RESEARCH ARTICLE

Creativity in biology: The impact of Problem-Oriented Project Based Learning on high school students

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Abstract: Creativity in biology education is a crucial aspect that enhances students' understanding of the subject. It consists of several indicators (fluency, flexibility, originality, and elaboration), which can also be used as measuring tools for creativity. This study aimed to determine the influence of the Problem-Oriented Project-Based Learning (POPBL) model in fostering creativity among high school students. The experiment was conducted in April until June 2023. The participants of this study consisted of 10th-grade students from State High School 1 Grogol. The cluster random sampling technique selected X6 as the control and X7 as the experimental classes. This was a quasi-experiment with a Pretest-Posttest Control Group Design, in which two groups were chosen randomly where the classes had previously been tested for equality first. The analysis employed was an analysis of the covariance test. The statistical analysis revealed that students' creativity in the experimental group was significantly higher than in the control group. Based on this study, we conclude that the POPBL model significantly improved student creativity. We suggest that with higher creativity, students will be able to solve the problems they face in life better.

Keywords: Creativity; POPBL; problem-oriented project-based learning model

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Introduction

Quality education is a system in which all students receive learning experiences that enable them to develop a creative and innovative character, along with the necessary competencies (Fomba et al., 2023). Creativity is a mental process carried out by individuals in the form of ideas new products, or a combination of the two, which will ultimately stay with them (Sternberg & Karami, 2022). Developing students' creativity is necessary for addressing learning problems by utilizing imagination, intelligence, insight, and ideas, which are then combined into a new concept (Acar et al., 2017; Mevarech & Paz-Baruch, 2022; Sternberg & Lebuda, 2019). Based on the results of the Global Creativity Index (GCI) research conducted by the Martin Prosperity Institute, which assesses a country's creativity index based on three indicators - namely technology, talent, and tolerance in 2015 - it is known that Indonesia is ranked 115th out of 139 countries. Low creativity in high school students is evidenced by a passive attitude and a lack of development of creative ideas when responding to teacher questions (McInerney, 2023) Another study revealed that the creativity of high school students was still relatively low (Setiawan et al., 2017). This was identified based on the results of a questionnaire where only around 40% of students exhibited creative traits. Fostering creativity in science education is important because it not only enhances students' understanding of scientific concepts but also equips them with the skills and mindset needed to navigate an ever-changing world and contribute meaningfully to scientific progress and societal advancement (Haigh, 2020; Soomro et al., 2023; Vincent-Lancrin, 2021) .

Based on the results of a preliminary study conducted in February 2023 through interviews and documentation studies with the head of the curriculum at SMAN 1 Grogol, it is known that the creativity of students on the Education report card at SMAN 1 Grogol for 2021/2022 is still lacking, with a score of

2 (in the developing category). This score is below average when compared with the education unit value of 2.23, the district/city average value of 2.31, the provincial average value of 2.3, and the national average value of 2.25. Based on this data, it can be concluded that student creativity is still below the district/city and national averages. Innovation and solutions are needed to increase student creativity because enhancing student creativity will impact student learning outcomes (Adawiyah et al., 2023).

Increasing students' creativity is very important because it equips them with the ability to find solutions to various problems they encounter in the real world. This skill is essential as students grow up and face life's challenges. In a world that continues to change rapidly, the ability to adapt and adjust to new situations is crucial for the new generation. Creativity fosters flexibility and openness to change, thereby better-preparing students to confront future challenges. To enhance student creativity, it is achieved through a learning process that nurtures creativity, as exemplified in the Problem-Oriented Project-Based Learning (POPBL) learning model. Problem-based learning and project-based learning are learning models with a constructivist approach, reported to effectively foster students' creativity (Dai et al., 2023; Guaman-Quintanilla et al., 2023). Rongbutsri (2017) integrates project-based learning activities into the problem-based learning process, creating a collaborative learning model known as Problem-Oriented Project-Based Learning (POPBL). The main principles of this approach are problem-oriented, project-based, interdisciplinary, student-centered, and collaborative (Rongbutsri, 2017). The POPBL learning model, developed by Rongbutsri (2017), comprises eight stages: group formation, problem formulation, planning, data gathering, analysis, problem-solving, reporting, and preparation for the examination. However, several weaknesses need to be considered when implementing these stages, particularly regarding the time required (Mihić et al., 2017; Sumarni, 2013) .

Implementing the POPBL model demands ample time for planning, execution, and evaluation of student projects, posing a challenge within a busy curriculum and tight time constraints. Thus, Ibrohim, along with his research team, conducted a study to streamline the POPBL learning steps, making them more applicable to the curriculum and aligned with the characteristics of Indonesian students. As a result, the POPBL learning model was condensed into four stages: orientation and problem formulation, organizing student learning, designing and implementing projects, and presenting results and evaluation. Previous studies have demonstrated the effectiveness of the POPBL to critical thinking and collaboration skills (Filmi et al., 2024; Suwistika et al., 2024). The POPBL model can be applied to various learning materials, enabling students to explore real-world problems and find relevant solutions. Additionally, biology learning is closely linked to problem-solving processes in the real world. Therefore, it is important to foster creativity since students must derive solutions from the knowledge acquired through projects conducted in real-life situations (Goto et al., 2023; de Alencar & de Oliveira, 2016; Strobel & van Barneveld, 2009). Consequently, the study aims to ascertain the impact of the POPBL model on fostering creativity among high school students.

Method

The type of research is quasi-experimental, consisting of two classes. The experimental class is taught using the POPBL learning model, while the control class employs conventional learning methods, including discussions and lectures. The design utilized is the Pretest-Posttest Control Group Design, involving two randomly chosen groups, which were previously tested for equality. This research took place at SMAN 1 Grogol during the 2022/2023 academic year, approximately from April to June 2023. The population comprised all class X students at SMAN 1 Grogol, Kediri Regency. The Cluster Random Sampling technique was used, involving the random selection of two classes with similar characteristics. In the randomization process, class X6 was chosen as the control class, while class X7 was selected as the experimental class. In experimental classes taught using the POPBL model, students are tasked with finding solutions to problems provided by the teacher. The steps in the POPBL learning model include 1) Orientation and problem formulation, 2) Organizing student study, 3) Designing and implementing projects, and 4) Presenting and evaluating project results. Meanwhile, in the control class, which is taught using the lecture and discussion method, learning activities commence with an explanation of concepts and materials by the teacher. Subsequently, the teacher distributes worksheets to students, which are not oriented towards contextual problems and do not necessitate students to find solutions, as the worksheets contain questions related to concepts. Following this, students in groups discuss the worksheet answers and then present them sequentially in front of the class. A classic question-and-answer and discussion process follows, concluding with the teacher providing reinforcement related to the topics covered and discussed.

The subject matter of this research pertains to ecosystems and environmental change. The instrument employed in this research was an essay test comprising four questions to assess student creativity. Additionally, this research utilizes POPBL learning tools, including a learning objectives flow and teaching modules containing handouts, as well as the use of worksheets and creativity test instruments. The POPBL learning tools developed were subsequently validated by learning experts, practitioners, and material experts. Before being administered to the sample group, the research instrument underwent validity and reliability testing. The data collected from the pre-test and post-test questions, which consisted of four essay questions related to student creativity. These data were then subjected to normality and homogeneity tests as prerequisites before analysis using one-way ANCOVA. If the p-value is <0.05, Ho is rejected, and the research hypothesis is accepted.

Results and Discussion

The research data measured on the creativity variable has met the prerequisite tests, allowing for the continuation of hypothesis testing. The prerequisite tests include normality and homogeneity tests. The normality test results were analyzed using a one-sample analysis Kolmogorov-Smirnov, which yielded the value of Asymp sig. (2-tailed) = 0.069, indicating that the data is normally distributed since it is greater than 0.05 for the initial test, and 0.056, which is also greater than 0.05, for the subsequent test. Similarly, the homogeneity test using Levene's Test of Equality of Error Variances also yielded a p-value greater than 0.05. Specifically, the pre-test value had a significance value of 0.504, and the post-test value had a significance value of 0.688, as indicated in Table 1. Subsequently, a hypothesis test was conducted using the ANCOVA test.

Table 1. Normality and homogeneity test results of creativity

Test	Pretest		Post Test	
	Sig.	Conclusion	Sig.	Conclusion
Normality	0.069	Normal	0.056	Normal
Homogeneity	0.504	Homogenous	0.688	Homogenous

The results of the covariance analysis indicate significant differences between the two classes in terms of the impact of learning models on student creativity. The treatment significance value for the learning model is p = 0.001, which is lower than the significance level α = 0.05, indicating that the research hypothesis is accepted and H0 is rejected. The class that implemented the POPBL learning model showed a corrected mean on the pre-test, 45.77, and a post-test mean of 65.07. Meanwhile, the class that used the discussion and presentation method had a corrected average of 44.34 on the initial and 55.82 on the final tests (Figure 1). Therefore, it can be concluded that there is a significant difference in student creativity between classes that apply the POPBL learning model and those that use the discussion and presentation approach. The statistical results also demonstrate that the learning model has a differential effect on student creativity in the two classes.

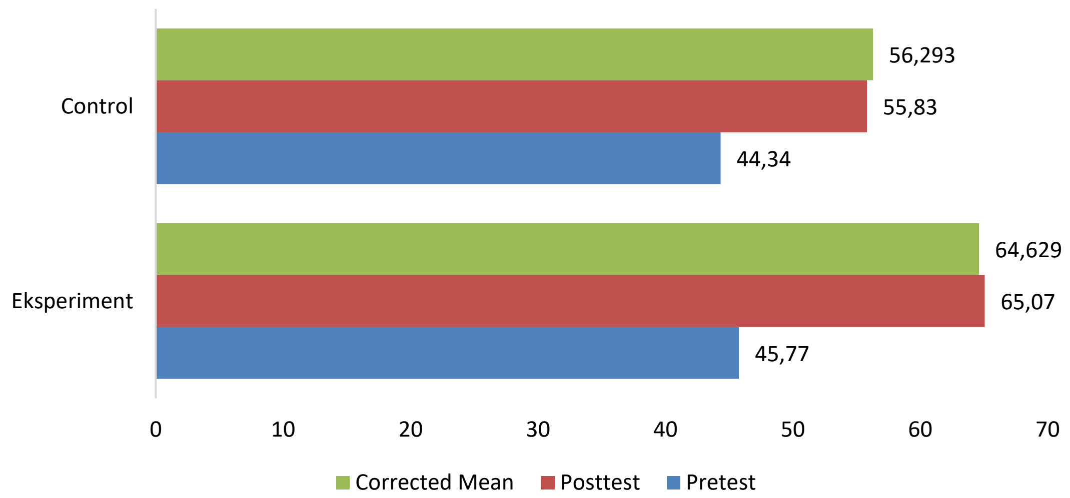

Figure 1. The influence of learning models on creativity

This testing is analyzed using the One-Way ANCOVA test with the assistance of SPSS version 26. Based on the results of the covariance analysis test, it is known that the p-value of level 0.001< the value of α = 0.05, then H0 is rejected. Thus, there are differences in creativity in the experimental class taught with the POPBL model and the control class using the conventional model. The summary data from Table 2 reveals that the class engaged in learning using the POPBL model achieved a corrected mean creativity score of 64.629. This demonstrates a significant difference compared to the corrected mean creativity score of the control class, which utilized the conventional learning model, reaching 56.293. The corrected. The mean for the experimental class falls within the high category, ranging between 61% and

80%, whereas the control class falls within the medium category, between 41% and 60%.

Table 2. Corrected Mean Effect of Learning Models on Creativity

Class	Pretest	Posttest	Difference	Corrected Mean	Improvements
Experiment	45.77	65.07	19.3	64.629	42.17%
Control	44.34	55.82	11.48	56.293	25.89%

Based on the findings by other researches (Muhajir et al., 2019; Supratman et al., 2020; Suwistika et al., 2024), it is known that POPBL can support students in applying their ideas or concepts to produce something unique or with their own characteristics. POPBL can influence student creativity through the steps undertaken by students during the learning process supported by existing learning theories. The covariance test results indicate a difference in students' mean creativity scores in Biology learning between the use of the POPBL model and conventional learning. Hero and Lindfors (2019) explain that students' learning experiences in solving various problems during project-based learning activities can develop various competencies, including student creativity. In solving these problems and projects, students must integrate various information and knowledge to develop ideas or solutions to problems (Furukawa, 2016). Creativity is a skill where students utilize imagination, knowledge, and ideas to face a problem (Acar et al., 2017; Mevarech & Paz-Baruch, 2022; Sternberg & Lebuda, 2019)
The difference in creativity between the experimental and control classes is also due to differences in the learning activities conducted. In the control class, learning activities begin with the teacher presenting concepts and materials. Then, the teacher provides worksheets that are not oriented toward contextual problems and do not require students to find solutions because the worksheets contain questions related to concepts. Next, students discuss the worksheet answers in groups and present them in turns in front of the class. Following this, a classic question-and-answer and discussion process occurs, and the learning activity concludes with the teacher providing reinforcement related to the topics covered and discussed. Creativity consists of several indicators that can also be used to measure creativity, namely fluency, flexibility, elaboration, and originality. The Tabel 3 present the results of the average pre-test and post-test scores for each indicator in the experimental and control classes.

Table 3. The average creativity score for each indicator

		Fluency	Flexibility	Elaboration	Originality
Experiment Class	Pretest	48.53	45.59	46.32	42.65
	Posttest	75.00	61.76	65.44	58.09
Control Class	Pretest	39.84	46.88	43.75	46.88
	Posttest	56.25	57.81	51.56	49.22

Based on Table 3, it can be observed that the largest average increase in the pretest to the posttest occurs in both the experimental and control classes, specifically in the fluency indicator. Meanwhile, the smallest average increase in the pretest to the posttest is observed in both the experimental and control classes, particularly in the originality indicator. For further details, refer to Figure 2.

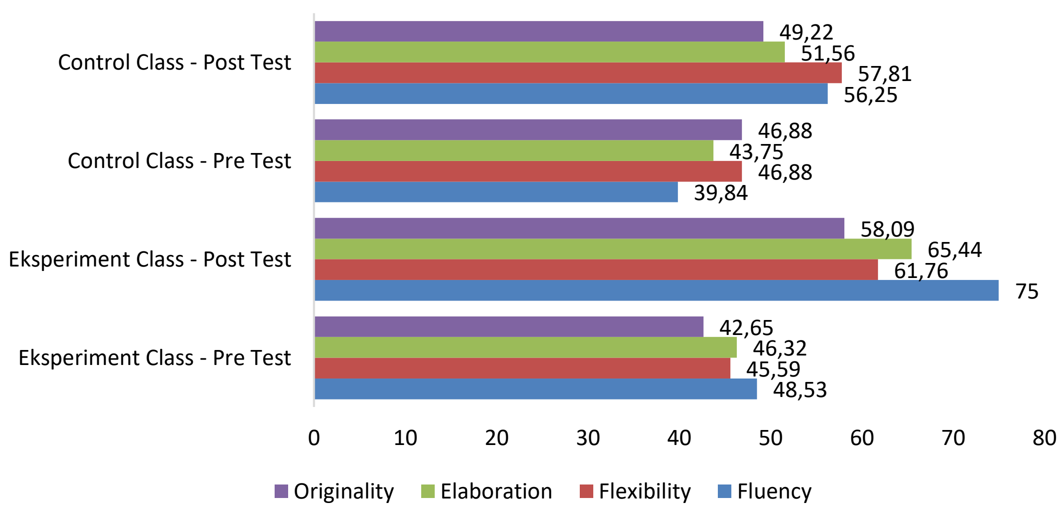

Figure 2. The differences average for each indicator

The differences in the average increase from pretest to post-test for each indicator are Influenced by the stages of learning in each class, which can be identified based on observations during the learning process. Observations during the learning process show that the learning model influences student creativity in two different classes. Differences in environmental attitudes between the experimental class using the POPBL model and the control class adopting the discussion and presentation approach are observed in each learning phase. In the first phase, orientation and problem formulation, students are presented with articles related to ecosystem and environmental issues in the Kediri area and its surroundings. In this activity, students are asked to identify problems presented in the provided articles in the Student Worksheet (LKPD). Subsequently, students are tasked with formulating several problems within their groups. From several problem formulations, students will choose one problem they consider important to find a solution for. This stage supports students in enhancing their creative abilities, particularly in the fluency indicator, where students are expected to generate their ideas spontaneously. Fluency as an indicator in the context of creativity refers to a person's ability to generate many ideas, concepts, or solutions quickly. In assessing creativity, fluency is often measured by counting the number of ideas or solutions generated within a specific time frame. Generating many ideas is important as it can lead to discovering more creative or innovative solutions (Robson, 2014).

Based on observations, almost all groups were able to formulate many problems and generate ideas or solution concepts related to the problems. However, some groups were able to identify problems but struggled to convey ideas or solutions related to the problems. However, with the teacher's facilitation, these groups eventually produced their ideas or concepts. This stage is also consistent with the cognitive learning theory proposed by Jerome Bruner, where students can develop their understanding and concepts through new experiences and the process of problem identification, as well as using learning as a way to understand concepts and improve their problem-solving abilities (Nurhadi, 2020)

The second stage of the POPBL learning model is organizing students for learning. In this phase, students will learn concepts related to the problem theme and then summarize the learning concepts from various learning sources. Afterward, students write them freely in the form of concept maps or points understood by students. This stage also aims to enhance the flexibility indicator in creativity since students are required to connect the concepts learned with the problems previously formulated by students, thus producing ideas relevant from various perspectives and developing them into a project theme (Andersen & Heilesen, 2015; Robson, 2014). Based on classroom observations, flexibility indicators in student creativity are seen when students create concept maps or mind maps and provide decorations or different colors for each concept they write. This is related to the constructivist learning theory developed by Piaget where students will build their knowledge after understanding concepts through various learning sources (Olusegun, 2015; Zhang, 2022).

The third learning stage of the POPBL model is designing and implementing projects, which is also a phase that empowers student creativity. Here, students design projects in groups and then present their ideas and imaginations so that the projects they create can be solutions to problems accurately. Here, the teacher acts as a facilitator who guides and provides directions, resources, and support needed to facilitate student learning, ensuring that students can successfully complete their projects (Malinić et al., 2021). This learning activity can enhance the originality indicator in student creativity because it can improve the ability to create new or innovative ideas or concepts that have never existed before (Acar et al., 2017). This learning activity also aligns with Vygotsky's sociocultural theory, where there is interaction between individuals and their environment, especially in the context of learning and student cognitive development (Pamungka et al., 2020). Based on observations, originality indicators appear when students come up with new original ideas for their project activities, such as conducting real socialization actions to residents around the Brantas River regarding illegal sand mining, conducting direct and social media-based socialization about the importance of using sunscreen among teenagers for self-protection against the effects of hot weather in the Kediri area, making eco-bricks from inorganic waste in the surrounding environment, or carrying out real planting actions in villages that are always affected by floods due to land conversion as an airport.

The last learning stage in the POPBL model is project presentation and evaluation. In this stage, students present their project works through posters, videos, presentation slides, or tangible objects. This learning activity certainly can enhance student creativity, especially in the elaboration indicator, where students can present their ideas or concepts by providing detailed, explanatory, or more in-depth and detailed arguments to their classmates. Afterward, an evaluation process related to student work is also conducted for reflection and improvement of the work produced by students (Widarni, 2023). Based on classroom observations, the elaboration indicator in student creativity is evident when students present and exhibit their work, where students can provide good explanations when their classmates ask about the products they have made, accompanied by reasons for choosing or making the product. In addition, students are also able to evaluate the strengths or weaknesses of the work they have done. This stage is in accordance with the principles of sociocultural learning theory proposed by Vygotsky, which emphasizes that the environment and culture around students play a major role in influencing the

interactions and cognitive development of students (Pamungka et al., 2020).
Increasing students' creativity is crucial because it empowers them to find solutions to various real-life problems. Students with high levels of creativity tend to excel in solving problems independently (Lu & Kaiser, 2022). They are able to expand the scope of their thinking and find unique solutions that others may not have thought of. In today's rapidly changing world, adapting and responding to new situations is a crucial skill. Creativity fosters flexibility and openness to change, thus better-preparing students to tackle future challenges (Fredagsvik, 2023). In the context of a competitive global environment, creativity can be a determining factor in creating competitive advantage (Maksić & Jošić, 2021). Students who can think creatively will have an advantage in competing in an increasingly complex job market.

Conclusion

Based on the results of the analysis and discussion that have been described, it can be inferred that the utilization of the Problem-Oriented Project Based Learning (POPBL) approach proves efficacious in enhancing creativity at SMAN 1 Grogol. The POPBL methodology fosters student creativity by providing opportunities for students to engage in hands-on projects, collaborate with peers, and explore innovative solutions to real-world problems.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

R. N. A. Komalasari: conducting the research, collecting data, writing the original article, revision; **I. Ibrohim:** developed the methodology and supervising the research and **D. Listyorini:** supervising the research and manuscript draft writing.

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