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Enhancing Sustainability Awareness and Creative Thinking Skills through Free Inquiry Learning

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ABSTRACT

Developing creative thinking skills and sustainability awareness is an important challenge in science learning, especially in dealing with global issues related to sustainability. However, prior studies have often emphasized guided inquiry or project-based approaches, while empirical evidence on the effectiveness of free inquiry particularly in simultaneously strengthening creative thinking and sustainability awareness at the junior high school level remains limited, creating a scientific urgency to test its impact in authentic classroom settings. This research aims to analyze the effectiveness of implementing free inquiry learning model in improving junior high school students' creative thinking skills and sustainability awareness. The research used a quasi-experimental method with a matching-only pretest–posttest control group design involving 60 class IX students, consisting of an experimental class and a control class. Research instruments include creative thinking skills tests, sustainability awareness questionnaires, and learning implementation observation sheets. Data analysis was carried out using quantitative techniques and conclusions were drawn based on samples using statistical tests. The research results show that the implementation of free inquiry model is in the very good category. The increase in students' creative thinking skills in the experimental class was moderate and higher than the control class. Apart from that, the sustainability awareness of experimental class students increased significantly and had a strong positive relationship with creative thinking skills. Statistical testing indicated significant posttest differences between groups ($p < 0.05$), supported by higher learning gains in the experimental class (N-gain = 0.45) compared to the control class (N-gain = 0.30), with the strongest improvements observed in originality and the conceptual–experiential dimensions of sustainability awareness. These findings indicate that free inquiry model is effective in developing students' 21st century competencies.

Keywords: Free Inquiry; Creative Thinking Skills; Sustainability Awareness; Science Learning; Sustainability Education.

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1. INTRODUCTION

21st-century education demands competency development that focuses not only on mastering knowledge but also on higher-order thinking skills relevant to global challenges. One key skill that needs to be developed through science learning is creative thinking, namely the ability to generate original, flexible, and useful ideas for solving complex problems (Henriksen et al., 2018; Martínez et al., 2021). In the context of Natural Science (Science) learning, creativity

plays a crucial role in helping students connect scientific concepts with real-world phenomena and fostering innovative solutions to environmental and technological problems (Lander, 2024). However, science classrooms are still frequently dominated by teacher centered instruction and cookbook/verification laboratory activities that limit students' opportunities to formulate questions, explore alternative ideas, and construct original solutions, which can constrain the development of creativity (Bullard & Bahar, 2023; Rokos & Zavodska, 2020).

In addition to creativity, sustainability awareness is a crucial competency that needs to be instilled starting in secondary education. Sustainability awareness encompasses students' understanding, attitudes, and concern for sustainability issues, such as the use of natural resources and energy, and the impact of human activities on the environment (Brandt et al., 2019; Gericke et al., 2019). International research shows that students with a high level of sustainability awareness tend to have more reflective skills and responsible decision-making in their daily lives (El-Said et al., 2025). In line with the aims of Education for Sustainable Development, strengthening sustainability awareness can also support students in developing a sense of responsibility and agency to participate in sustainability-oriented actions (UNESCO, 2017).

However, various studies reveal that science learning in schools is still dominated by conventional, teacher-centered approaches that emphasize memorization of concepts, thus providing little space for students to think creatively and develop a deeper awareness of sustainability (Aytaç et al., 2020). This situation is also found in the Indonesian educational context. Several studies in the Indonesian Education report that junior high school students' creative thinking skills are still in the low to moderate category due to minimal active student involvement in the learning process (Hayat et al., 2024; Qomariyah et al., 2021).

As an alternative to addressing this problem, the free inquiry learning model is seen as a potential approach. This model positions students as active subjects who independently formulate questions, design investigations, collect and analyze data, and draw conclusions based on scientific evidence (Long & Tan, 2025; Tomine et al., 2024). Free-form inquiry-based learning has been shown to enhance creative thinking skills because it provides students with ample opportunities to explore various possible solutions and develop original ideas (Morokuhi et al., 2025; Panjaitan & Siagian, 2020). In addition, recent studies indicate that open/free inquiry can strengthen students' higher-order thinking by engaging them in iterative cycles of questioning, testing, and reflecting throughout the investigation process (Lazonder & Harmsen, 2016). Moreover, with appropriate teacher support such as scaffolding and feedback, inquiry activities can remain rigorous and focused while still preserving students' autonomy in constructing scientific understanding (Haidar et al., 2020).

To ensure that creative thinking gains from free inquiry also develop sustainability awareness, inquiry tasks should be situated in authentic socio scientific and SDG related contexts so students' questioning and evidence-based reasoning remain connected to real environmental challenges. Contextualized inquiry can strengthen student engagement and the perceived relevance of learning, which supports sustained participation in solving real world problems (Attard et al., 2021). Aligning inquiry activities explicitly with the Sustainable Development Goals also helps students link classroom investigations with sustainability oriented citizenship competencies (Luque & Alcantud-Díaz, 2024). In line this, eco related literacy has been found to correlate positively with students' creative thinking when they address environmental issues, indicating that inquiry driven creativity can foster greater sensitivity to sustainability concerns (Sigit et al., 2023).

Furthermore, student engagement in contextual inquiry activities also contributes to increased sustainability awareness, as students are directly exposed to real-world problems related to the environment and everyday life. Recent research has shown a positive relationship between creative thinking skills and sustainability awareness, with students who are able to think creatively tending to be more sensitive to sustainability issues and able to respond adaptively to them (Baptista et al., 2025; Setiyaningsih et al., 2024). In addition, learning designs that use socio scientific issues as inquiry contexts are reported to promote students' critical engagement with sustainability dilemmas and strengthen the relevance of science learning to everyday environmental decisions (Viehmann et al., 2024).

However, empirical studies specifically examining the effectiveness of the free inquiry model in improving creative thinking skills and sustainability awareness in junior high school students are still limited, especially in the context of science learning in Indonesia. Therefore, this study is important to examine the implementation of the free inquiry learning model and its impact on the development of students' creativity and sustainability awareness. The results of this study are expected to provide theoretical and practical contributions to the development of science learning that is more meaningful, contextual, and relevant to the demands of 21st-century competencies.

2. METHODS

This quantitative research using experimental methods aimed to provide a treatment in the form of the application of an free inquiry learning model to determine its effect on the creative thinking skills and sustainability awareness of 9th-grade junior high school students under controlled conditions. This aligns with expert opinion stating that experimental research aims to determine the impact of a treatment on other variables under controlled conditions (Arib et al., 2024; Rukminingsih et al., 2020). Given that many external factors cannot be fully determined or controlled in a real-world context, the type of experiment conducted was a quasi-experiment (Creswell, 2012). The study used a matching-only pretest-posttest control group design (Fraenkel & Wallen, 2009) with two classes selected based on matching student academic characteristics, particularly academic ability. The experimental class implemented free inquiry learning model, while the control class used regular learning as usual with teachers' daily practices, with class determination carried out by random assignment after the matching process. The following illustrates the matching-only pretest-posttest control group design, as shwon In Table 1.

Table 1. The Matching-Only Pretest-Posttest Control Group Design

	Pretest	***Treatment***	***Posttest***
M	O	X	O
M	O	C	O

Source: (Fraenkel & Wallen, 2009)

Description:
M = Groups have been matched based on certain characteristics (matching).
O = Data collection from creative thinking skills tests and sustainability awareness questionnaires.
X = Treatment in the form of implementing free inquiry learning model.
C = Treatment in the form of learning typically conducted by teachers.

The study was conducted at a junior high school in Bandung Regency, with 60 ninth-grade students as subjects. The sample was divided into two classes: an experimental class and a control class, each with 30 students. The sample was selected using a matching technique based on

science academic scores to ensure equivalency of students' initial abilities, after two intact ninth-grade classes were first chosen through purposive (non-probability) sampling based on administrative feasibility and comparable class characteristics at the school. The experimental class and the control class were then randomly assigned. The experimental class received a free inquiry learning model, while the control class followed the teacher's usual learning method.

The research procedure began with a pretest administered to both groups to measure students' creative thinking skills and sustainability awareness. The learning process then lasted for four sessions, tailored to the material taught. After completing the entire learning series, both groups were given a posttest as a final assessment. To examine whether the learning outcomes differed significantly between the experimental and control classes, the posttest scores were analyzed using inferential statistics. Data distribution was first checked with a normality test and variance equality with a homogeneity test. If the assumptions were met, the difference in mean posttest scores was tested using an independentsamples t-test, and otherwise, the Mann–Whitney U test was applied. During the learning process, observations were conducted to monitor the implementation of the learning and ensure that the treatment was delivered consistently.

The first instrument is a creative thinking ability test, designed based on indicators of fluency, flexibility, originality, and elaboration. This test aims to measure students' ability to generate ideas fluently, variedly, originally, and in detail after participating in the learning process. Creative Thinking Skills Test Results. After all instruments with known validity and reliability were tested on students through pretests and posttests, student scores for each test were obtained. To determine the improvement in creative thinking skills before and after learning, the following formula was developed:

$$\langle g \rangle = \frac{\%\ posttest\ score - \%\ pretest\ score}{Maximum\ score - \%\ pretest\ score} \quad (1)$$

To interpret the normalized gain, the criteria presented in Table 2 were used.

Table 2. Interpretation of Average Normalized Gain

Value <g>	Classification
<g> > 0,7	High
0,3 < <g> ≤ 0,7	Medium
<g> ≤ 0,3	Low

Source: (Meltzer, 2002)

Student sustainability awareness is a written, non-test instrument in the form of a questionnaire. The questionnaire used is based on four indicators: conceptual awareness, experiential awareness, awareness of engagement, and awareness of adaptation (Eliyawati et al., 2024). This instrument is used to assess students' awareness before and after learning. The questionnaires administered for the pretest and posttest are the same test instrument. This study used two types of questions: positive statements and negative statements. Sustainability awareness questionnaire results the statements in the instrument used to obtain data on students' sustainability awareness were phrased in both positive and negative terms. The scoring used is presented in Table 3.

Table 3. Student Response Item Scores

Response Item	Positive Statement	Negative Statement
Strongly Agree	4	1
Agree	3	2
Disagree	2	3
Strongly Disagree	1	4

After determining the score for each answer, the calculation is performed to categorize sustainable awareness using the following formula:

$$\%\ Percentage = \frac{Total\ Score\ Obtained}{Maximum\ Score} X100 \quad (2)$$

The results of the calculation using the formula above are adjusted to the sustainable awareness categories. Sustainable awareness categories are shown in Table 4.

Table 4. Sustainable Awareness Categories

Average	Category	Meaning
0 – 50%	Rendah	Low habits not practiced
51 – 70%	Sedang	Moderate habits once practiced
71 – 100%	Tinggi	High habits always practiced

Source: Modified (Clarisa et al., 2020)

Afterward, the data were tested for correlation to determine the relationship between creative thinking skills and sustainability awareness. This correlation test is important to identify whether there is a significant relationship between the two variables, as well as the strength and direction of that relationship. In this study, the correlation test used was the Pearson Product Moment correlation, which is an appropriate analytical technique for measuring the closeness of a linear relationship between two variables on an interval or ratio scale. The formula for the Pearson Product Moment correlation is as follows:

$$r_{xy} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}} \quad (3)$$

Description:

r_{xy} = correlation coefficient between variables X and Y
n = number of samples
$\sum XY$ = sum of the multiplication of the scores for X and Y
$\sum X$ = sum of the scores for variable X (creative thinking skills)
$\sum Y$ = sum of the scores for variable Y (sustainability awareness)
$\sum X^2$ = sum of the squares of the scores for variable X
$\sum Y^2$ = sum of the squares of the scores for variable Y

The correlation coefficient (r_{xy}) ranges from -1 to +1, where values closer to +1 indicate a strong positive relationship, values closer to -1 indicate a strong negative relationship, and values closer to 0 indicate no linear relationship between the two variables.

3. RESULT AND DISCUSSION

3.1 Sustainability Awareness of Students in Classes Implementing the Free Inquiry Learning Model with Classes Following Regular Learning

Students' sustainability awareness in this study reflects their level of awareness of sustainability issues, particularly those related to environmentally friendly electrical energy sources, energy conservation, and the electrical energy crisis. This awareness was measured through four indicators: conceptual awareness, experiential awareness, engagement awareness, and adaptation awareness. The average pretest and posttest results of students' sustainability awareness in the control and experimental classes are presented in the following Table 5.

Tabel 5. Average Results of the Pretest and Posttest of Sustainability Awareness of Students in the Control Class and the Experimental Class

Test	Control	Experiment
Pretest	72	75
Posttest	74	81

Table 5 shows a comparison of the average pretest and posttest results for students' sustainability awareness in the control and experimental classes. In the control class, there was an increase in the average score from pretest to posttest, but the increase was relatively small. This indicates that conventional learning still contributed to increasing student awareness, although not optimally. Conversely, in the experimental class, which implemented the free inquiry learning model, the increase in sustainability awareness scores from pretest to posttest was more significant. The average posttest score in the experimental class was higher than in the control class, indicating that free inquiry learning was more effective in increasing student awareness of sustainability issues, particularly those related to environmentally friendly electrical energy.

The difference in improvement between the two classes indicates that active student involvement in all stages of inquiry, from problem formulation and investigation to analysis, through reflection and implementation, plays a crucial role in building deeper and more meaningful sustainability awareness. To provide a comprehensive overview of the effectiveness of the free inquiry learning model, the following presents a comparison of sustainability awareness posttest scores and their indicators between the experimental and control classes. This data demonstrates student achievement across various dimensions of sustainability awareness, including conceptual awareness, experiential awareness, engagement awareness, and adaptation awareness, allowing us to identify which dimensions are most impacted by the implementation of this learning model, as shown in Figure 1.

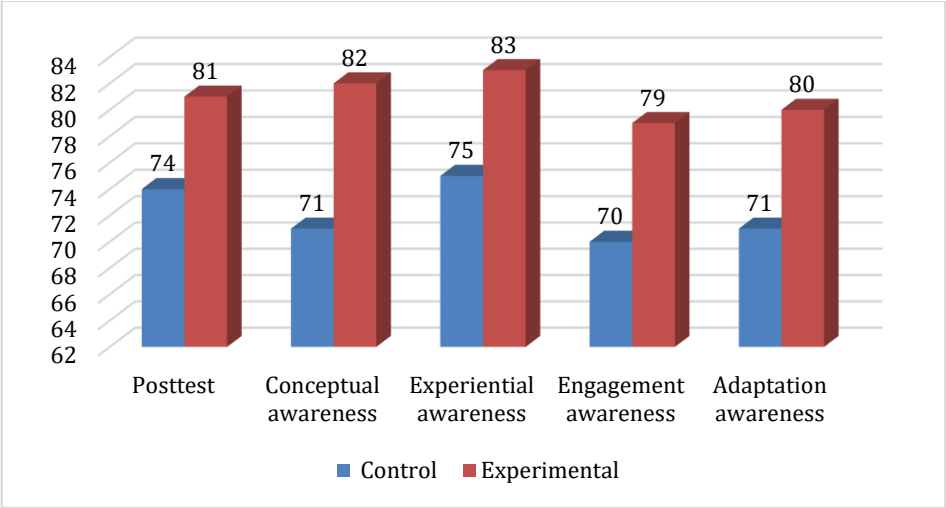

Figure 1. Average Results of the Sustainability Awareness Posttest of Students in the Control Class and the Experimental Class for Each Indicator

Based on the post-test comparison, the experimental class consistently outperformed the control class across all sustainability awareness indicators. Overall, the experimental class achieved a post-test mean of 81, while the control class reached 74, indicating a 7-point advantage and suggesting that free inquiry learning is more effective in developing students' sustainability awareness. By indicator, the experimental class showed higher scores in Conceptual Awareness (82 vs. 71), highlighting stronger conceptual understanding through in-depth exploration and reflective investigation. Experiential Awareness produced the highest scores (83 vs. 75), showing that direct involvement in authentic investigations and real-world observations strengthened both understanding and emotional sensitivity toward sustainability issues. Engagement Awareness was also higher (79 vs. 70), indicating that student autonomy increased agency and motivation to participate in sustainability efforts. Similarly, Adaptation Awareness improved (80 vs. 71), suggesting that facing uncertainty and adjusting methods during inquiry supported flexible and adaptive thinking for addressing dynamic sustainability challenges.

3.2 Students' Creative Thinking Skills in Classes Implementing the Free Inquiry Learning Model with Classes Following Regular Learning

Student creativity in learning is the ability to generate original and useful ideas, concepts, and solutions in response to problems encountered. In the context of this research, student creativity is viewed as the result of a learning process that positions students as active subjects in exploring, formulating problems, and finding solutions independently. Therefore, comparing student creativity between classes implementing the Free Inquiry learning model and classes following conventional learning is important to understand how different learning approaches influence students' creative thinking skills and idea development. To determine differences in the improvement of creative thinking skills between the experimental and control classes, an n-gain was calculated for each class. The n-gain results will indicate which class achieved greater improvement and which did not. Table 6 below presents the n-gain for each class.

Table 6. N-Gain for Creative Thinking Skills

Class	N-Gain	Criteria
Experimental	0.45	Medium
Control	0.30	Low

The results showed a significant difference in the improvement of creative thinking skills between the experimental and control classes. The experimental class, which implemented the Free Inquiry Learning model, demonstrated an N-Gain of 0.45, categorized as "Medium," while the control class, which followed regular learning, only achieved an N-Gain of 0.30, categorized as "Low," a difference of 0.15 points, or approximately 50% higher. The substantial improvement in the experimental class can be explained by the characteristics of inquiry learning, which provides students with the freedom to independently explore sustainability topics, formulate their own research questions, and develop innovative solutions. This model creates a learning environment conducive to the development of dimensions of creative thinking such as fluency, flexibility, originality, and elaboration, and allows students to develop divergent thinking skills and take intellectual risks in addressing sustainability issues.

In contrast, the regular learning implemented in the control class tended to be teacher-centered with a more conventional structure, resulting in relatively limited improvement due to the lack of space for students to freely explore ideas and develop unconventional thinking. These findings have important pedagogical implications in the context of sustainability education, demonstrating that providing autonomy and freedom to students not only increases their intrinsic motivation but also significantly develops the capacity for creative thinking and generating innovative solutions, in line with constructivist learning principles. Although the experimental class achieved the "Medium" criteria and did not reach the "High" category, this achievement still shows positive and meaningful progress, indicating that the free inquiry learning intervention has had a substantial impact, although there is still room for improvement in the implementation of this model, as shown in Figure 2.

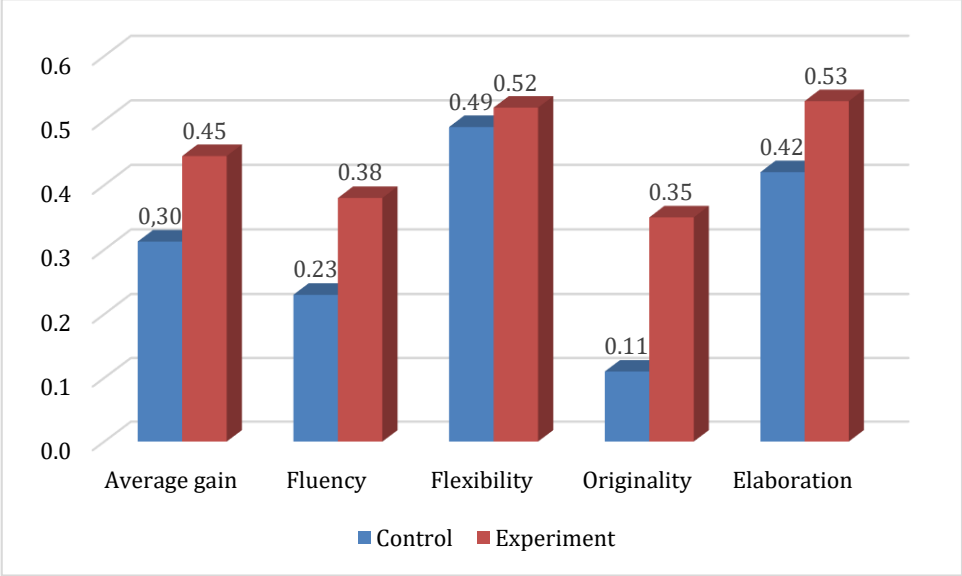

Figure 2. Normalized average gain score <g> on each indicator of creative thinking skills

Figure 2 shows that the experimental class consistently achieved greater improvement than the control class across all creative thinking indicators. Overall, the experimental class obtained an average gain of 0.45, while the control class reached 0.30, indicating a 0.15-point advantage and confirming that Free Inquiry Learning is more effective for developing creative thinking skills in a more holistic way. Across indicators, the experimental class outperformed the control class in Fluency (0.38 vs. 0.23), suggesting that the open, exploratory inquiry process stimulated students to generate more diverse ideas. Flexibility showed the highest gains in both groups (0.52 vs. 0.49), with only a small difference, implying that the complexity of sustainability-related topics naturally promotes flexible thinking, although inquiry still provides a slight advantage through independent exploration. The largest gap appeared in Originality (0.35 vs. 0.11), highlighting that free inquiry strongly supports novel idea generation by reducing reliance on conventional, teacher-directed solutions. Elaboration was also higher in the experimental class (0.53 vs. 0.42), indicating that systematic inquiry activities trained students to develop ideas in greater detail and depth.

3.3 The Relationship between Creativity and Students' Sustainability Awareness After Participating in Learning

The relationship between students' creativity and sustainability awareness was analyzed to determine the extent to which creative thinking skills are related to students' level of awareness of environmentally friendly electrical energy sources. Creativity in this study is understood as creative thinking skills, while sustainability awareness reflects students' understanding, experience, involvement, and adaptability to environmentally friendly electrical energy issues. The results of the correlation test between students' creativity and sustainability awareness after participating in the learning, as shown in Table 7.

Table 7. Results of the Correlation Test of the Relationship between Creativity and Sustainability Awareness

Variable	Creative Thinking Skills	Sustainability Awareness
Creative Thinking Skills	1	0,643
Sustainability Awareness	0,643	1
Sig. (2-tailed)	-	0,000
N	30	30

Table 7 shows the results of the Pearson correlation test between students' creative thinking skills and sustainability awareness after participating in the learning. The correlation coefficient value obtained was r = 0.643 with a significance value (Sig. 2-tailed) of 0.000 (<0.01). These results indicate a positive and significant relationship between the two variables, with a relatively strong correlation. These findings indicate that improvements in students' creative thinking skills are in line with improvements in sustainability awareness. Students who are able to think creatively tend to be better able to understand sustainability issues, relate the concept of environmentally friendly electrical energy to real-life contexts, and demonstrate greater concern for issues of environmentally friendly electrical energy sources, electricity conservation, and the electricity crisis. Therefore, the results of this correlation test confirm that developing creativity through free inquiry learning contributes to increased student sustainability awareness.

3.4 Discussion Sustainability Awareness of Students in Classes Implementing the Free Inquiry Learning Model with Classes Following Regular Learning

The results of the study indicate that the implementation of the free inquiry learning model had a significant impact on increasing students' sustainability awareness compared to regular learning. The experimental class achieved an average posttest score of 81, while the control class only achieved 74, with a difference of 7 points, indicating the effectiveness of this model in developing awareness. This finding is in line with research conducted which stated that inquiry-based learning significantly improves students' conceptual understanding and awareness of complex issues, including sustainability (Pedaste et al., 2015). Furthermore, research confirmed that students' active involvement in the authentic investigation process is key to building a deep and meaningful awareness of the environment and desires (Hofstein et al., 2011).

On the Conceptual Awareness indicator, the experimental class achieved a higher score than the control class. This significant difference indicates that the inquiry process involving in-depth exploration has a substantial impact on students' conceptual understanding of sustainability issues. Through free inquiry learning, students do not merely receive information passively but actively construct understanding through in-depth investigation, analysis, and reflection. This finding is supported, which emphasizes that inquiry-based learning facilitates deeper knowledge construction because students are actively involved in the process of discovery and problem-solving (Hmelo-Silver et al., 2007). In a local context, shows that a local context-based inquiry model effectively improves junior high school students' conceptual understanding of environmental issues in Bali, with students being able to develop an integrated understanding of the environmental, social, and economic dimensions of sustainable development (Suardana et al., 2018).

Experiential Awareness demonstrated the highest achievement among all indicators, with the experimental class achieving a score of 83 and the control class achieving 75, a difference of 8 points. This high achievement indicates that free inquiry learning successfully created an authentic and meaningful learning experience. Students were directly involved in the investigation process, collecting field data, and observing real phenomena related to sustainability issues. Experiential learning theory, emphasized that learning involving direct experience and active reflection produces deeper and more lasting understanding than learning based solely on information transmission (Kolb, 2015). Found that students involved in field investigations related to environmental issues showed significant increases in experiential awareness and empathy toward sustainability issues (Karpudewan et al., 2012). In Indonesia, Suastra et al. (2021) reported that local wisdom-based science learning involving students' direct exploration of traditional sustainable practices in Bali significantly increased students' experiential awareness, with students developing strong emotional connections to sustainability issues in their environment.

Engagement Awareness scores were higher in the experimental class than in the control class. This suggests that the inquiry process, which provides students with autonomy in designing and implementing their investigations, significantly increases their sense of agency and intrinsic motivation to engage in sustainability efforts. When students feel in control of the learning process and see the direct relevance of their investigations to real-world problems, they develop a stronger commitment to contributing to solutions. This finding aligns with the Self-Determination Theory proposed by Ryan & Deci (2020), which states that autonomy is a basic psychological need that drives intrinsic motivation and sustained engagement. Students given autonomy in environmental learning demonstrate higher levels of participation in sustainability actions in

their communities (Monroe et al., 2019). In the Indonesian educational context, found that junior high school students involved in an inquiry project based on a local environmental issue demonstrated a significant increase in engagement awareness and willingness to actively participate in environmental conservation efforts in their communities.

Adaptation Awareness scores were higher in the experimental class than in the control class. The free inquiry learning model successfully develops students' adaptive and responsive thinking skills to the dynamics of change in the context of sustainability. The inquiry process, which requires students to face uncertainty, adjust methodologies based on findings, and respond to unexpected challenges, trains them to develop a flexible and adaptive mindset (Widiyatmoko & Shimizu, 2018). According to Wolf (2021), adaptability is a key competency in sustainability education because sustainability issues are dynamic and complex, requiring a responsive approach to solutions to changing conditions. Research by Redman et al. (2021) confirms that inquiry-based learning, involving problem-solving in real-world contexts, effectively develops students' adaptive capacity. In Indonesia showed that students accustomed to inquiry learning demonstrated a better ability to adapt their knowledge to address emerging environmental issues than students solely exposed to conventional learning (Rahayu et al., 2011).

The consistent pattern across all indicators indicates that free inquiry learning not only improves one specific aspect of sustainability awareness but develops it holistically. Interestingly, experiential awareness scored highest in both groups, indicating that experiential learning, albeit with varying degrees of freedom, has a strong impact on the development of sustainability awareness. However, the experimental class still demonstrated significant superiority, particularly in conceptual awareness, which is a crucial foundation for comprehensive sustainability awareness. These findings support the argument of Bourn et al. (2022) who stated that effective sustainability education must integrate cognitive, affective, and conative dimensions through a student-centered, authentic experience-based learning approach.

Overall, the findings of this study have significant pedagogical implications for sustainability education at the junior high school level. The data suggest that to develop comprehensive sustainability awareness, encompassing conceptual, experiential, participatory, and adaptive dimensions, the learning approach must provide opportunities for students to actively engage in authentic investigations, experience firsthand the complexities of sustainability issues, and develop their sense of agency as agents of change. The free inquiry learning model, with its student-centered characteristics and independent exploration, has proven effective in facilitating the development of holistic and transformative sustainability awareness, in line with UNESCO (2020) Education for Sustainable Development (ESD) goal of developing the knowledge, skills, values, and attitudes necessary to create a sustainable future.

3.5 Discussion Students' Creative Thinking Skills in Classes Implementing the Free Inquiry Learning Model with Classes Following Regular Learning

The results of the study showed a significant difference in the improvement of creative thinking skills between the experimental and control classes. The experimental class implementing the Free Inquiry Learning model demonstrated an N-Gain of 0.45, categorized as "Medium," while the control class following regular learning only achieved an N-Gain of 0.30, categorized as "Low." This finding aligns with research by Wartono et al. (2018), which found that inquiry-based learning significantly improves students' creative thinking skills because it provides opportunities to explore problems independently. Research also confirmed that inquiry-

based learning, which provides autonomy in the investigative process, enhances divergent thinking skills and generates original ideas (Chu et al., 2021).

The free inquiry learning model creates a learning environment conducive to the development of dimensions of creative thinking such as fluency, flexibility, originality, and elaboration. According these four dimensions are fundamental components of creative thinking that need to be developed holistically in education (Guilford, 1967; Kim, 2017). Soh (2017) research supports this argument by showing that a learning environment that provides freedom to explore and encourages intellectual risk-taking significantly improves all dimensions of student creativity.

On the Fluency indicator, the experimental class achieved a gain score of 0.38 compared to the control class, which only scored 0.23. This indicates that the open and exploratory inquiry process provides a stronger stimulus for students to generate diverse ideas related to sustainability issues. This finding is supported by Hargrove (2013), who found that students in inquiry-based learning demonstrated higher fluency because they were accustomed to exploring various possible solutions without being limited by predetermined answers. Showed that Indonesian students accustomed to teacher-centered learning showed limitations in generating diverse ideas due to a lack of opportunities for free and exploratory thinking (Suardana et al., 2018).

Flexibility demonstrated relatively high achievement in both groups, with the experimental class achieving a gain score of 0.52 and the control class achieving 0.49. Flexibility was the only indicator that reached the "medium-high" category in both groups, indicating that discussions about sustainability, with their inherent complexity and interdisciplinarity, naturally encourage students to develop flexible thinking, regardless of the learning model used. This finding aligns, who stated that complex and multidimensional sustainability issues inherently require flexible thinking and the ability to view problems from multiple perspectives (Wiek et al., 2011). Found that students engaged in inquiry-based learning on socio-scientific issues demonstrated significant increases in flexibility due to having to consider multiple stakeholder perspectives (Wiyarsi et al., 2025).

Originality showed the most dramatic difference, with the experimental class achieving a gain score of 0.35 compared to the control class. This finding is highly significant because it reveals that regular learning is very limited in facilitating the development of original thinking. Explain that originality requires the courage to take intellectual risks and step out of cognitive comfort zones, which can only develop in a learning environment that supports free exploration (Runco & Jaeger, 2012). Confirmed that Indonesian students exposed to inquiry learning demonstrated a dramatic increase in originality compared to conventional learning because they were trained to boldly propose hypotheses and develop unconventional solutions (Safkolam et al., 2024).

Elaboration showed that the experimental class achieved a gain score of 0.53, the highest among all indicators, while the control class achieved 0.42. This indicates that the in-depth and systematic inquiry process trains students not only to generate ideas but also to develop them comprehensively. Elaboration is a critical skill that distinguishes raw creative ideas from implementable innovative solutions (Thornhill-miller et al., 2025). Students involved in long-term inquiry projects demonstrated superior elaboration skills because they had to develop ideas through various stages of refinement and improvement (Stresle et al., 2023).

Although the experimental class achieved the "Medium" criteria and did not yet reach the "High" category, this achievement still shows positive and meaningful progress. Suggest that developing higher-order thinking skills such as creativity requires sufficient time and consistent practice, so long-term intervention with appropriate scaffolding support can increase achievement to the "High" category (Nussbaum et al., 2021). Recommend that the implementation

of the inquiry model needs to be supported by continuous teacher professional development, the development of contextual teaching materials, and an assessment system aligned with the goals of developing creativity to maximize the potential of this learning model (Attard et al., 2021).

3.6 Discussion The Relationship between Creativity and Students' Sustainability Awareness After Participating in Learning

The results of the correlation test showed a positive and significant relationship between creative thinking skills and students' sustainability awareness after participating in the course, with a correlation coefficient of $r = 0.643$ and a significance level of 0.000 ($p < 0.01$). This correlation value indicates a relatively strong relationship between the two variables, meaning that improvements in creative thinking skills align with improvements in students' sustainability awareness. This finding aligns which states that creativity and environmental awareness are closely related because both involve the ability to view problems from different perspectives, identify innovative solutions, and adapt thinking to changing contexts (Sternberg, 2021). Furthermore, revealed that creative thinking skills are a fundamental competency in sustainability education because they enable individuals to envision alternative, more sustainable futures and develop transformative solutions to complex environmental challenges (Kwauk & Casey, 2021).

The positive relationship between creativity and sustainability awareness can be explained through several cognitive and affective mechanisms. This suggests that students with strong creative thinking skills tend to have a higher ability to understand the complexity of sustainability issues. The flexibility dimension of creative thinking allows students to view electrical energy issues from multiple perspectives, including environmental, economic, and social dimensions, thus developing a more holistic understanding of sustainability. According to Wiek & Redman (2022), systems thinking and future thinking are key competencies in sustainability that are closely related to the ability to think flexibly and creatively.

4. CONCLUSION

This study concluded that the Free Inquiry Learning model was more effective than conventional learning in enhancing students' sustainability awareness and creative thinking skills, as indicated by a statistically significant difference in posttest outcomes between the experimental and control groups ($p < 0.05$) along with a meaningful effect size. In addition, the experimental class demonstrated a higher improvement than the control class on both variables, as reflected in the N-gain scores (experimental class = 0.45; control class = 0.30), reinforcing that the observed effectiveness was supported not only by significance testing but also by the magnitude of the improvement.. Students in the experimental class showed higher improvements in all dimensions of sustainability awareness, particularly in the conceptual and experiential aspects, indicating a deeper and more meaningful learning experience. The model also resulted in greater improvements in creative thinking skills, particularly in originality, highlighting its potential to foster innovative and independent thinking. Furthermore, a strong positive relationship was found between creative thinking skills and sustainability awareness, indicating that developing creativity supports students' ability to understand and respond to sustainability issues. Overall, Free Inquiry Learning offers a promising student-centered approach to enhancing essential competencies in science education. However, this study has limitations, including the use of a relatively small sample from a single school and the short duration of the intervention, which may limit the generalizability of the findings to broader contexts. Future studies should

replicate this research with a larger and multi school sample and implement Free Inquiry Learning over a longer period with a delayed posttest to strengthen generalizability and examine the durability of gains in sustainability awareness and creative thinking.

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