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Implication of STEAM Learning Model on Students' Scientific Creativity

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ABSTRACT
This research is motivated by the low level of students' scientific creativity in biology learning. The study aimed to examine the implications of the STEAM learning model on students' scientific creativity in the topic of water pollution. A quasi-experimental method with a non-equivalent control group design was applied, involving 60 grade X high school students divided into experimental and control classes. Data were collected through scientific creativity tests, observations, and student response questionnaires. The results showed a significant difference in posttest scores between the two groups (Sig. 0.000). The experimental class achieved an N-Gain of 0.74 (high category), while the control class scored 0.52 (medium category). Students' responses toward the learning process were very positive, with an average score of 86.67%. These findings indicate that the STEAM model effectively enhances students' scientific creativity. STEAM learning not only improves students' scientific creativity in specific contexts but also carries broader educational implications. This model can be adapted to various science topics and other subjects, strengthen interdisciplinary skills, and serve as a reference for curriculum development and teacher training. Thus, STEAM plays an important role in preparing students to face 21st-century learning challenges that emphasize creativity, collaboration, and problem-solving.

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1. INTRODUCTION

In this 21st century, students are required to have 21st century skills, namely 4C skills including collaboration, critical thinking, creative, and communication (Rahmaniar & Latief, 2021). Several studies have concluded that of the many existing thinking skills, one of which is important in supporting the achievement of 21st century skills is scientific creativity (Hidayati et al., 2020). Scientific creativity is an important ability that needs to be developed in learners because it contributes to increasing their interest and engagement in science learning, and even affects the tendency to choose careers in STEM fields. Research by Pont-Niclòs et al. (2024) showed that developing scientific creativity can increase students' participation in science-related fields more broadly.

One type of creativity that is essential in developing student competence is scientific creativity. So far, students' scientific creativity still shows a low level (Astutik et al., 2020). One study reported that around 64% of students scored low on scientific creativity, which is in the 0-60 interval (Lailiyah Qiftiyatul & Suliyanah, 2018). Mustika et al. (2019) reported that the average scores of students' scientific creativity and critical thinking were 23.67 and 17.36 out of a maximum score of 64 and 48, respectively, which can be directly categorized as low achievement. Another study at SMAN 8 Banjarmasin on buffer solutions using the Creative Problem Solving model showed an improvement from "fair" to "good" in overall scientific creativity (Dahlena et al., 2020). The low level of ability is due to the limitations of students to use their knowledge and abilities creatively in solving problems or creating innovative products and the low scientific creativity of students is also due to the fact that in learning activities, students receive more material so that it has an impact on the lack of students' ability to independently use their creative ideas to find ideas about the topics studied. Therefore, students' scientific creativity needs to be enhanced by giving students the widest possible opportunity to convey their creative ideas. By using an inquiry-based learning model, scientific creativity can be trained with a focus on students and the teacher acts as a facilitator (Zulaichah et al., 2021).

Based on the problems that have been described, a learning model that can stimulate students' scientific creativity is needed, namely by implementing a learning model that can contribute positively to students' scientific creativity abilities. One of the learning models that can be implemented is the STEAM (Science, Technology, Engineering, Art, Mathematic) learning model. The STEAM learning model is one of the learning models that is in accordance with 21st century skills, because the STEAM learning model links various disciplines so that it can provide a holistic learning experience. This can create opportunities for students to think creatively and develop 21st century skills, including creativity (Mansur et al., 2022). Syntax in STEAM learning:

a. Identify Problem and Constraint: Students identify problems, constraints, and limitations.
b. Research: Students observe and collect information from various sources to understand concepts and alternative solutions.
c. Ideate: Students develop ideas or product proposals to solve the problem.
d. Analyze Idea: Students analyze the feasibility of ideas to ensure they can serve as solutions.
e. Build: Students develop a product based on the analysis.
f. Test and Refine: The product is tested and refined if deficiencies are found.
g. Communicate and Reflect: Students communicate the product created and conduct reflection.

The project-based STEAM learning model is designed to solve problems relevant to real life. When designing a project with regard to STEAM is to incorporate one activity from each discipline (Science, Technology, Engineering, Arts and Mathematics) into one unit of learning activity project so that the learning objectives can be achieved as expected. In learning, educators should be able to provide understanding to students to be able to think logically, analytically, systematically, critically and creatively in solving problems and have an attitude of appreciating the usefulness of science (Amelia & Marini, 2022).

STEAM learning can also form human resources (HR) who are able to think critically, think logically, think systematically and be able to reason, so that they can face the challenges of the global era, including in increasing the nation's competitiveness (Hasanah, 2019). Not only that, STEAM-based learning equips people with information management skills, continuous learning, innovation, global awareness, and strong character to meet the high market demand for science-based products and technological skills (Atmojo, 2020).

Project-based STEAM that integrates different domains (science, technology, art) significantly improves students' scientific creativity, including in the aspects of hypothesis generation and problem-solving (Tran et al., 2021). In the context of 21st century education, the characteristics of the STEAM model are considered to have an important contribution to the development of students' scientific creativity. This is in line with the view of Filipe et al. (2024) that "STEAM education aims to enhance and develop the creativity inherent in the arts to enrich STEM education, while maintaining a focus on student-centered learning, where students investigate, communicate, and solve problems." (Filipe et al., 2024). The STEAM model differs from PJBL in encouraging students' scientific creativity. PJBL emphasizes real projects and problem solving, but lacks interdisciplinary integration. STEAM, on the other hand, brings together science, technology, engineering, art, and mathematics, thereby fostering imagination, innovation, and indicators of scientific creativity such as creative experimentation and hypothesis formulation. The artistic element in STEAM provides space for original ideas that are not often seen in PJBL.

2. RESEARCH METHOD

This research uses a quantitative approach, quasi-experiment method with a non-equivalent control group design pattern. In this design there are two groups, namely the experimental group and the control group which are not randomly selected where one group gets treatment using the STEAM learning model, while the control group gets treatment with the PJBL learning model. The research design can be seen in table 1.

Table 1. Research Design

Q^1	X^1	Q^2
Q^3	X^2	Q^4

Source : (Sugiyono, 2022)

Description:
Q^1 and Q^3 : Pretests of experimental class and control class
Q^2 and Q^4 : Posttests of experimental class and control class
X^1 : Application of STEAM learning model in experimental class
X^2 : Application of PJBL learning model in control class

The population of this study were all grade X students of SMAN 2 Kota Sukabumi. The number of research samples was 60 grade X students divided into 30 experimental class students and 30 control class students. This research was conducted in the even semester of May 2025.

Independent variables are factors that can have an influence. The independent variable in this study is the STEAM learning model. The dependent variable is the variable that results from the influence. The dependent variable in this study is students' scientific creativity on ecosystem material. The STEAM learning model used by researchers in experimental classes uses learning steps according to James Morgan (cited by Setiono, Sistiana

Windyariani, 2023) which consists of, (1) Identify Problems and Constraints, (2) Research, (3) Ideation, (4) Analyze Ideas, (5) Build, (6) Test and Refund, (7) Communicate and Reflect. In the PJBL learning model, the steps in learning are determining fundamental questions, developing projects, developing project schedules, monitoring students, testing results, and evaluating experiences (Mulyani et al., 2024).

To obtain qualified research instrument data, the data must first be analyzed so that it can be classified as good or can be used in research. The instrument used is a description of students' scientific creativity ability with a total of 10 questions based on 5 indicators, namely Problems Finding, Unusual Use, Product Improvement, Creative Experiment, and Formulating Hypothesis. Data analysis of the research results was carried out using SPSS ver 25 software by conducting normality tests, homogeneity tests and hypothesis tests. The normality test aims to determine whether the data variables are normally distributed or not. The homogeneity test aims to determine whether the population variant of the data is the same or not. Then, hypothesis testing aims to establish an objective basis in determining whether the assumptions of the statements that have been made are accepted or rejected.

The operationalization of STEAM steps in this study was directly linked to five indicators of scientific creativity: Problem Finding, Unusual Use, Product Improvement, Creative Experiment, and Formulating Hypothesis. In the Identify Problems and Constraints stage, students observed ecosystem phenomena to train Problem Finding. The Research stage supported idea generation and hypothesis development. Ideation encouraged creative solutions and Unusual Use, while Analyze Ideas focused on refining ideas and formulating hypotheses. In Build, students created prototypes to practice Product Improvement. Test and Refine involved experiments (Creative Experiment) and product revision. Finally, in Communicate and Reflect, students presented and evaluated their projects, reinforcing all indicators of scientific creativity.

3. RESULT AND DISCUSSION

The implementation of learning begins with filling out a pre-test given to experimental and control class students before being treated, this is done to determine the ability of scientific creativity in the two classes. Furthermore, the core activities were carried out immediately after students completed the pretest. A series of learning in the experimental class was carried out for two meetings with the final result in the form of a product in the form of a simple water filter as a form of student solution in solving the problem of water pollution, and in the control class carried out for two meetings with the same final result in the form of a product as a solution to solve the problem of water pollution. The implementation of learning between the two classes ended with filling out a posttest to determine students' scientific creativity abilities after being given treatment and filling out a student response questionnaire by the experimental class. Based on the results of the research conducted, student data was obtained in the experimental class using the STEAM learning model and control class students using PJBL learning. The STEAM model enhances scientific creativity indicators as follows:

1. Problem Finding: Encourages students to identify real-world problems through observation and critical analysis.
2. Unusual Use: Stimulates divergent thinking by integrating arts, leading to innovative and uncommon ideas.
3. Creative Experiment: Promotes designing and testing creative experiments by combining science, technology, and engineering.
4. Product Improvement: Trains students to evaluate and refine products through iterative processes.
5. Formulating Hypothesis: Guides students to develop testable and logical hypotheses based on interdisciplinary knowledge.

Table 2. Data N-Gain Score of Scientific Creativity

	Pre-Test	Post-Test	N-Gain	Category
Eksperiment	48,83	86,83	0,74	Haigh
Control	49,41	75,83	0,52	Medium

Table 2 shows that there are differences in the scientific creativity scores of experimental class students who use the STEAM learning model with control class students who use the PJBL learning model, the scientific creativity scores in the experimental class tend to be higher than the control class, this indicates that STEAM learning that integrates science, technology, engineering, art, and mathematics not only builds conceptual understanding, but also stimulates creative and scientific thinking skills. According to (Tran et al., 2021), students who received STEAM learning showed higher scientific creativity scores compared to the control group. This shows the superiority of the STEAM approach in building creativity and scientific problem solving among students. Furthermore, to find out whether the difference is significant or not, statistical tests of pretest-posttest data of experimental and control classes are carried out, namely normality test, homogeneity test, and hypothesis test. The calculation of the three tests was carried out using SPSS ver 25. Researchers also calculated the N-Gain value obtained from the difference in pretest-posttest scores. The following are the results of the recapitulation of the normality test, homogeneity test, and hypothesis test.

Table 3. Recapitulation of Normality Test, Homogeneity Test, and Hypothesis Test of Scientific Creativity

Test	**Pre-Test**		**Post-Test**		**Kategori**
	Experiment	Control	Experiment	Control	
Normalitas	0,57	0,83	0,102	0,130	Normal
Homogenitas	0,739		0,613		Homogen
Hipotesis	0,715		0,000		

Based on the results of the posttest data hypothesis test, it is known that there is a significant difference between the experimental class posttest and the control class posttest. So that the hypothesis in this study is H_0: There is no implication of STEAM learning model on students' scientific creativity ability. H_1: There is an implication of the STEAM learning model on students' scientific creativity abilities. Based on the results of the independent sample t-test test on the posttest value data, the Sig value is 0.000 <0.05. Then it can be stated that H_0 is rejected and H_1 is accepted. This means that there is an implication of the STEAM learning model on students' scientific creativity.

The achievement of scientific creativity ability can be seen in more detail based on each indicator of scientific creativity ability. The following is the average value of students' scientific creativity abilities based on each indicator, found in table 4.

Table 4. Average Value of Students' Scientific Creativity Ability Indicators

Indikator	**Pretest**		**Postest**	
	Experiment	**Control**	**Experiment**	**Control**
Problems Finding	47,50	47,08	89,17	77,50
Unusual Use	55,83	56,25	88,75	76,25
Product Improvement	52,08	52,50	85,00	75,83
Creative Experiment	44,17	45,83	79,58	65,42
Formulating Hypothesis	44,58	45,42	91,67	84,17

Based on the table above, the results show that the STEAM learning model applied to the experimental group provides a higher increase in students' scientific creativity compared to the control group. This can be seen from the average posttest score on each indicator of scientific creativity which is higher in the experimental group. The consistent increase in all indicators in the experimental group indicates that the learning approach used has a significant contribution to the development of students' scientific creativity.

The achievement of scientific creativity ability can be seen in more detail based on each indicator of scientific creativity ability. The following is the average value of students' scientific creativity abilities based on each indicator, found in table 5.

Table 5. Average Value of Students' Scientific Creativity Ability Indicators

Indikator	**Pretest**		**Postest**	
	Experiment	**Control**	**Experiment**	**Control**
Problems Finding	47,50	47,08	89,17	77,50
Unusual Use	55,83	56,25	88,75	76,25
Product Improvement	52,08	52,50	85,00	75,83
Creative Experiment	44,17	45,83	79,58	65,42
Formulating Hypothesis	44,58	45,42	91,67	84,17

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Researchers also calculated the N-Gain data from the scientific creativity test results of experimental and control class students classified based on scientific creativity indicators according to (Hu & Adey, 2002). The following is a graph of the N-Gain value per indicator of student scientific creativity obtained by experimental and control class students.

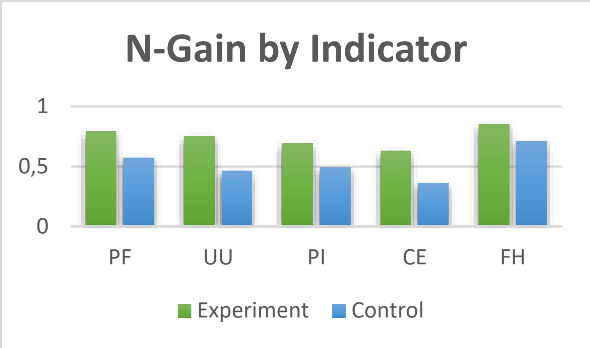

Figure 1: Graph of N-Gain Value Based on Scientific Creativity Indicators

Description
PF : Problems Finding
UU : Unusual Use
PI : Product Improvement
CE : Creative Experimen
FH : Formulating Hypothesis

The results of the scientific creativity test research on the graph show that each indicator of scientific creativity in the experimental class is higher than the value in the control class, the increase in scientific creativity scores in the experimental class occurred due to the use of the STEAM learning model.

The N-Gain value on the Problems Finding indicator in the experimental class obtained an N-Gain value of 0.79 with a high category, while the control class N-Gain value was at 0.057 with a medium category. This shows a significant increase compared to the control class. This is supported by the observation results which show that students are more active in asking questions and analyzing the causes of water pollution. This learning provides space for exploration and collaboration, in line with what was stated by Filipe et al. (2024) that interdisciplinary integration encourages creativity, critical thinking, and innovation in solving problems. Students' responses were positive, they showed high curiosity and felt challenged to further investigate the phenomena presented.

The N-Gain value on the Unusual Use indicator in this indicator the N-Gain value obtained by the experimental class with a high category is at 0.75 higher than the control class which is at 0.46 with a moderate category. These results indicate that the STEAM learning model applied in the experimental class is more effective in training students' ability to use unusual objects or concepts in a scientific context. Based on observations, experimental class students were more active in exploring new ideas and functions of the objects around them, especially when asked to organize a prototype solution to the water pollution case. This is in line with the opinion of Filipe et al. (2024) which states that the open and contextual STEAM approach can encourage aspects of flexibility and originality in scientific thinking. Students' responses were also positive, they felt more challenged to think of new ways to solve problems and felt proud of the unique ideas they had come up with.

The N-Gain value on the Product Improvement indicator in the experimental class reached 0.69 with a medium category, higher than the control class which obtained a value of 0.49 in the same category. This difference shows that the learning model in the experimental class is more effective in encouraging students' ability to improve and perfect existing ideas or products. During the learning activities, experimental class students were asked to develop solutions to water pollution cases by making simple prototypes from recycled materials. They were asked to evaluate and revise the initial design based on feedback from other groups. This activity provides space for students to think reflectively and creatively in improving the quality of the solutions they make. This is in line with what Ozkan & Umdu Topsakal (2021) stated that the iterative process in STEAM, especially the stages of ideation → prototyping → evaluation → revision - contributes significantly to improving students' scientific creativity. Classroom observations showed that students were actively involved in improvement discussions, and some students showed satisfaction with the improved end result after going through the revision and idea development process.

The results on the Creative Experiment indicator show an N-Gain value of 0.63 for the experimental class, which reflects the effectiveness of the STEAM approach in encouraging students to design and conduct experiments independently and creatively. Learning activities are designed so that students can develop solutions to contextual problems through exploration of ideas, initial testing, and improvements based on the results of group discussions. This approach allows for an iterative scientific thinking process. In line with this, a study by Pramashela et al. (2023) at the high school level confirmed that the integration of STEAM in project-based learning promotes students' ability to develop scientific solutions creatively and systematically. At the elementary level, L. Rahmayanti et al. (2024) also proved that explorative activities and simple STEAM-based experiments can simultaneously improve students' scientific process skills and creativity.

The N-Gain value on the formulating hypothesis indicator in the experimental class reached 0.85 with a high category, higher than the control class which obtained a value of 0.71 with the same category. Although both are included in the high category, the difference in value shows that STEAM learning applied to experimental classes is more optimal in training students' ability to formulate hypotheses based on observation and scientific reasoning. In learning practices, students are invited to observe contextual problems such as water pollution problems, then collect information, and discuss possible causes and formulate initial conjectures (hypotheses). This finding is in line with the results of research by Pramashela et al. (2023) which states that project-based STEAM learning encourages students to think analytically and formulate hypotheses as part of the scientific problem-solving process.

Figure 2. Student Product Results

Based on the findings in the field, the activity of pouring ideas when students design a simple water filter product as a solution to water pollution. Product design starts from selecting tools and materials for water filters, manufacturing procedures, product assembly, product testing, and product improvement. When students determine the tools and materials to be used, of course, based on the results of the literature study conducted. Supported by student responses in Figure 2 which are categorized as very good regarding the STEAM learning model. The series of STEAM learning activities in the experimental class can be carried out well. This attracts students' interest in participating in STEAM learning. This shows a positive relationship between student responses and the increase in posttest scores.

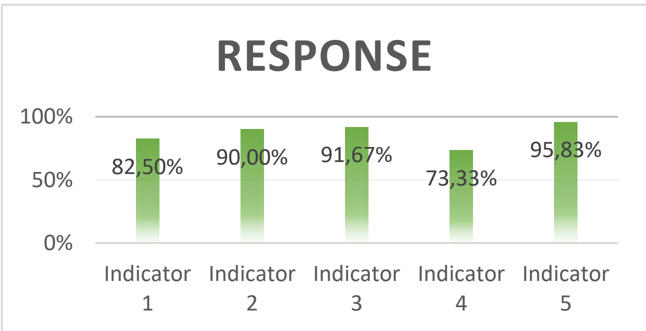

Figure 3. Percentage Chart Based on Response Indicator

Student responses showed a very good response. Student response to the STEAM learning model on scientific creativity skills is given to experimental class students in the form of a student response questionnaire consisting of 5 indicators, including: I) Student interest in the STEAM learning model, II) Scientific creativity possessed after implementing STEAM learning, III) Students' understanding of the material used using the STEAM learning model, IV) Students' ability to cooperate with friends when learning or completing tasks, V) Students' assessment of the relationship between the STEAM learning model and the concept of ecosystem material.

Based on the percentage of student response questionnaires to STEAM learning on each indicator, the overall average is 86.67% with a very good category. This indicates that the learning applied in the experimental class is able to provide a positive reaction to students' understanding and scientific creativity abilities on water pollution material, with the final result in the form of a simple water filter product that integrates STEAM and innovation in it. These findings are consistent with previous studies but also reveal some distinctions. Tran et al. (2021) found that STEAM-based learning significantly enhanced scientific creativity at the elementary level, particularly in hypothesis formulation, while in this study, the highest improvement was seen in the problem-finding and hypothesis indicators at the high school level. Similarly, Ozkan & Umdu Topsakal (2021) reported that iterative design processes in STEAM fostered creativity, which aligns with the product improvement results in this research, though their study emphasized middle school students. In contrast, Pramashela et al. (2023) highlighted that STEAM integration in project-based learning primarily improved creative thinking skills, whereas this study demonstrates broader impacts across five scientific creativity indicators. Furthermore, Rahmayanti et al. (2024) noted that STEAM at the primary level was effective in developing process skills, while this research shows its scalability in more complex high school contexts.

Despite these promising results, this study has certain limitations. The duration of the intervention was relatively short (two sessions), which may not fully capture the long-term development of creativity. The research was conducted in only one public high school in Sukabumi, which limits the generalizability of the findings to other regions and school contexts. Additionally, teacher-related factors, such as prior experience with STEAM implementation, may have influenced the outcomes. Future studies should employ longer interventions, involve multiple schools, and integrate teacher professional development to strengthen the robustness and applicability of findings.

4. CONCLUSION

Based on the research results and discussion above, it can be concluded as follows: (1) The results of hypothesis testing showed that H0 was rejected and H1 was accepted with Sig (2-tailed) 0.000 where the data was significantly different; (2) N-Gain of scientific creativity in the experimental class was 0.74 with a high category and the control class was 0.52 with a medium category; (3) The average student response questionnaire of 86.67% was in the very good category; (4) There are implications of the STEAM learning model on student scientific creativity in one of the public high schools in Sukabumi City; (5) It is expected that all public high schools in Sukabumi City are able to apply the STEAM learning model to student scientific creativity. The STEAM learning model can have implications for students' scientific creativity, and students can gain interesting learning experiences because it is based on everyday life problems. Future research could expand the application of STEAM to other subjects beyond biology to test the consistency of its effectiveness. In addition, longitudinal studies are needed to assess the long-term impact of STEAM on the development of students' scientific creativity. Research can also be directed toward exploring the scalability of STEAM implementation in schools with varying resource conditions, so that this model can be adapted more widely and equitably.

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