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The implementation of quantum learning strategies in ecology materials to enhance students' creative thinking skills

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ABSTRACT

Creative thinking is a key 21st-century skill that must be fostered in science education, particularly in ecology, which demands conceptual understanding and contextual problem solving. However, classroom learning often relies on conventional methods that limit student engagement and creativity. This study examines the effect of quantum learning strategies on improving students' creative thinking skills in ecology. Quantum learning was selected for its holistic approach that integrates emotional, intellectual, and social dimensions, potentially optimizing creative stimulation. The research employed a quasi-experimental design with a pretest–posttest control group. Participants were 10th-grade students at SMA Negeri 11 Medan, divided into experimental and control groups. Data were collected using ecology-based creative thinking tests. The findings revealed a significant improvement in the creative thinking abilities of students in the experimental group compared to those in the control group. These results demonstrate that quantum learning effectively enhances students' creativity in ecological learning contexts. The study suggests that adopting quantum learning strategies can help educators design more engaging and innovative learning environments aligned with 21st-century educational demands.

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INTRODUCTION

In the era of globalization and the 4.0 industrial revolution, education must produce graduates who are not only academically intelligent but also possess creative thinking skills. These skills include the elements of elaboration (idea development), originality, flexibility, and fluency.

All of these elements are crucial for solving various contextual problems, including environmental issues (Kurniawan & Haryanto, 2023). Creative thinking skills are particularly important in biology education, especially in ecology-related topics, as students are confronted with complex phenomena such as pollution, climate change, and the interactions between living organisms and their environments.

However, various studies show that Indonesian students generally exhibit low creative thinking skills, particularly in biology learning (Fitriani et al., 2022). Several national and international assessments, such as PISA and TIMSS, consistently indicate that students tend to have difficulty in generating innovative solutions, making connections between concepts, and applying knowledge in new contexts (OECD, 2023). This condition reflects a limited ability to think divergently and critically—two essential components of creative thinking. Theoretically, creative thinking should emerge when learning environments encourage exploration, experimentation, and idea generation (Guilford, 1986; Torrance, 1993). However, classroom practices in Indonesia remain dominated by conventional, teacher-centered approaches emphasizing rote memorization and cognitive outcomes rather than process-oriented inquiry. Lessons are often theoretical and rarely integrate authentic problem-solving or project-based tasks that can foster creativity. Consequently, students receive few opportunities to formulate hypotheses, conduct independent investigations, or express original ideas, leading to stagnant creative development and low engagement in biological learning contexts.

In fact, ecology material has great potential to help students become more creative. Students can actively participate in environmental education campaigns, problem-solving projects, or environmental observation activities that cover topics such as biodiversity, pollution, and biogeochemical cycles (Rahayu & Masykuri, 2020). Unfortunately, the methods teachers use to deliver the material have not yet fully tapped into its potential. As a result, innovative learning strategies are needed. These strategies must be enjoyable, meaningful, and intellectually and emotionally challenging.

Quantum learning is one of the proven effective methods for improving the quality of learning. This holistic approach integrates physical, emotional, and intellectual aspects to create meaningful learning experiences. Based on the principle that learning becomes more effective in an enjoyable, stimulating, and motivating environment (Sari & Hendayana, 2021), this approach aims to optimize brain function and foster creativity through diverse techniques such as mind mapping, music, inspirational stories, collaborative activities, and self-reflection. These techniques stimulate both hemispheres of the brain, enhance associative thinking, and encourage students to connect ideas across different concepts—key processes in creative thinking development. Recent studies also show that quantum learning encourages divergent thinking, originality, and flexibility in idea generation, leading to higher creative performance in students (Rachmawati et al., 2022; Ningsih & Prasetyo, 2023). By emphasizing active engagement, emotional involvement, and reflective learning, quantum learning not only improves academic achievement but also effectively nurtures students' creative thinking as an essential component of 21st-century skills (Sitorus & Hutauruk, 2020).

Quantum learning is an educational approach that focuses on creating a meaningful, empowering, and enabling learning environment by emphasizing active student engagement in all their potential—emotional, intellectual, and physical—in a positive and enjoyable learning environment (DePorter & Hernacki, 2020; Sari & Hendayana, 2021). The goal of quantum learning is to maximize students' absorption and creativity (DePorter & Hernacki, 2020; Sari & Hendayana, 2021).

In general, quantum learning syntax consists of seven main steps known as the TANDUR framework (Grow, Experience, Name, Demonstrate, Repeat, and Celebrate). These steps are grow (generating student motivation and interest), experience (connecting the material to real-life experiences), name (providing concepts or theories), repeat (providing reinforcement and reflection), and celebrate (providing appreciation for student achievements). Across various levels of education, this approach has proven successful in enhancing modern skills such as communication, creative thinking, and collaboration.

Previous studies have shown that implementing quantum learning strategies can enhance students' creativity and learning motivation. For instance, Utami et al. (2021) reported that, compared to conventional learning, this strategy significantly improved students' creative thinking skills by creating a learning environment that fulfills both cognitive and emotional needs. However, previous studies generally focused on general subjects or cognitive outcomes without specifically addressing creative thinking within the context of ecology learning, which requires complex conceptual understanding and contextual problem solving. In contrast, the present study examines the application of quantum learning specifically in ecology topics to determine its effectiveness in fostering students' creative thinking skills. This focus provides a more contextualized understanding of how quantum learning supports creativity in science learning that integrates ecological concepts with real-life environmental contexts.

Quantum learning emphasizes active and contextual learning, so the relationship between quantum learning strategies and ecological material is very important. Students can be encouraged to conduct direct observations of their surrounding environment, create simple conservation projects, or find innovative and practical solutions to environmental issues using this strategy (Kurniawan & Haryanto, 2023). Additionally, this method has the potential to enhance student engagement in the learning process. In turn, this will positively impact the achievement of overall biology learning objectives.

This research is important to determine how the application of quantum learning strategies in ecology can improve students' creative thinking skills. The results of this study are expected to help develop a more creative, critical, and environmentally responsible biology learning model that can produce a generation that thinks critically, creatively, and cares about the environment.

RESEARCH METHODS

Research Design

For this study, a quasi-experimental design was used. This design allows researchers to compare results between the experimental group (or control group) and the untreated group (or control group). All of this is done without randomly selecting subjects. To determine whether students' creative thinking skills improved before and after the implementation of the quantum learning strategy, two groups were given tests before and after. An unequal group control design was used (Sugiyono, 2021). The experimental class will use a quantum learning approach based on the TANDUR syntax (Grow, Experience, Name, Demonstrate, Repeat, and Celebrate). On the other hand, the control class will use conventional learning approaches such as discussion and questioning.

Population and Samples

The population of this study was all 180 tenth-grade students at SMA Negeri 11 Medan, consisting of six classes. The sample consisted of 60 students from the total population, comprising an experimental class and a control class. The sample was selected using purposive sampling. This technique was chosen because the researcher had specific considerations in determining the research subjects that were considered most relevant and representative of the study objectives. The selected sample had comparable characteristics in terms of the number of students, overall academic ability, and teachers' experience in teaching ecology material. This purposive selection allowed the researcher to control external variables that could influence the results, so that any differences in learning outcomes were more likely to be caused by the quantum learning treatment itself. The use of purposive sampling was also based on time constraints, resources, and the need to ensure that the learning strategy could be implemented optimally under the direct supervision of the researcher. This technique was considered appropriate in quasi-experimental research where pure randomization was not possible because the classes had already been formed administratively by the school (Sugiyono, 2021). In the context of educational research, purposive sampling is often used when researchers want to obtain in-depth information from subjects with specific characteristics who are considered capable of providing the required data optimally (Creswell, 2018). Therefore, this technique is not only practical in terms of methodology but also supports the internal validity of the research by selecting classes that are homogeneous and relevant to the learning context.

Instruments

The instrument used in this study was an essay test designed to measure students' creative thinking abilities in ecology. The test was developed based on four main indicators of creative thinking, namely fluency, flexibility, originality, and elaboration (Fitriani et al., 2022). Each item consisted of open-ended questions that required students to explore ecological concepts, analyze environmental problems, and propose innovative solutions within the framework of quantum learning. To ensure the instrument's feasibility and accuracy, content validity was examined through expert judgment involving three lecturers specializing in biology education and educational evaluation. The reliability test, conducted using Cronbach's Alpha, produced a coefficient value of 0.86, indicating high internal consistency. Thus, the instrument was deemed valid and reliable for assessing students' creative thinking skills in the context of ecology learning. The indicators and corresponding test items used in this study are presented in Table 1.

Table 1. Indicators of Instruments Used in the Study

No.	Creative Thinking Ability Indicators	Question Description	Maximum Score
1.	Fluency – Expressing many ideas or solutions related to an ecological problem	Students are asked to list various ways to address environmental pollution around the school	5
2.	Flexibility – Demonstrating the ability to think from different perspectives or approaches	Students are asked to explain two different solutions (biological and social) to address river ecosystem damage	5
3.	Originality – Presenting unique ideas that are not commonly used	Students were asked to come up with creative and unusual solutions to preserve biodiversity in the school environment	5
4.	Elaboration – Explaining ideas in detail and depth	Students are asked to explain the concrete steps of one innovative idea they have chosen to maintain ecosystem balance	5

(Sources: Utami et al., 2021; Sari & Hendayana, 2021; Fitriani et al., 2022; Kurniawan & Haryanto, 2023)

Procedures

This research procedure began with planning, which included identifying problems, formulating objectives, and developing research instruments. This research was conducted using a quantitative approach and a quasi-experimental design. Specifically, an unequal control group design was used, involving two groups of students, an experimental group and a control group. Unlike the control group, the experimental group used a quantum learning strategy for ecology material. Quantum learning was chosen as the strategy because it emphasizes students' emotional and physical engagement and makes learning enjoyable, interactive, and meaningful. This has been proven to enhance students' creativity (Setiawan & Mahmudah, 2021).

A contextual approach was used to deliver ecology material, linking ideas about the environment to real-world situations, thereby increasing the relevance and engagement of students in learning (Sari et al., 2022). The Guilford-based creative thinking ability test, which includes fluency, flexibility, elaboration, and originality, is the primary tool used. Data were analyzed using the t-test to determine differences in creative thinking scores between groups. Before being used to collect data, the instrument was tested for validity and reliability.

Every step was carried out in accordance with research ethics standards, which included school approval and student data protection. This study is expected to help determine useful learning approaches to enhance student creativity in biology, especially ecology (Putra & Dewi, 2023; Wulandari et al., 2021).

Data Analysis

In this study, data analysis was conducted in several steps. First, descriptive analysis was performed to determine the minimum, maximum, mean, and standard deviation for each group of creative thinking ability test results. To ensure that the data met the assumptions of parametric statistics, prerequisite tests were conducted. These included the Kolmogorov-Smirnov normality test and Levene's test of homogeneity of variances.

After the prerequisite tests for normality and homogeneity were fulfilled, an independent sample t-test was conducted to determine the difference in creative thinking abilities between the experimental and control groups. The data analysis was performed using SPSS version 25 with a significance level of 0.05. The results of the t-test confirmed that there was a statistically significant difference between the two groups, indicating that the learning treatment effectively improved students' creative thinking skills. The use of this test is appropriate for evaluating the effect of different learning strategies on students' cognitive and creative outcomes (Putra & Dewi, 2023; Wulandari et al., 2021).

RESULTS

The average pretest and posttest scores for students' creative thinking abilities are shown in Figure 1. Figure 1 illustrates the comparison of students' creative thinking scores between the experimental and control classes before and after treatment. Prior to the implementation of the quantum learning strategy, both groups showed relatively similar pretest averages, indicating equivalent initial abilities. After treatment, a clear difference emerged: the experimental class achieved a substantial increase in posttest scores, reaching an average of 84.6, whereas the control class improved only modestly, with an average of 68.3. This upward trend in the experimental group reflects the effectiveness of the quantum learning approach in enhancing students' fluency, flexibility, originality, and elaboration. The improvement also demonstrates that a learning environment integrating emotional and intellectual engagement—as emphasized in quantum learning—can significantly stimulate students' creative responses to ecological problems. Thus,

Figure 1 visually confirms that the strategy produced measurable learning gains beyond conventional instruction.

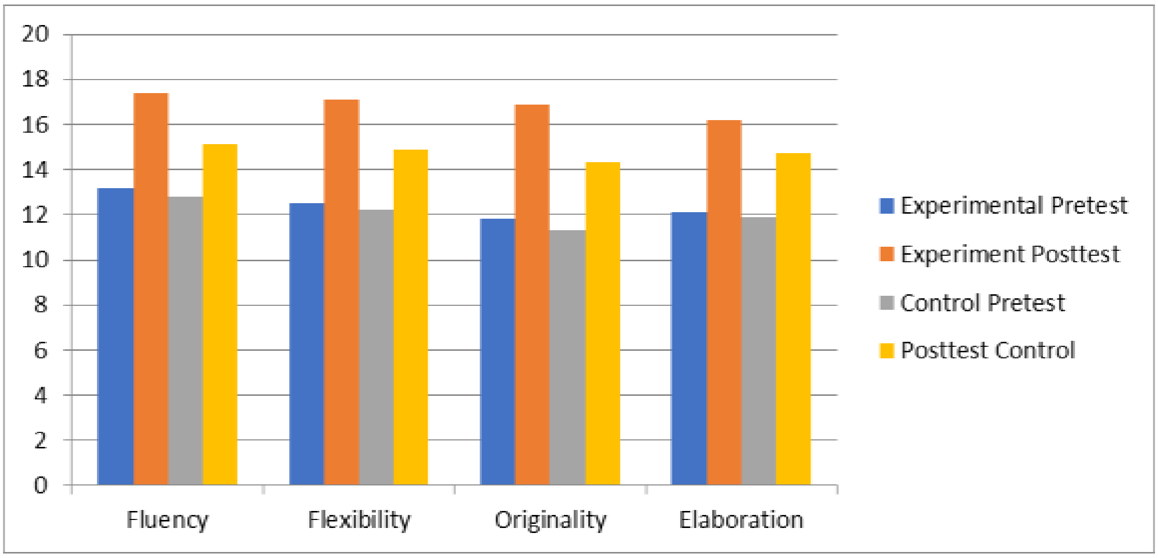

Figure 1. Average Pretest and Posttest Scores of Students' Creative Thinking Ability

The results of the data analysis prerequisite test before conducting the independent t-test can be seen in Table 2. Table 2 presents the results of the data prerequisite tests before the t-test analysis. The Kolmogorov–Smirnov normality test results showed a p-value of 0.9613 for the experimental class and 0.9410 for the control class, both of which were greater than 0.05. This indicates that the data were normally distributed. The homogeneity test using Levene's Test also showed a p-value of 0.2840 (> 0.05), which means the variances of both data groups were homogeneous. These results prove that the data used have met the basic assumptions of parametric statistics, so that subsequent inferential analysis can be carried out validly and reliably. Fulfillment of this prerequisite test strengthens the validity of the t-test results in Table 3, which show a significant difference between the two groups.

Table 2. Results of Data Analysis Prerequisite Tests before Independent t-test

Test	Statistics	p-Value	Description
Kolmogorov-Smirnov class experiment	0.0872	0.9613	Normally distributed data
Kolmogorov-Smirnov class control	0.0920	0.9410	Normally distributed data
Levene's Test	1.1693	0.2840	Varians homogen

The Kolmogorov-Smirnov normality test showed that the posttest data from both groups (experimental and control) were normally distributed because the p-value was > 0.05. The Levene's test for homogeneity showed that the variances of both groups were homogeneous (p = 0.2840 > 0.05), so the assumption of homogeneity was fulfilled. Furthermore, the results of the independent t-test of students' creative abilities are shown in Table 3.

Table 3. Results of the Independent Posttest T-test for Creative Thinking Ability

Variables	Average Posttest	Standard Deviation	T-count	df	Sig. (2-tailed)	Description
Experimental Class	84.6	6.35	5,72	58	0,000	There is a significant difference
Control Class	68.3	7.11				

DISCUSSION

The results of this study indicate a significant improvement in students' creative thinking abilities after the implementation of quantum learning strategies in ecology lessons. This improvement did not occur by chance, but rather because quantum learning strategies systematically create enjoyable, meaningful learning conditions that activate both the left and right sides of the brain in a balanced manner. This strategy is able to build emotional and intellectual connections between students and the learning material. When students feel emotionally engaged, they are more motivated to explore and create new ideas. This is one of the reasons why creative thinking skills increased significantly in the experimental class.

The process of implementing quantum learning is carried out through structured steps using the "TANDUR" syntax (Grow, Experience, Name, Demonstrate, Repeat, and Celebrate). Each step is designed to accommodate students' cognitive, affective, and psychomotor involvement. For example, in the "Experience" stage, students are encouraged to directly observe ecological phenomena such as biotic and abiotic interactions, thereby forming concrete experiences that serve as the foundation for creative thinking. This stage plays a crucial role in creating a real-world context for original and elaborative thinking. Through this approach, students do not merely memorize concepts but construct their own knowledge.

Based on statistical test results, the experimental class experienced an increase in scores on all indicators of creative thinking, namely fluency, flexibility, originality, and elaboration. This shows that the quantum learning strategy successfully facilitated the development of all important aspects of creative thinking. The highest improvement was observed in the originality indicator, indicating that students were able to generate new and unconventional ideas. This achievement demonstrates the effectiveness of the quantum strategy in creating a safe space for idea experimentation within the learning environment.

This study is in line with the results of a study conducted by Sari & Setiawan (2020), which found that the application of quantum learning in biology lessons can improve students' higher-order thinking skills, including creative thinking. Another study by Nasution and Rosmiati (2021) also showed that quantum teaching creates an interactive and inspiring classroom atmosphere, encouraging students to express their ideas. The similarity of these results demonstrates the consistency of the effectiveness of quantum strategies in various science learning contexts.

Furthermore, these results are also relevant to the findings of Susanti et al. (2022), which prove that the use of experience-based learning strategies and positive emotions increases students' innovative capacity. The quantum strategy combines elements of real-world experience and emotional motivation through rewards and celebrations of learning outcomes, which have been proven to have a positive impact on creative thinking abilities. Therefore, this strategy is not only cognitive but also affective, which is highly important in 21st-century learning.

The integrated process in the quantum strategy allows students to learn in a collaborative and open environment. Group discussions, problem solving, and demonstrations become tools for students to practice flexible thinking and develop alternative solutions. Such a learning environment also strengthens students' self-efficacy, which in turn boosts their confidence in expressing original ideas. Thus, the enhancement of creativity is not solely the result of teaching methods but also stems from the creation of a supportive learning environment.

Theoretically, the quantum learning approach is based on the principles of constructivism and neuro-linguistic programming (NLP), which emphasize the importance of activating various learning styles of students and utilizing the full potential of the brain (DePorter & Hernacki, 2019). This provides a strong scientific basis that learning must address emotional aspects, physical environment, and intrinsic motivation to foster creativity. Therefore, a holistic quantum learning design can be considered the primary foundation for success in this research.

In the control group that used conventional methods, there was also an increase in creative thinking skills, but not as much as in the experimental group. This can be explained by the fact that conventional methods tend to be teacher-centered and emphasize basic cognitive achievement. The lack of student involvement in the learning process limits opportunities for flexible and original thinking. Thus, this method does not provide sufficient stimulation to develop the full creative potential of students.

These results further strengthen the argument that innovative and student-centered learning strategies are urgently needed in biology education, particularly in ecology, which is rich in real-world and complex phenomena. Quantum learning addresses this need through a comprehensive and enjoyable approach. When students are able to connect learning to their daily lives and engage actively, they are more likely to develop divergent thinking, which is a hallmark of creative thinking.

A study by Arifin and Hidayat (2020) also supports this finding, in which students taught using creative and reflective strategies in ecology learning showed a significant improvement in higher-order thinking skills. This reinforces the position that learning approaches involving self-reflection and open exploration are highly effective in improving creative thinking skills. Quantum learning strategies can be seen as a combination of these various approaches into a systematic and practical package.

In addition to cognitive aspects, quantum learning also influences students' social and communication skills. In this study, students who were actively involved in discussions and presentations experienced improvements in expressing their ideas logically and structurally. These skills are very important in developing creativity because they enable students to realize their ideas and convey them to others in a convincing manner. This is an important aspect that is often overlooked in conventional learning.

The implications of these findings suggest that biology teachers should consider quantum learning as an effective alternative learning strategy to foster student creativity. This strategy is particularly relevant for ecology, which is rich in real-world phenomena and applications. The application of quantum learning also opens up space for the development of a more flexible and adaptive curriculum tailored to students' learning needs. This supports the implementation of the Independent Curriculum, which emphasizes differentiated learning.

From a practical perspective, the success of this strategy demonstrates the need for teacher training in designing and implementing effective quantum learning. Understanding the syntax is not enough; teachers also need to master creative classroom management, active learning techniques, and self-reflection strategies that foster student creativity. Therefore, educational institutions and local governments need to provide professional development programs oriented toward learning innovations such as quantum learning.

This research makes a significant contribution to science education because it provides empirical evidence that quantum learning not only improves cognitive learning outcomes but also creative thinking skills, a crucial indicator in 21st-century education. In the context of biology learning, this strategy can be an approach that integrates scientific concepts with humanistic and social values, producing students who are not only intelligent but also innovative and adaptable.

Overall, these results and discussion confirm that quantum learning has significant potential to improve the quality of biology instruction. By providing meaningful learning experiences, this strategy fosters active, creative, and reflective students. Further research can be conducted by extending the learning process to different educational levels or integrating digital technology to enrich the quantum approach. These results are expected to serve as a reference for transforming learning toward a more creative and student-centered approach.

CONCLUSION

This study concluded that the application of quantum learning strategies significantly improved students' creative thinking skills in ecology. This was demonstrated by statistical test results showing a significant difference between the experimental group using quantum learning and the control group using conventional methods. Quantum learning strategies, which emphasize a fun learning atmosphere, active student involvement, and integration between emotional, physical, and intellectual abilities, have been shown to create a learning environment conducive to the development of original ideas and creative problem-solving. This improvement is evident in indicators of creative thinking skills such as fluency, flexibility, elaboration, and originality. Based on these findings, it is recommended that biology teachers integrate quantum learning strategies into their teaching, particularly in subjects requiring higher-order thinking skills such as ecology. Furthermore, educational institutions need to provide ongoing training to teachers to understand the philosophy and technical aspects of optimal quantum learning implementation. Further research can be conducted with broader material coverage, the development of quantum learning-based learning media, or integration with project-based approaches and digital technology to foster student creativity in the context of 21st-century learning.

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