the uniqueness or diversity of the statements or questions (Fauziah et al., 2021). The increase in the fluency indicator score in the experimental class was also influenced by the implementation of the STEM-SSI learning model.



Figure 4. Students identifying problems and conducting information research

This can be seen in Figure 2, where the average creativity score based on the EDP fluency indicator achieved the highest score of 88.39, categorized as very good. In the learning process (Figure 4), students are guided to identify as many problems as possible related to organic waste management and to search for various references on bioethanol production from rice waste, along with the appropriate formulation, based on valid information sources such as articles or journals. According to Harahap et al., (2021), students who meet the fluency indicator are those who can generate many ideas or concepts quickly without hesitation, enabling them to easily answer numerous questions.

This is also reinforced by product assessments which show that fluency scores between groups are in the range of 81 to 88 (Table 7). These scores indicate that the bioethanol products produced largely met fluency requirements, such as being made using the correct process, being feasible as a solution to problems, being effective for their intended function, and having potential uses in everyday life. Although the products made by each group were of the same type, differences in formulations, such as yeast type and fermentation time, demonstrated that students were able to generate diverse ideas to solve contextual problems.

Table 6 shows that the flexibility indicator also yielded similar results in both classes, namely 0.3029 (moderate category) in the experimental class and 0.3011 (moderate category) in the control class. This indicates that students are capable of solving problems in various ways, without being fixated on a single method or perspective. Student achievement on the flexibility indicator is considered good, as evidenced by the emergence of diverse, innovative answers and the courage to explore various alternative solutions, rather than simply following the patterns commonly taught. This indicator was measured by observing how students posed questions or statements that reflected different perspectives in formulating solutions to a problem (Fauziah et al., 2021). In

addition to quantitative data, these results were also supported by findings during the learning process.



Figure 5. Students discussing the solution to be used

In Figure 2, the average creativity score of students based on EDP is 81.25, which falls into the very good category. The increase in flexibility scores in the experimental class that used the STEM-SSI learning model encouraged students to consider various perspectives before determining a solution, resulting in more varied ideas or answers. During the learning process shown in Figure 4, students in the experimental class were more active in discussing, exchanging ideas, and daring to propose solutions that were not limited to one method. For example, when designing the process of producing bioethanol from rice waste, each group had different formulations, different fermentation times, and used different fermentation methods. The product scores on the flexibility indicator also showed diversity between groups, with scores ranging from 67 to 83. The highest-scoring group produced a product that met the developmental aspects of alternative materials, multiple functions, and diverse uses. Although all groups produced bioethanol from rice waste, the formulations used differed, reflecting the students' flexibility in choosing the most appropriate approach. This finding aligns with the opinion of Harahap et al. (2021), who state that flexibility in creativity is not only measured by the number of ideas but also by the diversity and variation in those ideas.

In Figure 6 originality indicator, there was a difference in categories, where the experimental class obtained an N-Gain of 0.3017 in the moderate category, while the control class was lower with a value of 0.2377 in the low category. This difference shows that learning with the STEM-SSI model is more capable of encouraging students to produce ideas that are unique, unusual, and different from the general answers. The average student creativity score based on the EDP also supports this, as during the experimental class, students appeared more willing to offer unconventional solutions and tended to be more creative in modifying materials or processes. For example, students modified the formulation of the ratio of materials (rice waste and yeast) used, the fermentation time, and even how they stored the fermentation to produce effective and abundant bioethanol. Product assessments also supported these findings, with originality indicators ranging from 63 to 88. The highest-scoring groups demonstrated the courage to create new approaches to bioethanol formulation, even considering the possibility of developing the product into a renewable alternative energy source that differs from common solutions. In line with the research conducted by Retno et al. (2025), students involved in STEM learning tend to show courage in trying new approaches, modifying methods, and selecting strategies according to their ideas. This reinforces that the application of a model emphasizing exploration, problem-solving, and literature-based solution-seeking can enhance students' originality, thereby contributing to their creativity (Setiono et al., 2024). This contrasts with the control group, which tends to rely on existing ideas.

Interestingly, based on the elaboration indicator, the control class actually had a higher N-Gain score, at 0.3574 (moderate category), compared to the experimental class, which was 0.3396 (moderate category). These results indicate that students in the control class were better able to develop ideas in detail, elaborate on them, and clarify the concepts they had generated. This achievement in the elaboration indicator was likely influenced by the stages in the discovery learning model, which provided more time for students to engage in data processing, verification, and generalization. This process encouraged students to focus more on deepening and developing the information they had acquired. On the other hand, although the elaboration score in the experimental class was lower, students' ability to develop ideas was still evident. During the EDP stage, particularly during prototype construction and redesign, students demonstrated efforts to improve and refine their bioethanol products. The average elaboration score for students' products ranged from 69 to 87.5, reflecting a comprehensive product development effort. The limited time for the STEM-SSI learning process, which was only conducted in three meetings, was one factor why students did not have sufficient opportunity to delve into the redesign stage in depth. As a result, the process of refining the bioethanol formulation, both in terms of ingredient ratios, fermentation time, and product effectiveness analysis, was not fully optimized. This differs from students in the control class, who tended to focus on data exploration and developing details within a more flexible time. Nevertheless, this finding remains in line with the view of Hilmi et al. (2018), elaboration is the ability to enrich, add details, and refine ideas or products created.

Overall, the results of this study confirm that the implementation of the STEM Socio-Scientific Issues learning model can significantly enhance student creativity, particularly in terms of fluency, flexibility, and originality. In contrast, the elaboration indicator performs better with the discovery learning model. Limitations in time, resources, and student readiness may be factors contributing to the lack of improvement in the elaboration indicator. Researchers acknowledge the need for further improvements in this area. The researchers suggest that future studies should place greater emphasis on the elaboration indicator to ensure that the STEM-SSI learning process runs optimally and enhances all indicators of creativity.

CONCLUSION

This study shows that the implementation of the STEM-Socio Scientific Issues (STEM-SSI) learning model has a significant effect on increasing student creativity. This is evidenced by the difference in N-Gain scores between the experimental class and the control class, where the experimental class obtained an N-Gain of 0.513 (moderate category) and the control class obtained 0.355 (moderate category). This is supported by students' very positive responses to STEM-SSI learning, with an average percentage of 81%, reflecting high enthusiasm and involvement during the learning process. Thus, the STEM-SSI model is worthy of being implemented as an alternative learning model that is able to encourage student creativity.

REFERENCES

- Benek, I., & Akcay, B. (2022). The effects of socio-scientific STEM activities on 21st century skills of middle school students. *Participatory Educational Research*, 9(2), 25–52. <https://doi.org/10.17275/PER.22.27.9.2>
- Damayanti, M., Ramdhan, B., & Setiono, S. (2024). Implementasi Model Pembelajaran STEM Terhadap Kreativitas Melalui Projek Ecoprint. *Jurnal Educatio FKIP UNMA*, 10(3), 706–713. <https://doi.org/10.31949/educatio.v10i3.6150>
- Fauziah, L., Rizkiyah, F., Miarsyah, M., & Ristanto, R. H. (2021). *Pengembangan TTCT-V (Torrance Test of Creative Thinking Verbal) Berbasis Lingkungan Untuk Tingkat SMA*. 8(1), 1–11. <https://doi.org/10.31849/bl.v8i1.4534>

- Firdaus, A., & Alfani Hadi. (2023). Implementasi Manajemen Kurikulum Merdeka Dalam Meningkatkan Mutu Pendidikan Di Sekolah Abata. *LITERASI: Jurnal Pendidikan Guru Indonesia*, 2(1), 40–45. <https://doi.org/10.58218/literasi.v2i1.492>
- Firdaus, H. M., Widodo, A., & Rochintaniawati, D. (2018). Analisis Kemampuan Berpikir Kreatif dan Proses Pengembangan Kemampuan Berpikir Kreatif Siswa SMP pada Pembelajaran Biologi. *Assimilation: Indonesian Journal of Biology Education*, 1(1), 21–28. <https://doi.org/10.17509/aijbe.v1i1.11452>
- Florida, Richard & Mellander, C. (2023). The Global Creativity Index: National Creativity Ecosystems and Their Relationship to Economic Development and Inequality. *Global Creative Ecosystems*, 173–196. https://doi.org/10.1007/978-3-031-33961-5_10
- Harahap, S. S., Elindra, R., & Ardiana, N. (2021). Analisis Kemampuan Berpikir Kreatif Siswa Dalam Menyelesaikan Soal Matematika Kelas X Tkj Smk Swasta Harapan. *JURNAL MathEdu (Mathematic Education Journal)*, 4(3), 19–26. <https://doi.org/10.37081/mathedu.v4i3.2552>
- Hasanah, H., Faizi, N., & Wijaya, A. (2023). Perkembangan Kreativitas Peserta Didik: Tinjauan Literatur dalam Konteks Kehidupan Abad Ke-21. *Pionir: Jurnal Pendidikan*, 12(3), 143–154. <https://doi.org/10.22373/pjp.v12i3.18564>
- Indriani, T., & Jayanti, U. N. A. D. J. (2022). Interactive Socio-Scientific Inquiry: The Effects on Creative Thinking Skills. *Jurnal Pendidikan MIPA*, 23(2), 995–1005. <https://doi.org/10.23960/jpmipa/v23i3.pp995-1005>
- Julianto, & Nurhamidah, U. (2018). Pengaruh Model Creative Problem Solving (CPS) Terhadap Keterampilan Berpikir Kreatif Siswa Dalam Pemecahan Masalah Pada Mata Pelajaran IPA Kelas IV Sekolah Dasar. *Jpgsd*, 06(06), 1009–1019. <https://ejournal.unesa.ac.id/index.php/jurnal-penelitian-pgsd/article/view/23923/21864>
- Kemendikbudristek. (2022). Dimensi, Elemen, dan Subelemen Profil Pelajar Pancasila pada Kurikulum Merdeka. *Kemendikbudristek*, 1–37. <https://kurikulum.kemendikbud.go.id/wp-content/uploads/2022/07/V.2-Dimensi-elemen-subelemen-Profil-Pelajar-Pancasila-pada-Kurikulum-Merdeka.pdf>
- Marisya, A., & Sukma, E. (2020). Konsep Model Discovery Learning pada Pembelajaran Tematik Terpadu di Sekolah Dasar Menurut Pandangan Para Ahli. *Jurnal Pendidikan Tambusa*, 4(3), 2191. <https://doi.org/10.31004/jptam.v4i3.697>
- Muliardi, M. (2023). Mengembangkan kreativitas dan karakter bangsa melalui Kurikulum Merdeka di Madrasah. *Takuana: Jurnal Pendidikan, Sains, Dan Humaniora*, 2(1), 1–12. <https://doi.org/10.56113/takuana.v2i1.68>
- Murdiyanto, D., Suparno, N. R., Dyah, N., Sari, A. M., Hafizi, I., Ningsih, J. R., & Anwaristi, A. Y. (2022). Opportunities and Challenges in Implementing Independent Learning on Merdeka Belajar Kampus Merdeka (MBKM) in Dentistry Study Program. *The 16th University Research Colloquium, September*, 267. https://www.researchgate.net/publication/370057698_Opportunities_and_Challenges_in_Implementing_Independent_Learning_on_Merdeka_Belajar_Kampus_Merdeka_MBKM_in_Dentistry_Study_Program
- Permanasari, A. (2022). *Merdeka Belajar Dalam Konteks Pendidikan Sains*. <https://ipapasca.unpak.ac.id/pdf/Merdeka-Belajar-Dalam-Konteks-Pendidikan-Sains.pdf>
- Prasetyo, T., M.S, Z., & Fahrurrozi, F. (2021). Analisis Berpikir Kreatif Mahasiswa dalam Pembelajaran Daring Bahasa Indonesia. *Edukatif: Jurnal Ilmu Pendidikan*, 3(6), 3617–3628. <https://doi.org/10.31004/edukatif.v3i6.669>
- Rahmawati, W., Ratnasari, J., & Suhendar, S. (2018). Pengaruh Pendekatan Pembelajaran Socioscientific Issues Terhadap Kemampuan Berpikir Kreatif Peserta Didik. *Jurnal Pelita*

- Pendidikan*, 6(2), 124–132. <https://doi.org/10.24114/jpp.v6i2.10150>
- Retno, R. S., Hidayat, A., Mashfufah, A., & Chairul, E. (2025). *Students' Creative Thinking in STEM Integrated Project-Based Learning (PjBL-STEM)*. 9(1), 142–152. <https://doi.org/10.23887/jere.v9i1.84704>
- Richardson, C., & Mishra, P. (2018). Learning environments that support student creativity: Developing the SCALE, Thinking skills and Creativity. *Thinking Skills and Creativity*, 27, 45–54. <https://doi.org/10.1016/j.tsc.2017.11.004>
- Setiono, S., Windyariani, S., & Juhanda, A. (2023). *STEM at home*. DEEPUBLISH.
- Setiono, Windyariani, S., & Agustiani, N. (2024). *Creativity profile of biology teacher candidates: An exploratory study*. 17(1), 215–222. <https://doi.org/10.21009/biosferjpb.38636>
- SIPSN. (2024). *Komposisi Sampah Berdasarkan Sumber Sampah*. Sistem Informasi Pengelolaan Sampah Nasional (SIPSN) – Kementerian Lingkungan Hidup Dan Kehutanan. <https://sipsn.menlhk.go.id/sipsn/public/data/sumber>
- Sri Hanipah. (2023). Analisis Kurikulum Merdeka Belajar Dalam Memfasilitasi Pembelajaran Abad Ke-21 Pada Siswa Menengah Atas. *Jurnal Bintang Pendidikan Indonesia*, 1(2), 264–275. <https://doi.org/10.55606/jubpi.v1i2.1860>
- Sugiarto, A., & Djukri, D. (2015). Pembelajaran Berbasis Sets Sebagai Upaya Meningkatkan Kreativitas Dalam Pemecahan Masalah Pencemaran Lingkungan. *Jurnal Inovasi Pendidikan IPA*, 1(1). <https://doi.org/10.21831/jipi.v1i1.4527>
- Sugiyono, S. (2018). *Metode Penelitian Kuantitatif*. ALFABETA.
- Suhartini, E., Putri, R., & Haerani, R. (2023). *Bahan Ajar Konsep Dasar IPA Berbasis STEM Berkonteks Socio-Scientific Issues (SSI) untuk Meningkatkan Keterampilan Berpikir Kritis Mahasiswa PGSD*. <https://ojs.unm.ac.id/semnaslemlit/article/view/54316>
- Sukarso, A. A., Widodo, A., Rochintaniawati, D., & Purwianingsih, W. (2023). Investigating the Effect of Authentic Research Project-Based Laboratory Work on Creative Thinking, Attitudes and Scientific Work Skills of High School Students. *Atlantis Press SARL*, 1. https://doi.org/10.2991/978-2-38476-012-1_2
- Susanti, W., Saleh, L. F., Nurhabibah, N., Gultom, A. B., Saloom, G., Ndorang, T. A., Sukwika, T., Nurlely, L., Suroyo, S., Mulya, R., & Lisnasari, S. F. (2022). Pemikiran Kritis dan Kreatif. In *Sustainability (Switzerland)*, 11(1). https://sciteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI
- Syarah, M. M., Rahmi, Y. L., & Darrussyamsu, R. (2021). Analisis Penerapan Pendekatan STEM pada Pembelajaran Biologi. *Jurnal Pendidikan Biologi*, 12(3), 146–157. <https://doi.org/10.32938/jbe.v6i3.1260>
- Wahono, B., Chang, C.-Y., & Khuyen, N. T. T. (2021). Teaching socio-scientific issues through integrated STEM education: an effective practical averment from Indonesian science lessons. *International Journal of Science Education*, 43(16), 2663–2683. <https://doi.org/10.1080/09500693.2021.1983226>
- Widodo, A. (2021). *Pembelajaran Ilmu Pengetahuan Alam Dasar-Dasar untuk Praktik*. In UPI Press.
- Windyariani, S., & Setiono, S. (2024). Performance Assessment Creative Thinking Rubric in Science Technology Engineering and Mathematics (STEM) Learning. *Jise*, 13(2), 64–73. <https://journal.unnes.ac.id/journals/jise/>