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The Study of Scientific Creativity using a Project-Based Learning Management Model

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Abstract

This research aims to investigate the scientific creativity of 9th grade students following the implementation of a project-based learning (PjBL) approach. The study involved a sample of 21 students from a high school in a Roi Et province during the first semester of the academic year 2023. Participants were randomly selected using classrooms as the sampling units. The research employed a pre-experimental design, specifically a one-group pretest-posttest design. The research tools included: 1. PjBL plans. 2. Assessment of scientific creativity. 3. Satisfaction questionnaire. Data analysis involved the use of means, standard deviations, and the dependent t-test statistic. It was discovered that students' scores on creative scientific thinking after the intervention were significantly higher than before, with statistical significance at the 0.05 level. Additionally, students expressed satisfaction after participating in the PjBL, with an average rating of 4.50, falling within the criteria for a high level of satisfaction.

Introduction

The importance of scientific knowledge and creative thinking for continual societal development is underscored (Sternberg, 2010). Not only is creative thinking deemed an essential skill for enhancing individuals' potential in the 21st century, but it also holds significance in the realm of education (Ozkan & Topsakal, 2019). Viewing scientific creativity as a pivotal skill of this century, learning science encompasses diverse creative thinking abilities such as formulating hypotheses, designing experiments, problem-solving, and drawing conclusions—all reliant on creativity (Lin et al., 2003). Furthermore, it serves to tackle challenges stemming from the dynamic world and to progress (De Vries & Lubart, 2019). The importance of scientific creativity is explicitly emphasized in national science education curricula and government policies of various countries, emphasizing the need to foster students' scientific creative thinking (Bi et al., 2020). These reasons support the assertion that scientific creativity is indispensable for students' comprehension of science and for those exploring the societal implications of science (Hu & Adey, 2002).

Scientific creativity is a specific and focused form of creativity in developing knowledge and generating scientific knowledge. Before the creation of something new, creative thinking is necessary. If creative thinking is combined with knowledge in scientific process skills, it is referred to as scientific creativity (Moravcsik, 1981). expressed the view that scientific creativity is a manifestation of innovative thinking, flexible thinking, and adaptable

problem-solving. (Aktamış & Ergin, 2006) It is pointed out that scientific creativity, related to science, is defined as "scientific creativity" and it is essential to distinguish between scientific creativity and general creativity. Creativity is a different and unique way of thinking. It involves adding something new beyond the existing situation. (Er, 2023). The creative attitude and behavior that is the basis of every field of creativity. This type of creativity may not be an unearthed work. While it is defined as talent in the first, it is a character trait formed by the development of situations such as seeing, perceiving and reacting. (Akca & Kavak, 2021). In numerous research works, creativity is a widespread phenomenon that varies in the way creativity is managed in the context of art, social sciences, literature, and science. However, even though it may be categorized from the perspective of producing diverse outcomes, for instance, in artistic creativity, emphasis is placed on emotions and significant thoughts. Meanwhile, scientific creativity often highlights knowledge and the application of knowledge in novel situations. (Can, 2007). In this study of scientific creativity, researchers followed the model proposed by Hu and Ade (2002), known as The Scientific Structure Creativity Model (SSCM), which measures scientific creativity along three dimensions: 1) Trait Dimension, 2) Scientific Process Dimension, and 3) Product Dimension.

Project-Based Learning (PjBL) emerges as an effective and suitable strategy for cultivating students' creativity. It is a learning approach rooted in authentic activities and assignments that challenge students to solve real-world problems, mirroring the types of tasks encountered in daily life beyond the classroom. Guided to actively and independently participate in the learning process, students engage in collaboration and communication with their peers (Kokotsaki, Menzies & Wiggins, 2016). PjBL serves as a foundational framework that stimulates students' thinking skills (Yustina et al., 2020), ultimately contributing to the fostering of creativity. Therefore, integrating this model into the learning process is crucial for enhancing students' cognitive abilities (Fajrina et al., 2018).

Recognized as particularly suitable for students in science disciplines (Crippen et al., 2016; Movahedzadeh, Patwell, Rieker, & Gonzalez, 2012), PjBL has demonstrated positive impacts on learning outcomes (Fini, Awadallah, Parast, & Abu-Lebdeh, 2018), creative thinking skills (Antika & Nawawi, 2017; Rambely et al., 2013), and increased student motivation (Movahedzadeh et al., 2012). Specifically in the context of nurturing creative thinking, PjBL has proven effective in both teaching and enhancing this skill among students (Kardoyo et al., 2020; Yamin et al., 2020).

Regarded as an innovative learning approach imparting various strategies for students' success in the 21st century (Bell, 2010), PjBL has been identified by Milla et al. (2019) as a means to develop students' scientific process skills, including creative thinking. It is considered a key strategy for preparing students for success in the contemporary era (Moylan, 2008), effectively bridging the gap between the knowledge and skills required for success in the 21st century.

Several research studies using PjBL for studying or developing students' scientific creativity have found that students who learn through PjBL activities tend to have higher scientific creativity after the learning compared to before. Based on the discussed background and significance, the researcher is interested in studying scientific creativity using the PjBL to enhance students' creative thinking. This approach aims to cultivate students' scientific creativity, promote their development, encourage them to express their thoughts through experiments or

presentations, and ultimately benefit their education.

Method

Research Design

In this study, the researcher employs a pre-experimental design, specifically a one-group pretest-posttest design. This design entails testing a single sample group both before and after the instructional intervention. Subsequently, the results obtained from the pretest and posttest are compared to examine the differences in the average scores of scientific creativity.

Participants

The population consists of 9th grade students at a certain high school in a Roi Et province, during the first semester of the academic year 2023. There are a total of 3 classrooms, with 70 students in this group. The sample group comprises of 9th grade students randomly selected from one classroom, totaling 21 students. The selection was carried out using a group randomization method, with classrooms as the unit of randomization.

Research Tools

1. PjBL was developed based on the works of Yoelao et al. (2012) and Payoungkiattikun et al. (2022). This plan comprises a total of 8 modules, totaling 13 hours, and has undergone scrutiny for appropriateness by three experts. The overall average score is 4.53, indicating a high level of suitability. The learning management activities have been detailed as follows:

1. Fundamental Knowledge:

- Assess students' prior knowledge before delving into the content.
- Subsequently, the teacher imparts foundational knowledge related to the upcoming lesson. This knowledge is intended for use during the learning activity to enhance understanding.

2. Stimulate Interest:

- The teacher prepares activities to ignite students' interest, creating engaging and enjoyable experiences during collaborative activities.
- These activities may be designed by the teacher or aligned with students' existing interests.
- During this phase, the teacher should create opportunities for students to present.
- Activities align with the teacher's learning management, connecting to the community or personal experiences of students to promote independent learning.

3. Collaborative Grouping:

- Students are grouped into teams, each consisting of 5-6 members based on their interests.
- Following that, the teacher communicates the purpose of the activity, providing guidance for proper

execution.

- Each group collaboratively engages in the activity, utilizing group processes to plan and execute it.
- Within the groups, students collectively brainstorm, consult, and assign tasks as a guide for collaborative implementation after understanding the topics in each activity.

4. Seek Knowledge:

- In the knowledge-seeking stage, practical guidelines for students to follow in conducting activities include:

1. Students initiate the activity based on the topics of interest within their groups.
2. Students fulfill their roles as agreed upon within the group, collaborating to carry out the activity.
3. They seek advice from the teacher when in doubt or faced with problems.
4. Students collectively write a summary report based on the activities they have undertaken.

5. Summarize Learning:

- Students summarize what they have learned from the activity and record it in the assignment sheet provided by the teacher.
- The teacher employs questioning techniques to guide students in summarizing their learning experiences during the activity.

6. Presentation:

- Each group of students presents the results of their activity.
- Each group formulates questions for the presenting group, and the presenting group asks questions for the audience to answer.
- This is done to stimulate focused listening among the students.
- The teacher provides additional suggestions to ensure a correct understanding among the students.

2. A science creativity assessment test, comprising 7 essay-type questions, has been reviewed by 3 experts, resulting in an Index of item objective congruence (IOC) value of 0.90.

3. A satisfaction survey for 9th grade students regarding the PjBL management plan, consisting of 4 aspects and a total of 20 items, has been examined by 3 experts. The IOC was found to be 0.95.

Data Collection

The researcher conducted data collection personally during the first semester of the academic year 2023, following the sequential steps outlined below:

1. The researcher selected students as the sample group and contacted the school administration to request permission for data collection, clearly stating the research objectives.
2. Students were instructed to complete a creativity measurement test before the learning process.

3. PjBL was implemented with 9th grade students as the sample group, following the designed learning plan.
4. After completing the PjBL, students were asked to take the creativity measurement test again.
5. Students were also provided with a satisfaction survey regarding the PjBL approach.
6. The collected data were analyzed using statistical methods to summarize the research findings.

Data Analysis

The learning management plan was scrutinized using mean and standard deviation for analysis. T-test statistics were applied to evaluate students' scientific creativity. Furthermore, the mean and standard deviation were calculated based on a 5-level rating scale derived from Likert's principle (1979) to assess satisfaction with PjBL.

Results

Results of the analysis of creative scientific thinking using PjBL management as the foundation for 9th grade students before and after learning as shown in Table 1.

Table 1. The Scientific Creativity

Scientific Creativity	Full Score	N	\bar{X}	S.D.	t	p
Pre-test	38	21	15.67	2.03		
Post-test	38	21	29.33	3.43	27.64*	.000

*p<.05

From Table 1, it is found that 9th grade students who underwent PjBL had an scientific creativity score before the study, the mean had been 15.67 Following the study, the mean increased to 29.33, When comparing the average scores before and after learning, it is evident that students who experienced PjBL had significantly higher scientific creativity scores after learning compared to before learning, with statistical significance at the .05 level.

Table 2. The Scientific Creativity Structure

Scientific Creativity Structure	N	Full Score	Pre-test		Post-test		
			\bar{X}	S.D.	\bar{X}	S.D.	
Trait dimension	Fluency	21	7	2.71	0.72	5.48	1.03
	Flexibility	21	7	2.43	0.68	4.95	0.67
	Originality	21	7	2.33	0.86	5.38	0.74
Scientific Process dimension	Scientific imagination	21	5	2.86	0.57	4.24	0.62
	Scientific thinking	21	5	2.14	0.65	3.81	0.75
Product dimension	Technical product	21	2	0.67	0.48	1.52	0.51
	Science knowledge	21	1	0.67	0.48	0.86	0.36
	Science phenomena	21	2	0.81	0.51	1.48	0.51
	Science problem	21	2	1.05	0.38	1.62	0.50

The result of the Scientific Creativity Structure table reveals the enhancement of students' scientific creativity after implementing the PjBL approach, with noticeable progress in every detail: In the Traits dimension, students showed an increase in both original thinking and flexibility, with statistically significant improvements. In the Scientific Process dimension, there was an overall increase in both scientific imagination and scientific thinking. In the Product dimension, technical product creation and scientific knowledge demonstrated notable improvements, particularly in science problem-solving. results of the analysis of satisfaction among 9th grade students after utilizing the PjBL management approach as shown in Table 3.

Table 3. The Results of the Satisfaction

List	\bar{X}	S.D.	Level of satisfaction
Learning Activity Organization	4.49	0.62	good
1. Aligned with objectives, content, and assessment methods.	4.43	0.68	good
2. Learning management activities promote creative thinking in learners.	4.48	0.68	good
3. Teaching and learning activities are enjoyable and interesting.	4.57	0.60	very good
4. Instructors use diverse teaching media to stimulate learner interest.	4.52	0.50	very good
5. Learners actively participate in classroom activities.	4.48	0.68	good
6. The duration of teaching and learning activities is appropriate.	4.48	0.51	good
Measurement and Assessment	4.43	0.65	good
1. Instructors clearly communicate assessment results to students.	4.48	0.51	good
2. Assessment is conducted both before and after learning.	4.33	0.66	good
3. Assessment tools are diverse.	4.52	0.60	very good
4. Evaluation of teaching and learning aligns with activities designed for learners and is based on learner development.	4.38	0.67	good
Instructor	4.52	0.56	very good
1. Plans and prepares for teaching management.	4.52	0.60	very good
2. Maintains a professional appearance, attire, and appropriate speech.	4.52	0.51	very good
3. Provides guidance, assistance, and facilitates activities for learners.	4.57	0.51	very good
4. Encourages learners to ask questions and listens to their feedback.	4.52	0.60	very good
5. Demonstrates responsibility and punctuality in teaching.	4.52	0.51	very good
6. Clearly explains content and ensures easy understanding.	4.48	0.60	good
Benefits	4.55	0.53	very good
1. Students have practiced expressing scientific creativity more.	4.62	0.50	very good
2. Students have exchanged ideas with peers and the teacher during activities.	4.43	0.60	good
3. Promotes a better understanding of lesson content for students.	4.57	0.51	very good
4. Students have connected real-life experiences to hands-on learning and sought answers through practical application.	4.57	0.51	very good
Overall average in all aspects.	4.50	0.59	good

From Table 3, it is observed that students who underwent PjBL management have an overall average satisfaction

score after learning, represented as $\bar{x}= 4.50$. The overall satisfaction of students after learning is rated as "good."

Discussion and Conclusion

The results of studying the scientific creativity of 9th grade students who underwent PjBL showed significantly higher scores in scientific creativity after the learning compared to before the learning, at a statistical significance level of .05. (Kokotsaki, Menzies & Wiggins, 2016). It suggests that PjBL approaches can stimulate students' thinking skills. This is in line with the research conducted by Marivane de Oliveira Biazus and Sayidah Mahtari (2022), which found that students' creative thinking who underwent PjBL interventions after learning was significantly higher than before learning at the .05 statistical significance level. PjBL interventions foster a learning format that challenges students to solve problems in areas of interest to them. Students are encouraged to participate eagerly and independently in the learning process, receiving guidance to engage actively and autonomously.

Additionally, students collaborate and communicate with peers, enhancing their teamwork skills. This is because designing activities at each stage of teaching promotes students to practice thinking processes, enabling them to reflect the dimensions of scientific creativity in all three dimensions according to the SSCM conceptual framework. Behavioral indicators of students that express the trait dimension, such as being able to deliver work on time, choosing to create works from nearby materials, producing unique, outstanding, and non-repetitive works, among others.

PjBL promotes the scientific process dimension by fostering students' ability to create works. To be creative, students must go through systematic work processes, including planning group work steps, starting from design processes that require both imagination and scientific thinking, material selection, and work creation steps. This approach opens up opportunities for students to exchange ideas and present their own research findings. Furthermore, there are activities that also promote scientific creativity in the product dimension. The behavioral indicators of students include their ability to perform activities at an improved level, practicing until they become proficient in that particular area. Students utilize scientific knowledge in the process of seeking information, conducting research, and verifying until it becomes reliable. They demonstrate scientific abilities in the process of seeking knowledge to explain scientific phenomena. Additionally, students practice problem-solving from situations or predefined questions, enjoying finding answers on their own, consistent with the theory of constructing knowledge independently (Mingsiritham, 2011). These characteristics stimulate students' creative thinking and enable them to demonstrate their knowledge in both the outcomes and scientific process dimensions effectively.

It can be observed that students will practice and develop scientific creativity in multiple dimensions simultaneously, consistent with the research of Karademir (2016), which investigated students' scientific creativity through project activities using the SSCM conceptual framework. The study found a significant relationship between activities that promote creativity and the development of scientific process skills and scientific creativity. Providing opportunities for students to think critically will enhance their creativity by imagining what components

of the process are needed, thus making complex problem-solving easier. aligning with the views of (Tiantong & Siksen, 2013) They assert that the application of PjBL is effective in enhancing students' knowledge and creative thinking.

Satisfaction of students grade 9 with the use of PjBL. When considering the elements in each aspect in order from most to least as follows: 1. The benefits received have an average of (4.55). 2. The teacher aspect has an average of (4.52). 3. Learning Activity Organization the average satisfaction score is (4.49). 4. Assessment and Evaluation the average satisfaction score is (4.43). The overall satisfaction score after the learning is 4.50, indicating a good level of satisfaction. When considering individual items, the aspect that students were most satisfied with after experiencing PjBL is that they have improved their ability to express scientific creativity. In line with the research of Ngereja, B., Hussein, B., & Andersen, B. (2020), the study found that PjBL can have positive long-term effects on learners even after they have completed their education. It is considered a pathway to building real-life skills such as appropriate communication, teamwork, emotional intelligence, and problem-solving. The study further reveals that students enjoy PjBL as a teaching tool due to the level of engagement it offers and the positive attitudes toward learning it fosters. This may be attributed to the fact that PjBL is a teaching and learning process that provides students with the freedom to think, focuses on connecting real-life experiences to learning, and encourages students to find answers through hands-on activities. Through a continuous process, students can construct knowledge on their own based on their interests and abilities, making learning enjoyable. Additionally, students develop their thinking processes and have the opportunity to express themselves fully. The success factors are academic competence, interest and motivation play an important role in the reflection of creativity and innovation skills in any field (Ozturk & Susuz, 2023). aligning with (Guilford, 1956) theory of intelligence structure, which states that the brain's ability is a characteristic of creative thinking, responsive learning, and knowledge creation. Learning is divided into three dimensions: content, thinking process, and the results of thinking. Content dimension occurs when stimulated by various media, the thinking process dimension happens when students are stimulated and learn by doing, and the results dimension involves applying acquired knowledge to create outcomes. Moreover, it is an activity that allows students to express their opinions and showcase their potential, providing freedom in the learning process.

The PjBL plan has been developed and is highly suitable. When implemented with 9th-grade students, it was observed that their scientific creativity scores increased. When examining the increase in scientific thinking based on the structure, it was found that every dimension showed improved scores. Additionally, students in this group expressed high satisfaction with the learning management plan, indicating a high level of contentment. PjBL has developed activities to align with the students' context. Teachers should thoroughly study these activities to effectively manage teaching and learning.

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