JURNAL UPI

Pedagogia Jurnal Ilmu Pendidikan

Journal homepage: http://ejournal.upi.edu/index.php/pedagogia

PEDAGOGIA

Supporting Senior High School Students' Creative Thinking and Collaboration Skills through Combined PBL Model - TAI

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ABSTRACT

This study aimed to determine whether there is a simultaneous difference in students' creative thinking and collaboration skills when using the Problem-Based Learning (PBL) model integrated with Team Assisted Individualization (TAI). The research employed a quasi-experimental design with a posttest-only control group design. The study population comprised tenth-grade students at SMA N 7 Surakarta during the 2023/2024 academic year. The sample included control and experimental classes selected through cluster random sampling. Data were collected using a creative thinking skills posttest, collaboration observation sheets, and documentation. The hypothesis was tested using MANOVA. The data analysis revealed that the creative thinking and collaboration skills of students in the experimental class were higher than those in the control class. The hypothesis test results indicated that the significance value was 0.021 (sig = 0.021 < 0.05), leading to the rejection of H0. This finding signifies that there is a simultaneous difference in creative thinking and collaboration skills when applying the PBL model integrated with TAI. It is concluded that the PBL model integrated with TAI creates a significant difference compared to the PBL model alone in fostering students' creative thinking and collaboration skills.

ARTICLE INFO

Article History:
Submitted/Received 24 Feb 2024
First Revised 19 March 2024
Accepted 07 July 2024
First Available Online 28 July 2024
Publication Date 01 August 2024

Keyword:
Collaboration, Creative Thinking, Problem-Based Learning (PBL), Team Assisted Individualization (TAI).

1. INTRODUCTION

Creative thinking involves cognitive processes for generating new ideas, developing concepts, and producing innovative solutions in concrete or abstract forms (Sugiyanto et al., 2018). Building on Guilford's divergent thinking theory, Torrance outlined four primary indicators of creative thinking: fluency, flexibility, elaboration, and originality, which have since been refined and validated (Lucas, 2016). These skills are essential in equipping individuals to navigate complex global challenges. Likewise, collaboration skills have become critical in education, emphasizing productive teamwork, adaptability, and active contributions within groups (Thornhill-Miller et al., 2023). Ofstedal and Dahlberg further identified 11 collaboration indicators, including participation, contribution, time management, interaction, and reflection, which serve as benchmarks for measuring student success in teamwork (Ofstedal & Dahlberg, 2009).

Observations conducted during a Professional Teaching Program (PLP) and interviews with biology teachers at SMA Negeri 7 Surakarta revealed that students' creative thinking and collaboration skills are still developing and require substantial improvement. Classroom participation remains limited, with only 3–5 students actively answering questions, while the diversity of ideas presented during discussions averages around 30%. In group work, task distribution is inconsistent, with only a minority of group members demonstrating responsibility and active contributions. These challenges align with data from the Global Innovation Index (GII) 2020, which ranks Indonesia 85th out of 131 countries, highlighting a below-average innovation score compared to global benchmarks (Cornell University, INSEAD, & WIPO, 2020). This data underscores the need for intensifying efforts to empower creative thinking and collaboration among Indonesian students.

Research highlights similar concerns regarding low student collaboration and social interaction. Students often lack the necessary cooperation and teamwork skills, emphasizing the need for targeted interventions to enhance their abilities (Kori, 2023; Le et al., 2018). Poor social interaction hinders students' teamwork capabilities, ultimately affecting their learning outcomes (Lee & Reigeluth, 2015; Qureshi et al., 2023). In the educational context, deficits in creative thinking and collaboration hinder academic achievement and students' preparedness to address real-world challenges effectively.

Problem-Based Learning (PBL) is recognized as a powerful approach to fostering creative thinking skills. Rooted in constructivist theory, PBL engages students in active learning by presenting meaningful problems as the foundation of instruction (Yew & Goh, 2016). PBL has been shown to significantly improve creative thinking skills among tenth-grade students (Al-Khrisha et al., 2021; Simanjuntak et al., 2021). Similarly, it has been effective in developing collaboration skills. However, PBL has limitations, particularly in addressing individual student needs, which can hinder the progress of students with lower academic abilities.

Team Assisted Individualization (TAI) offers a complementary approach to address these limitations. TAI integrates cooperative learning with individualized instruction, wherein high-performing students support their peers within group settings (Salim & Hidayati, 2021). This model creates an inclusive environment, enabling students to contribute according to their abilities. TAI has been shown to increase engagement and improve biology learning outcomes, although it places limited emphasis on collaborative problem-solving, which is essential in 21st-century education (Razak, 2019).

Integrating PBL and TAI provides a promising solution to the limitations of each model. PBL's focus on problem-solving can be combined with TAI's emphasis on individual and team learning. The integration of PBL and TAI has been found to enhance students' metacognitive

DOI: https://doi.org/10.17509/pdgia.v22i2.68490
p- ISSN p. ISSN 1693-5276 e- ISSN 2579-7700

skills more effectively than using either method alone (Shofyan et al., 2020). This suggests that combining these models can significantly improve students' creative thinking and collaboration skills.

As a biology topic, biodiversity offers significant opportunities for developing creative thinking and collaboration skills. The effectiveness of PBL in improving learning outcomes on biodiversity topics has been well-documented (Kricsfalusy et al., 2018; Mantek et al., 2019). However, these studies did not integrate TAI into their instructional strategies. While PBL positively impacts student engagement in biodiversity topics, it does not fully optimize collaboration and individual outcomes simultaneously (Wulandari et al., 2020).

This study seeks to integrate PBL and TAI to enhance students' creative thinking and collaboration skills in biology education. While supporting prior research on the effectiveness of PBL and TAI, it also offers a novel instructional approach by combining these models for biodiversity topics. By leveraging the strengths of both PBL and TAI, this study aims to address the challenges of 21st-century education and empower Indonesian students to succeed in global contexts.

2. METHODOLOGY

2.1 Research Design

The research employed a quantitative approach with a quasi-experimental method and a posttest-only control group design. Quasi-experiments involve two groups, an experimental group and a control group, where the independent variable is manipulated, but participants are not randomly assigned to treatment groups (Ary et al., 2010). The posttest-only control group research design is presented in Table 1.

Tabel 1. Research Design

Group	Independent Variable	Posttest
Experimental	X	Y_2
Control	-	Y_2

Y_2 : *Posttest in Experimental and Control Groups*
X : Treatment: Integration of PBL and TAI

The population of this study comprised tenth-grade students of SMA Negeri 7 Surakarta in the 2023/2024 academic year. The tenth grade consisted of ten classes with 360 students, distributed randomly into heterogeneous groups. The sampling method employed was cluster random sampling, which involves randomly selecting clusters or groups, such as classes, from a population (Firmansyah & Dede, 2022). The selected clusters must exhibit homogeneity and an equal likelihood of being chosen as part of the sample (Hibberts et al., 2012). The sample for this study included Class X-C, consisting of 36 students, designated as the control group utilizing the PBL model, and Class X-B, also consisting of 36 students, designated as the experimental group, which employed the integrated PBL and TAI model.

2.2 Data Collection Technique

The independent variable in this study was the learning model, specifically the PBL model integrated with TAI and PBL without TAI. The dependent variables were students' creative thinking and collaboration skills. Data collection techniques included observation, interviews, post-tests, and documentation. Observations were conducted during the preliminary study and data collection stages, focusing on monitoring the implementation of the PBL syntax and the PBL integrated with the TAI model, as well as observing collaboration based on eleven indicators (Ofstedal & Dahlberg, 2009).

The post-test included eight essay questions on biodiversity aimed at assessing students' creative thinking skills. The test instruments were developed based on creative thinking indicators, including fluency, flexibility, elaboration, and originality, as outlined by Torrance (as cited in Erwin et al., 2022). The creative thinking scores were categorized into several levels, as shown in Table 2.

Table 2. Creative Thinking Ability Score Categories

Percentage Score Interval (%)	Category
81 – 100	Very High
61 – 80	High
41 – 60	Moderate
21 – 40	Low
0 – 20	Very Low

Collaboration in this study was measured using an observation sheet developed based on eleven indicators identified by Ofstedal & Dahlberg (2009). These indicators provided a comprehensive framework for evaluating students' ability to work effectively in groups. The total scores from the observation were interpreted within predefined ranges, categorizing the students' collaboration skills into emerging, developing, or established levels, as shown in Table 3.

Table 3. Interpretation of Students' Collaboration Total Scores

Total Score Interval	Category
10 – 25	Emerging
26 – 34	Developing
35 – 44	Established

2.3 Data Analysis Technique

The hypothesis testing in this study was conducted using Multivariate Analysis of Variance (MANOVA) with the assistance of SPSS software. MANOVA is a statistical technique used to determine whether there are significant differences between groups across multiple dependent variables. This method is particularly effective for examining complex relationships and interactions within the data.

Before performing MANOVA, certain assumptions must be met to ensure the validity of the analysis. The normality of the data distribution was tested using the Kolmogorov-Smirnov test, which assesses whether the sample data significantly deviates from a normal distribution. Additionally, the homogeneity of variances was evaluated using Levene's Test of Equality of Variance, which verifies whether the variance of the dependent variables is consistent across the groups. Meeting these prerequisites is essential to maintain the robustness and reliability of the MANOVA results.

DOI: https://doi.org/10.17509/pdgia.v22i2.68490
p- ISSN p. ISSN 1693-5276 e- ISSN 2579-7700

3. RESULT AND DISCUSSION

3.1 Result

Data on students' creative thinking skills were obtained through written tests on biodiversity topics. The experimental class achieved an average score of 66.04, which was higher than the control class, with an average score of 58.30. A comparison of the creative thinking abilities of students from both sample classes is presented in Table 4.

Table 4. Distribution of Students' Creative Thinking Skill Data

Criteria	Control Class (PBL)	Experimental Class (PBL + TAI)
N	36	36
Average	58,30	66,04
Maximum	82,50	93,75
Minimum	41,25	33,75

The average scores for each aspect of creative thinking skills in the experimental class consistently exceeded those in the control class, highlighting the effectiveness of the intervention. Among the four aspects assessed, fluency (B1) emerged as the strongest performer, reflecting students' ability to generate ideas with ease and quantity. This was followed by flexibility (B2), indicating adaptability and the ability to approach problems from multiple perspectives. Originality (B4), which measures the uniqueness and novelty of ideas, ranked third, while elaboration (B3), assessing the level of detail and depth in ideas, recorded the lowest scores. These results suggest that while students excelled in idea generation and adaptability, further emphasis might be needed to enhance the depth and originality of their creative outputs. The comparative data for each aspect of creative thinking in both the experimental and control classes is visualized in Figure 1, providing a clear representation of the observed trends.

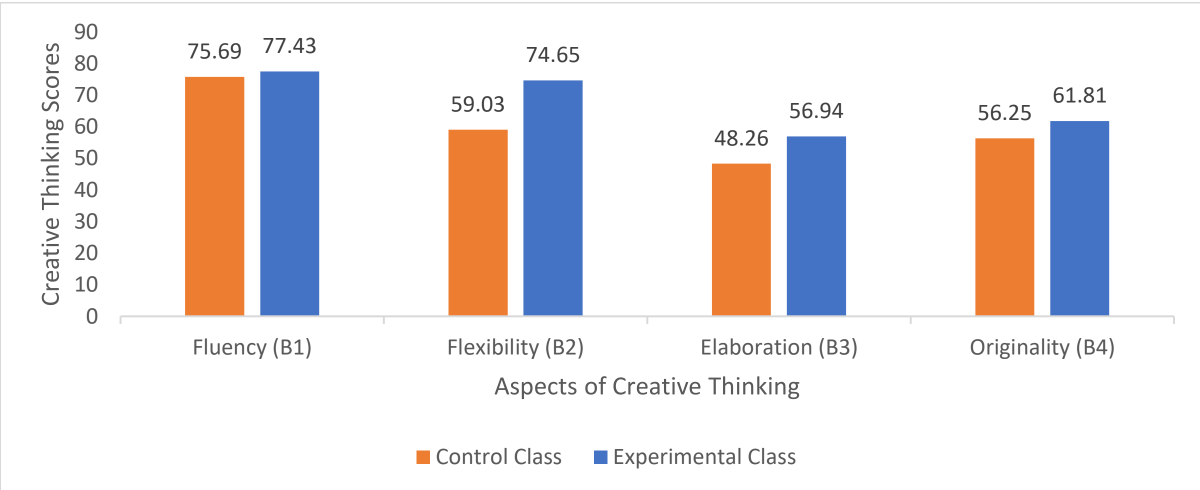

Figure 1. Average Scores for Each Aspect of Students' Creative Thinking Skills

Data on students' collaboration skills were obtained through observations. The average collaboration skill score in the experimental class was 33.47, which was higher than the control class's average score of 29.76. A detailed comparison of students' collaboration skills between the two sample classes is presented in Table 9.

Table 5. Distribution of Students' Collaboration Skill Scores

Criteria	Control Class (PBL)	Experimental Class (PBL + TAI)
N	36	36
Average	28,88	32,03
Maximum	40,67	41,00
Minimum	18,67	19,67

The average scores for the eleven aspects of collaboration skills in the experimental class were higher than those in the control class. The average scores for each aspect of collaboration skills across the two sample classes varied in order. Based on the average scores for each aspect of collaboration skills: (1) preparedness ranked as the highest aspect of collaboration in both sample classes, with average percentages of 80.09% and 84.26%; and (2) reflection ranked as the lowest aspect of collaboration in both sample classes, with average percentages of 50.00% and 57.64%. The distribution of data for each aspect of students' collaboration skills in the experimental and control classes is illustrated in Figure 2.

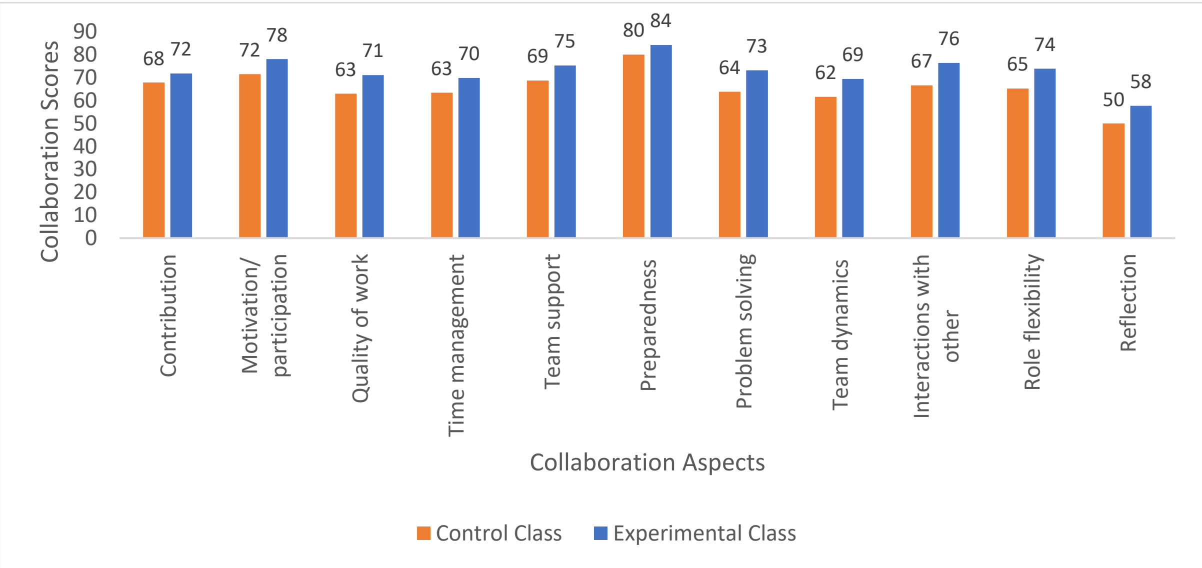

Figure 2. Average Scores for Each Aspect of Students' Collaboration Skills

The data obtained from the study were analyzed using SPSS version 25. The analysis began with a normality test using the Kolmogorov-Smirnov Test and a homogeneity test using Levene's Test of Equality of Error Variances. The decision criterion for the normality test is that if the sig. value is greater than α (sig. > 0.05), then H0 is accepted, indicating that the data are normally distributed. Similarly, for the homogeneity test, if the sig. value is greater than α (sig. > 0.05), then H0 is accepted, meaning the data have equal or homogeneous variance. A summary of the normality and homogeneity tests is presented in Table 6.

DOI: https://doi.org/10.17509/pdgia.v22i2.68490
p- ISSN p. ISSN 1693-5276 e- ISSN 2579-7700

Tabel 1. Summary of Normality and Homogeneity Tests

Data	Class	Normality Test			Homogeneity Test		
		N	**sig.**	**Decision**	**Levene's test**	**sig.**	**Decision**
Creative Thinking	Control (PBL)	36	0,200	H_0 Accepted (normal)	3,043	0.085	H_0 Accepted (homogen)
	Experimental (PBL + TAI)	36	0,200	H_0 Accepted (normal)			
Collaboration	Kontrol (PBL)	36	0,200	H_0 Accepted (normal)	0,016	0.900	H_0 Accepted (homogen)
	Eksperimen (PBL + TAI)	36	0,128	H_0 Accepted (normal)			

The data can be further analyzed using MANOVA based on the results of the prerequisite tests. The decision rule for MANOVA is that if the significance value (sig.) is less than 0.05, H0 is rejected, and H1 is accepted, indicating a significant difference in creative thinking and collaboration skills between the PBL model and the PBL integrated with TAI model. The results of the MANOVA analysis regarding students' creative thinking and collaboration skills based on the learning models are presented in Table 11.

Table 7. Summary of MANOVA Analysis Results

Effect	Value	F	Result	
			sig.	**Decision**
Pillai's Trace	0,105	$4{,}068^{b}$	0,021	
Wilk's Lambda	0,895	$4{,}068^{b}$	0,021	*sig.*<0,05 (H_0 Rejected)
Hotelling's Trace	0,118	$4{,}068^{b}$	0,021	
Roy's Largest Root	0,118	$4{,}068^{b}$	0,021	

3.2 Discussion

The research findings revealed significant differences in students' creative thinking and collaboration skills between the class using the Problem-Based Learning (PBL) model integrated with Team Assisted Individualization (TAI) and the control class. These differences affirm the effectiveness of the PBL integrated with the TAI model in enhancing both skills. PBL, which emphasizes problem-based learning, is designed to develop students' knowledge, higher-order thinking skills, problem-solving abilities, collaboration, and self-regulation (Ansari & Saleh, 2021). Meanwhile, TAI emphasizes group learning, fostering students' creativity, critical thinking, and social awareness through structured teamwork (Sepriyaningsih et al., 2019). The combination of these two models positively impacts student engagement and competency mastery while addressing the limitations of each model when implemented independently (Salim & Hidayati, 2021).

The distinct learning models applied influenced the observed differences in creative thinking and collaboration skills among students in the two sample classes. The experimental class implemented the PBL model integrated with TAI, introducing additional syntax elements such as a placement test, student creativity sessions, fact tests, team scoring and recognition, and whole-class units. Except for the placement test, these unique components significantly

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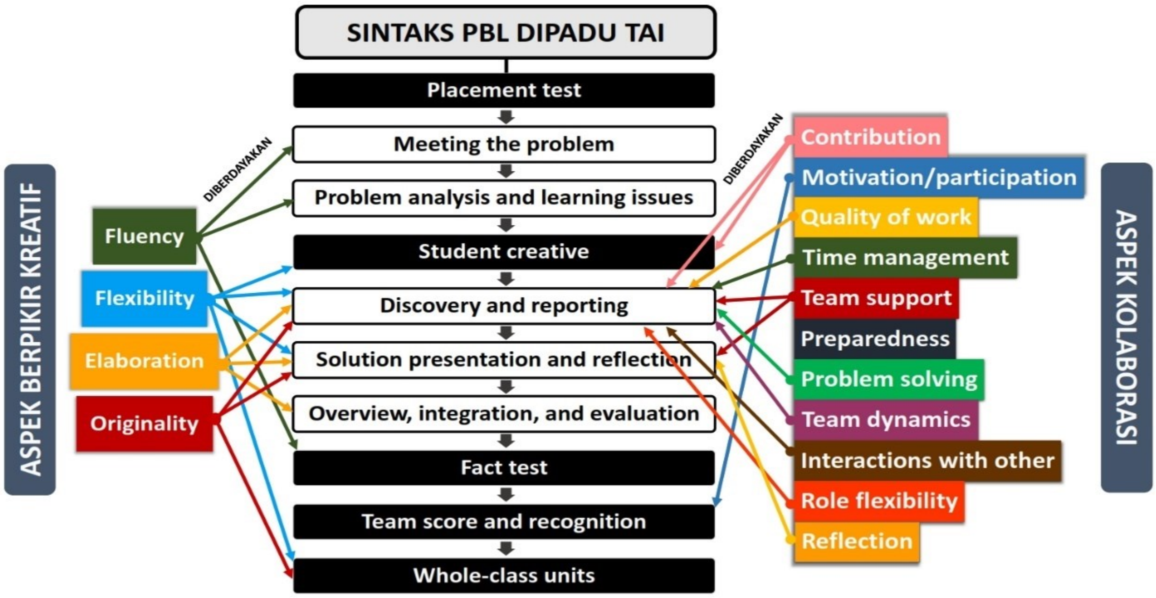
enhanced creative thinking skills. Collaboration skills were further developed by including rewards in the TAI learning process.

The syntax of the PBL model integrated with TAI was designed to empower and train each aspect of creative thinking. A general representation of how each aspect of creative thinking and collaboration was empowered through the PBL integrated with the TAI model is illustrated in Figure 3. The left section of the diagram represents aspects of creative thinking, the right section illustrates aspects of collaboration, and the center outlines the syntax of the PBL integrated with the TAI model. The central diagram specifically showcases the learning steps within the integrated model.



Fugure 3. Empowerment Scheme for Creative Thinking and Collaboration Aspects through PBL Integrated with TAI

The key difference between PBL and PBL integrated with TAI lies in the formation of groups based on placement test scores and the presence of an assistant within each group. Groups in TAI-based learning are structured more systematically compared to PBL, as they are formed according to placement test scores. This ensures an equitable distribution of students with high and low abilities within each group. The inclusion of an assistant, typically a high-performing student, is a result of this structured grouping approach. The assistant plays a vital role in supporting low-achieving students by addressing their learning difficulties.

The integration of PBL and TAI aligns with Bruner's constructivist learning theory, which posits that knowledge is built by students through meaningful learning experiences based on their prior understanding. PBL is grounded in constructivist learning principles, where students actively engage in learning by tackling meaningful problems (Yew & Goh, 2016). Such problems serve as a starting point for students to gather and integrate new knowledge (Indarta et al., 2022).

Vygotsky argued that knowledge is a social product, emerging first on a social level before being internalized on an individual level (Sawyer & Stetsenko, 2018). Vygotsky's theory of social interaction in learning is highly relevant to the integration of PBL and TAI in fostering creative thinking and collaboration skills. Social interactions in PBL combined with TAI occur between teachers and students, as well as among peers within groups. The presence of an

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assistant, a high-achieving peer, as a key feature of TAI, acts as a peer tutor to aid struggling students (Novalinda et al., 2020). Group activities and peer interactions, supported by the group assistant, distinguish the creative thinking and collaboration skills developed through PBL integrated with TAI from those fostered by PBL alone.

The differences between the PBL model and the PBL integrated with TAI model are evident in several aspects based on the findings of this study. In terms of syntax, PBL follows five main steps, while PBL integrated with TAI incorporates additional components such as placement tests, structured group formations, and peer-assisted learning. Group formation in PBL is generally heterogeneous but lacks specific roles within the groups. In contrast, PBL integrated with TAI features more structured groups, with each group including an assistant—a high-achieving student tasked with supporting their peers. This structured approach in PBL integrated with TAI facilitates more effective collaboration and peer support, enhancing both creative thinking and collaboration skills. These distinctions highlight how the integration of TAI complements and extends the strengths of the PBL model.

From a theoretical perspective, PBL is grounded in Bruner's constructivist learning theory, focusing on student-centered problem-solving activities (Hoidn & Hoidn, 2017; Hoidn & Reusser, 2020). Meanwhile, PBL integrated with TAI combines Bruner's constructivism with Vygotsky's social learning theory, emphasizing the role of social interaction in knowledge construction. Collaboration in PBL is seen as an essential skill, with students encouraged to work together effectively. However, in PBL integrated with TAI, collaboration is enhanced through structured group interactions and the presence of group assistants, enabling more meaningful peer interactions.

The PBL model combined with TAI simultaneously impacts students' creative thinking and collaboration skills, as demonstrated by the results of hypothesis testing, which revealed significant differences between the two sample classes. Creative thinking skills and collaboration are interconnected and mutually influential. Students' creative thinking is influenced by their collaboration skills (Jumadi et al., 2021; Kim, 2019). This statement is supported by research which highlights that creative thinking skills are linked to collaboration abilities, as both contribute to the development of other competencies (Birgili, 2015; Thornhill-Miller et al., 2023). Collaboration enhances students' creative thinking by facilitating the sharing of ideas, concepts, and information, thus increasing the quantity and quality of ideas. Group cooperation enables students to work together to solve problems effectively, further strengthening their creative thinking abilities.

4. CONCLUSSION

This study concludes that there is a significant difference in students' creative thinking and collaboration skills between those taught using the Problem-Based Learning (PBL) model and those taught using the integrated PBL and Team Assisted Individualization (TAI) model. The integration of PBL and TAI has been demonstrated to simultaneously enhance these skills, providing a more comprehensive and effective instructional approach. This combined model capitalizes on the problem-solving emphasis of PBL and the collaborative, individualized learning components of TAI, resulting in a balanced and impactful teaching strategy. The findings underscore the necessity of adopting innovative instructional models that address both cognitive and non-cognitive skills, meeting the requirements of 21st-century education.

The implications of this research highlight the effectiveness of the PBL-TAI combination in fostering active learning environments where students not only acquire subject knowledge but also develop critical collaboration and creative thinking skills. For educators, this model

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p- ISSN p. ISSN 1693-5276 e- ISSN 2579-7700

serves as a framework for addressing diverse student needs while simultaneously improving engagement and learning outcomes. However, the additional syntaxes involved in implementing the PBL-TAI model require careful time management to ensure its effectiveness within the constraints of standard classroom schedules.

Future research is recommended to explore the broader applicability of the PBL-TAI model in other biology topics, especially those involving real-world problem-solving scenarios. Expanding the scope of this research could provide further insights into the efficacy of this model across different contexts and subject areas. Additionally, longitudinal studies are needed to examine the long-term impact of PBL-TAI on students' skill development and academic performance.

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DOI: https://doi.org/10.17509/pdgia.v22i2.68490
p- ISSN p. ISSN 1693-5276 e- ISSN 2579-7700