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Research article

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Analysis of students' creative thinking skills in ecology: Digital mind maps supporting sustainable development goals

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ABSTRACT

Creative thinking skills, one of the four components of 21st-century skills, are essential for generating ideas, solving problems, and supporting quality education in line with the Sustainable Development Goals (SDGs), particularly SDG 4 on quality education. However, the 2022 PISA results show that Indonesia is among the 14 countries with the lowest creative thinking skills. To address this issue, innovative learning tools such as digital mind maps are proposed as a solution. Research indicates that digital concept maps, which have been explored as an innovative learning method, can effectively support the development of creative thinking skills. This study aims to assess the creative thinking skills of biology students in an ecology course, with a focus on the topic of biological control. A descriptive quantitative approach was used, involving 21 biology students as participants. A creative thinking skills test covering aspects of fluency, flexibility, originality, and elaboration was administered to the participants. Data were analyzed using a rubric-based scoring system. The results showed that 57.14% of students had moderate creativity, 28.57% were less creative, and 14.28% were creative. The elaboration indicator received the highest score (69.04%), while flexibility received the lowest score (35.71%). Specifically, the results of the fluency and originality tests were also included in the analysis, highlighting students' strengths and weaknesses in various aspects of creative thinking. To enhance creative thinking skills in ecology courses focused on SDGs, the use of digital mind maps is recommended. These concept maps can help organize concepts, stimulate divergent thinking, and encourage students' creativity by providing a clear structure for visualizing and exploring ideas.

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INTRODUCTION

High-quality education is a crucial component in achieving the Sustainable Development Goals (Oktavianatun & Nugraheni, 2024). One of the relevant ones is Goal 4, which emphasizes quality

education by providing quality, relevant, and inclusive education for every individual (Chankseliani & McCowan, 2021). This goal is relevant to education in the 21st century which is required to develop the learning process and a series of skills in individuals, one of which is creativity (Joynes et al., 2019). Creativity in education is shown by the skills to generate new ideas (Muliardi, 2023) and solve various social and environmental problems (Yang et al., 2022). Therefore, the current education system needs to teach students how to think creatively.

On the other hand, the results of the Programme for International Student Assessment (PISA) 2022 have identified Indonesia as one of the 14 countries with the lowest creative thinking performance. PISA assesses creative thinking abilities across six proficiency levels, ranging from level 1 (the lowest) to level 6 (the highest). At level 1, students demonstrate basic skills such as recognizing simple ideas and providing basic responses to familiar problems. At level 2, students can generate basic visual representations or brief descriptions but lack the capacity for complex analysis. Levels 3 to 4 represent intermediate abilities where students can propose creative ideas and make simple associations. At levels 5 and 6, which represent the highest proficiency, students are capable of generating original, diverse ideas for complex tasks, formulating unconventional associations, analyzing problems from multiple perspectives, and integrating various elements in innovative ways. According to PISA data, only 4.8% of Indonesian students achieved levels 5 or 6, indicating that only a small proportion of students are able to demonstrate high-level creative thinking abilities. Meanwhile, a significant portion (68.8%) of Indonesian students are positioned at level 2 or below, reflecting a predominant inability to go beyond basic expressions and to generate novel or diverse solutions for problems. This suggests that the majority of Indonesian students are only capable of producing simple responses, such as visual representations and brief descriptions, without offering substantial creative differentiation from existing solutions to social issues (OECD, 2024). Several studies in biology education have raised concerns about students' underdeveloped creative thinking skills. Sugiyanto et al., (2018) highlighted that flexibility and originality were particularly weak among students. These findings are further supported by Nasution et al., (2023), who documented students' challenges with divergent thinking in biology lessons, particularly when it comes to applying creativity to solve problems in the subject.

In college education, ecology is an interesting subject that helps develop a comprehensive understanding of environmental sustainability and ecological problem solving. However, a preliminary study at a local university in Palangkaraya shows that students aspiring to become biology teachers still lack knowledge related to ecology and have low creative thinking skills (Jumrodah et al., 2021). According to Rinjani et al., (2022), many students have difficulty grasping the basic principles of ecology, which is attributed to the use of traditional teaching methods that are less effective in promoting active learning and conceptual understanding. Conventional learning methods, which rely heavily on lectures and rote memorization, do not encourage students to construct their own knowledge, making it difficult for them to fully engage with and understand the material. As a result, there is a need for innovative teaching methods that can foster a more interactive and student-centered learning environment (Purwanto et al., 2020).
One such innovative approach is the use of digital mind maps, which are interactive tools that help students organize and visualize complex concepts. Digital mind maps allow students to create a visual representation of ecological relationships, facilitating a deeper understanding of the subject matter. These tools encourage active learning, promote critical thinking, and provide students with the opportunity to engage in more meaningful connections between ideas. By using digital mind maps, students can better organize their thoughts, identify key concepts, and develop a more comprehensive understanding of ecological systems and environmental issues.

Education is starting to apply technology to create innovative learning and move away from conventional learning (Sekarsari & Aznam, 2019; Thomhill-Miller et al., 2023, Nasihah et al., 2024). Among the various innovative learning methods, digital mind maps have gained popularity as an effective tool for organizing and visually representing concepts, ideas, and information in the form of branched diagrams (Abd Karim & Mustapha, 2022). Digital mind maps are one of the many tools available that can enhance the learning process. The use of digital mind maps offers several advantages. Research shows that digital mind maps are effective in stimulating creative thinking skills. Su et al., (2021) shows that the preparation of digital mind maps builds a digital world for individuals to create tasks by providing stimulation of creative thinking skills. As a visual-based tool, digital mind maps promote divergent thinking, helping to develop creative ideas, stimulate individual thought processes, and maintain creative thinking potential, all of which support sustainability and innovation (Dong et al., 2021). Furthermore, digital mind maps facilitate group thinking, encourage the generation of diverse ideas, control communication within groups (Sun et al., 2022), and support the application of technology in learning. They also promote collaboration among students and have been shown to improve academic performance (Machano & Carvalho, 2020).

Previous research has demonstrated the potential of digital mind maps in enhancing creative thinking skills at various levels of education, including primary, secondary, and tertiary levels (Debbag et al., 2021; Putra et al., 2024; Zhao et al., 2022). These studies highlight the effectiveness of digital mind maps in promoting divergent thinking, improving idea generation, and fostering creativity among students. However, the implementation of digital mind maps in Ecology learning in higher education remains limited. While digital mind maps have been widely explored in other subjects, their application in specific disciplines such as Ecology, particularly in the context of higher education, has not been extensively studied. This study aims to analyze the creative thinking skills of biology students in Ecology courses, particularly in Biological Control materials related to the theory of the formation of the solar system and Earth, atmospheric composition, ocean composition, and Gaia hypothesis. The results are expected to provide insights into the characteristics and needs of biology students in learning ecology in higher education. The novelty of this research are depth analysis of students' creative thinking skills profiles and recommendations for implementing digital mind maps in Ecology learning at the college level. These contributions support the realization of quality education relevant to global challenges. Through these findings, this study aims to promote technology.

RESEARCH METHODS

This research employs a quantitative descriptive method to analyze the creative thinking skills of Biology students in Ecology courses, specifically in Biological Control material. The study focuses on students' creative thinking skills test. Figure 1 presents a systematic research flow chart to illustrate the research process.

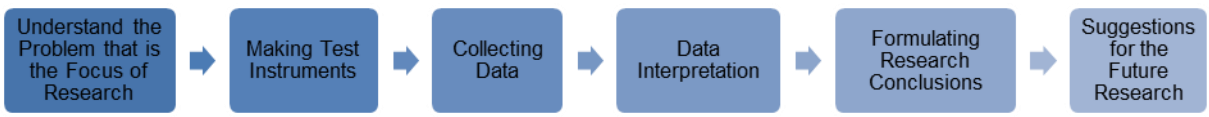

Figure 1. Flow of Research Methods (Dawana et al., 2025)

Understand the Problem that is the Focus of Research: The problem that is the focus of this research revolves around understanding how Biology students in Ecology courses engage with and

develop their creative thinking skills. Creative thinking is crucial in the study of Ecology as it helps students understand the process of the formation of the earth, the solar system, and the Gaia hypothesis. In this study, the focus is on requiring students to generate creative solutions for living organisms and their environment to maintain the conditions of the earth that allow life. The research seeks to assess the students' ability to think creatively in the context of biological control by evaluating their fluency, flexibility, originality, and elaboration in response to multiple-choice questions.

Making Test Instruments: To assess the students' creative thinking skills, we developed a creative thinking test based on fluency, flexibility, originality, and elaboration. The test instruments comprise 10 multiple-choice questions, each designed to evaluate the students' abilities across these four creative thinking indicators. The questions focus on concepts related to biological control, including topics such as the Gaia Hypothesis, Earth formation, atmospheric composition, and ocean composition. Each question was designed to test: a) Fluency: ability to generate many relevant ideas or answers and a smooth flow of thought; b) Flexibility: ability to generate diverse ideas and be able to change ways or approaches, and different directions of thought; c) Originality: ability to generate distinctive and rarely considered responses that distinctly differ from conventional thinking; d) Elaboration: developing, adding to, enriching an idea and elaborating on the details (Munandar, 2014).

The questions were carefully reviewed for clarity and relevance to the study's objective. To ensure the validity and reliability of the instrument, expert validators assessed the test, which was based on a 1-4 Likert scale to rate each criterion (Sugiyono, 2015). The test is considered valid (Table 1) if the mode of the assessment for each criterion is ≥ 3, and the instrument is deemed reliable if the reliability percentage is ≥ 75%.

Table 1. Criteria for Assessing the Validity of Creative Thinking Skills Test Instruments

Modus	Category
4	Very Valid
3	Valid
2	Less Valid
1	Invalid

Furthermore, the reliability test was carried out on the creative thinking skills test instrument and categorized based on Table 2 to determine the stability of the results of a measurement, using the formula:

$$Percentage\ of\ agreement\ = 100\% \times (1 - \frac{A-B}{A+B}) \quad (1)$$

Description:
A = Highest frequency of aspects assessed by validators
B = Lowest frequency of aspects assessed by validators

Table 2. Interpretation of Reliability Percentage

Reliability Percentage (%)	Criteria
10 - 20	Very Low
21 - 40	Low
41 - 60	Medium
61 - 80	High
81 - 100	Very High

An instrument is considered reliable if it achieves a reliability percentage ≥ 75%, falling within the high or very high category (Arikunto, 2017). The analysis of creative thinking skills test results employs descriptive quantitative methods. Each test item is scored on a 0-1 scale and categorized according to creative thinking skills indicators using the formula:

$$\text{Score of each indicator} = \frac{\text{Score obtained}}{\text{Maximum score per indicator}} \times 100\% \quad (2)$$

Data collection was conducted through administering the creative thinking skills test to a sample of 21 students from advanced classes who were enrolled in an ecology course at a state university in Surabaya. These students were selected using purposive sampling, which targets individuals with specific characteristics such as in-depth comprehension of material, high curiosity, and diligence in academic tasks.

Data Analysis and Interpretation: Following data collection, the results were analyzed using descriptive quantitative methods. The scores for each student were calculated and categorized according to predefined criteria based on creative thinking skills:

Table 3. Categories of Creative Thinking Skills

Score Range	Creative Thinking Skills Category
0 – 20	Not Creative
21 – 40	Less Creative
41 - 60	Moderately Creative
61 - 80	Creative
81 - 100	Very Creative

These categories helped to identify how students performed in terms of their creative thinking abilities and the relationship between their performance and their understanding of biological control.

The research conclusions will summarize the students' performance in creative thinking based on their test results, focusing on the four key indicators: fluency, flexibility, originality, and elaboration. This evaluation will provide a clear understanding of how well students applied creative thinking skills in the context of Biological Control. Additionally, the study will assess whether factors such as academic engagement, curiosity, and in-depth comprehension of the material significantly influence creative thinking abilities. The findings will also offer practical implications for teaching methods, particularly in Ecology courses, by identifying effective strategies to enhance students' creativity in solving environmental problems. These insights aim to guide educators in fostering creative thinking within the classroom.

Building on the findings of this study, future research could explore several directions. Longitudinal studies could track the development of students' creative thinking skills over time, providing deeper insights into how these abilities evolve across different courses or academic years. Comparative studies could also examine creativity across disciplines, such as between Ecology, Chemistry, or Physics, to identify potential discipline-specific differences in creative thinking.

FINDING AND DISCUSSION

This study aims to assess students' understanding and level of creative thinking in biology, particularly in ecological concepts related to biological control material, including the theory of earth

formation, atmospheric composition, ocean composition, and the Gaia hypothesis. To ensure the quality of our assessment, we first conducted validity and reliability tests on the creative thinking ability test instrument, which was developed based on four key indicators: fluency, flexibility, originality, and elaboration.

The test instrument underwent rigorous evaluation by three expert validators consisting of lecturers specializing in ecology and general biology. These experts examined the instrument's content validity, ensuring that the test items adequately measured the intended creative thinking constructs. Following the validation process, we conducted reliability tests to establish the consistency of the measurement tool. Only after confirming the instrument's validity and reliability did we proceed with data collection and analysis of students' creative thinking abilities.

Table 4. Validity and Reliability Test Results for the Creative Thinking Skills Measurement Instrument

Aspects Assessed	Validation (Modus)	Category	Reliability (%)	Category
Content Criteria				
Suitability with question indicators	4	Very Valid	98%	Very High
Suitability of questions with fluency indicators	4	Very Valid		
Suitability of questions with flexibility indicators	4	Very Valid		
Suitability of questions with originality indicators	4	Very Valid		
Suitability of questions with elaboration indicators	4	Very Valid		
Suitability of questions with biological control material	4	Very Valid		
Correctness of the answer key	3	Valid		
Language Criteria				
Easy to understand	4	Very Valid	100%	Very High
Accordance with Indonesian language rules	4	Very Valid		
Grammar does not cause double meanings	4	Very Valid		
Presentation Criteria				
Clarity of instructions for working on questions	4	Very Valid	100%	Very High
Clarity of question assessment criteria	4	Very Valid		

Based on the data presented in Table 4, the instrument for measuring creative thinking skills was deemed both valid and reliable. Regarding content validity, all evaluated aspects (fluency, flexibility, originality, and the biological control material) received a mode score of 4, which falls under the very valid category. This suggests a strong consensus among experts that the instrument aligns with the theoretical constructs it is intended to measure. Furthermore, the language and presentation aspects also obtained a mode score of 4, similarly categorized as very valid, indicating that the instrument demonstrates clarity in its language, procedural instructions, and assessment components. Reliability, assessed through internal consistency, yielded scores of 98% for content and 100% for language and presentation. According to Riduwan (2015) values exceeding 90% are categorized as very high, thereby confirming the instrument's strong reliability. In light of these findings, the instrument is considered suitable for application in educational research contexts.

The study assessed creative thinking skills among 21 high-achieving students using Biological Control material as the assessment framework. Based on an analysis of student profiles, it was found that there were significant differences in creative thinking skills among students. Students with a strong background in conceptual understanding tended to be better able to relate and explain the relationships between complex concepts, such as the theory of the formation of the solar system and the Gaia

hypothesis. Conversely, students who are more dominant in visual learning styles find it easier to organize and represent these concepts.

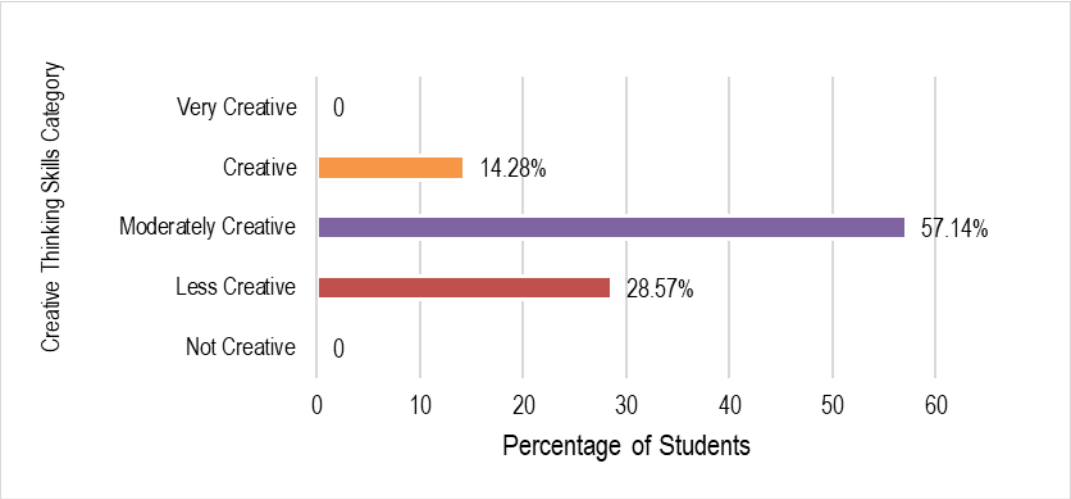

Figure 2. Distribution of Student Creative Thinking Skills Test Results

Figure 2 shows the results of the creative thinking skills test on cell biology material. Based on the scores obtained, 12 students had moderate creativity levels, 6 students had low creativity levels, and 3 students showed high creativity levels. No students were categorized as "very creative" or "not creative." Figure 3 shows the creative thinking skills scores based on indicators.

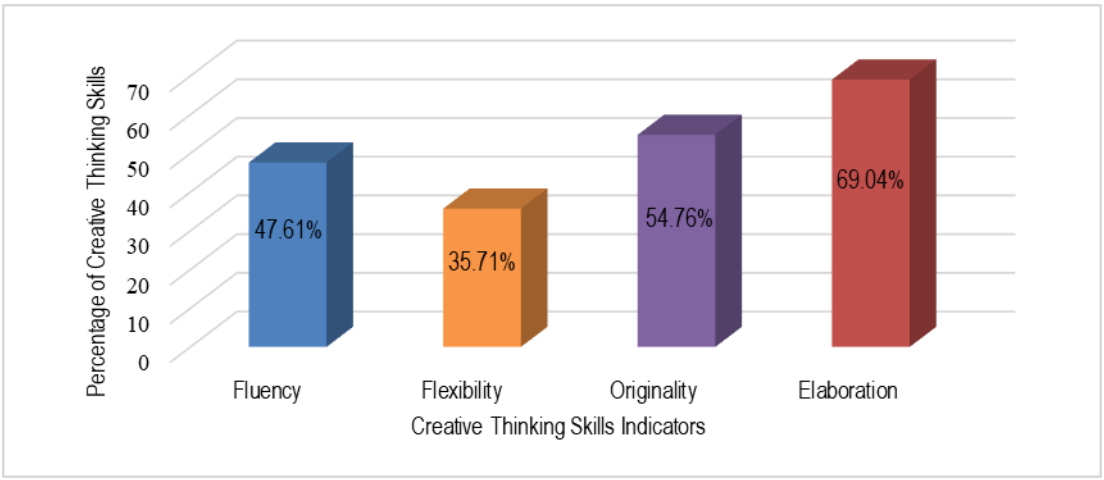

Figure 3. Student Creative Thinking Skills Test Results based on Indicators

The percentage of creative thinking scores for each indicator varies significantly, as illustrated in Figure 3. The order of creative thinking indicators from lowest to highest is flexibility, fluency, originality, and elaboration. This pattern indicates that students are quite capable of understanding the concepts of cell biology to provide detailed responses and generate original ideas. However, their ability to generate a variety of ideas is not yet fully developed. Several factors can influence this, including the learning approach used (Tamsah et al., 2021) interest in the material, as well as skills in connecting various information (Thomhill-Miller et al., 2023) to understand problems from different perspectives and formulating ideas or solutions (Treffinger et al., 2023) that are relevant to the ecological context. The level of students' creative thinking skills for each indicator is presented in Table 5.

Table 5. Level Of Creative Thinking Skills Of Students on Each Indicator

Creative Thinking Skills Category	Creative Thiking Skills Indicators			
	Fluency	Flexibility	Originality	Elaboration
Not Creative	0	7	3	2
Less Creative	7	0	0	0
Moderately Creative	9	13	13	9
Creative	5	0	0	0
Very Creative	0	1	5	10

Based on the levels of students' creative thinking across each indicator in Table 5, the majority of students demonstrated creative thinking abilities within the Moderately Creative category, particularly in the indicators of fluency, flexibility, and originality. This finding suggests that most students were able to generate a substantial number of diverse and original ideas. Interestingly, within the Very Creative category, the elaboration indicator ranked highest, followed by originality. These results suggest that students have a strong potential to develop ideas in a detailed and authentic manner. Conversely, some students still fell into the "Not Creative" and "Less Creative" categories, especially in the indicators of flexibility and fluency. This highlights the need to strengthen learning strategies that train students' fluency of thought and their ability to produce ideas from multiple perspectives. Overall, the distribution of creative thinking levels reveals a dominant tendency toward the moderately creative level among students.

The study's results revealed that the fluency indicator achieved a percentage of 47.61%, which is classified as moderate. This percentage indicates that 5 students could understand the question and be able to provide relevant answers to conceptual problems in ecology, such as questions related to the theory of solar system formation, the origin of the universe, and the composition of the atmospheric layers. However, other students still did not answer the questions at all. In the context of multiple-choice questions, adaptability is reflected in students' ability to select the most appropriate answer from several alternatives based on the diversity of ideas they possess (Suherman & Vidákovich, 2022). However, several students either left questions unanswered or selected incorrect responses, indicating that their ability to explore a range of possible answers remains suboptimal. This suggests that students are not yet fully capable of generating multiple ideas or alternative solutions to the problems presented in the questions, which are necessary to build interrelated conceptual connections (Sigit et al., 2023).

The flexibility indicator had a less creative category of 35.71%. This result showed that 7 students might have difficulty providing answers, solutions, and alternatives to answer questions or solve problems. Flexibility in thinking is very important in the field of ecology, especially when analyzing problems such as disturbances in ecosystem components, climate change, and pollution that change the balance of living systems. Flexibility in students indicated the weak ability of students to see and consider a condition or problem from various points of view (Dilekçi & Karatay, 2023). In addition, research by Ali et al., (2023) showed that students still had difficulty adapting to changes or new conditions, so they could not see many possibilities in learning and daily life.

The originality indicator places students in the moderate creativity category of 54.76%. This result suggests that 18 students possess a reasonably good ability to formulate responses in the form of ideas and solutions within the context of ecology and sustainable development. Originality appears through new perspectives or new explanations. This may be due to learning activities that train students to connect concepts holistically. According to Huang et al., (2021) originality is demonstrated through students' confidence in presenting answers based on their own thinking. The students are capable of original thinking when they are interested in the issues and materials being explored. The ability to generate

innovative solutions is essential for addressing increasingly complex environmental problems (Wang & Li, 2024). including the balance of terrestrial, marine, and atmospheric ecosystems, as well as emerging future challenges. Furthermore, the higher performance on the originality indicator compared to fluency and flexibility may be attributed to students' deeper engagement and comprehension of the subject matter. This suggests that students who perceive the material and associated issues as relevant and engaging are more likely to be motivated to think creatively and produce unique solutions (Sholikhah et al., 2024).

The elaboration indicator falls within the creative category of 69.04%. This result indicates that 10 students possess a reasonably strong theoretical understanding, enabling them to produce detailed and comprehensive responses. The high percentage on this indicator may be attributed to students' ability to systematically develop ideas and solutions with depth and clarity. Such elaboration skills are likely the result of thorough engagement with the material and opportunities to think critically and analyze content in a structured manner (Qiara, 2024). These results may also be influenced by tasks that require explanation and justification, which encourage students to elaborate more extensively. Additionally, the use of visual-based digital tools may help students organize and integrate meaningful ideas, while sufficient time for reflection supports deeper understanding. To maintain or further enhance this ability, it is essential to promote active participation in the learning process, and to allocate sufficient time for them to reflect on and elaborate on their ideas (Ali et al., 2023). Another contributing factor to the development of elaboration skills is the provision of intellectually challenging tasks or problems, which can stimulate students to think creatively and generate more detailed solutions (Li & Tu, 2024). Elaboration skills are important in planning and formulating strategies to achieve environmental issues (Saleh & Brem, 2023).

In the context of SDG 4 relating to quality education. Higher creativity is needed to create innovative solutions to the challenges faced in sustainable development (Chang et al., 2022). Enhancing creative thinking skills among university students, particularly in ecological studies, can contribute to achieving these goals. A deeper understanding and the ability to think flexibly will support the creation of more diverse and solutive ideas in responding to ecological issues (Leasa et al., 2021). This will also enable students to engage more actively in sustainable development initiatives that focus on nature conservation (Mokski et al., 2023), efficient resource utilization, and carbon emission reduction (Mariani et al., 2022).

The data from this study revealed weaknesses in several creative thinking aspects, with the following results: Fluency at 47.61%, Flexibility at 35.71%, Originality at 54.76%, and Elaboration at 69.04%. These results indicate that students showed varying levels of creative thinking skills, with Elaboration scoring the highest, followed by Originality, Fluency, and Flexibility. The use of digital mind maps serves as a tool to enhance students' creative thinking skills. The digital mind map method offers image and symbol-based visualization (Debbag et al., 2021) which helps in organizing knowledge and material concepts, as well as creating clear connections between ideas and information through a combination of text and images (Bhattacharya & Mohalik, 2020). Thus, it allows students to organize information visually, collaborate (Debbag et al., 2021), and improve understanding to solve problems in the surrounding environment (Afifah et al., 2023). Table 6 shows several studies demonstrating the relationship between digital mind maps and creative thinking skills that support SDGs.

Table 6 presents the top five relevant studies on the implementation of digital mind maps in education to foster creative thinking skills and support the Sustainable Development Goals (SDGs). Findings from these studies demonstrate that digital mind maps are effective in creating interactive and visually engaging learning environments, facilitating the understanding of scientific concepts, and enhancing students' creativity (Hidayati et al., 2022; Kachak & Kachak, 2022). Su et al., (2021) emphasized that digital mind mapping enables students to design learning tasks based on their thought

processes, thereby encouraging the development of creative thinking. Sun et al., (2022) further reported that computer-based mind maps enhance group creativity in science learning by fostering discussion and idea elaboration. In addition, Dong et al., (2021) highlighted the role of mind mapping as a divergent thinking tool that supports sustainable innovation through visual representation. Research by Debbag et al., (2021) and Theodorio et al., (2024) also reinforced the notion that digital mind maps not only improve conceptual understanding in science but also stimulate technology-driven creativity. Therefore, digital mind mapping emerges as an effective pedagogical strategy for cultivating students' creativity, collaboration, and innovation, while contributing to the achievement of educational SDGs, particularly those related to quality education (SDG 4) and industry, innovation, and infrastructure (SDG 9).

Table 6. Top 5 Relevant Paper Showed Digital Mind Map in Education Supporting Creative Thinking Skills and SDGs

Author (s)	Citation;SJR	Result
Su et al., (2021)	25; 1,79 (Q1)	Digital mind mapping creates a digital environment where children can design, develop, and work on tasks based on their thinking, thereby improving creative thinking skills.
Sun et al., (2022)	59; 3,65 (Q1)	The use of computer-based mind maps helps students enhance group creativity in science education. Students retain, elaborate on, and evaluate ideas, stimulating new discussions in scientific creativity tasks.
Dong et al., (2021)	23; 0,67 (Q1)	Mind mapping is a visual diagram-based divergent thinking tool that is easy to use, helps in developing creative ideas, stimulates student thinking, and assists students in sustainable and innovative creativity.
Hidayati et al., (2024)	27; 0,44 (Q2)	Digital mind maps create a learning environment that supports students in better understanding, extracting, and organizing scientific information in a visual format, thereby improving memory, concept mastery, and science problem solving.
Abd Karim & Mustapha, (2022)	9; 0,23 (Q3)	Digital mind maps are positively perceived by students as they facilitate the understanding, extraction, and organization of scientific information. Furthermore, this method enhances technology-based creativity and innovation.

Based on these findings, digital mind mapping is a supporting creative thinking skills and the achievement of SDGs. Several studies have shown that the digital mind map method helps individuals understand and organize scientific information visually while improving creativity, collaboration, and digital literacy. Our research supports this, as digital mind mapping in our study helped create an interactive learning environment and facilitated a digital space that stimulated creative ideas among students. Furthermore, our findings align with previous research, showing that digital mind maps enabled students to generate creative ideas or solutions and significantly improved their creative thinking skills (Tang et al., 2022). The relationship between digital mind map components and indicators of creative thinking skills is described by Aprilia & Mitarlis (2023). In the fluency indicator, individuals can determine keywords as themes, sub-themes, branches, and sub-branches correctly. For the flexibility indicator, individuals can add pictures or symbols to most branches that represent each keyword. Regarding the elaboration indicator, individuals can describe and assign each keyword with branches to existing keywords. For the originality indicator, individuals can create mind maps as products of their own imagination, combining writing and images, as shown in Figure 4.

Digital mind mapping also plays an important role in group learning. In our study, the use of computer-based mind mapping facilitated collaboration, stimulated diverse ideas, and organized communication between groups, which is consistent with the findings of (Sun et al., 2022). It encouraged divergent thinking and more innovative creativity, as observed in our participants, aligning with Dong et

al., 2021) research on the role of digital mind mapping in fostering creative thinking. Additionally, digital mind maps helped students make decisions when there were differences of opinion, enabling them to reach a common goal (Hidayati et al., 2020). These findings reflect how digital mind mapping supports group decision-making and creative collaboration in our research. The advantages of digital mind maps are further supported by research from Abd Karim & Mustapha (2022) which shows that digital mind mapping receives positive responses from students because it facilitates the organization of scientific information and increases technology-based creativity. In our study, students also responded positively to digital mind mapping, especially ini simplifying the organization of complex scientific concepts.

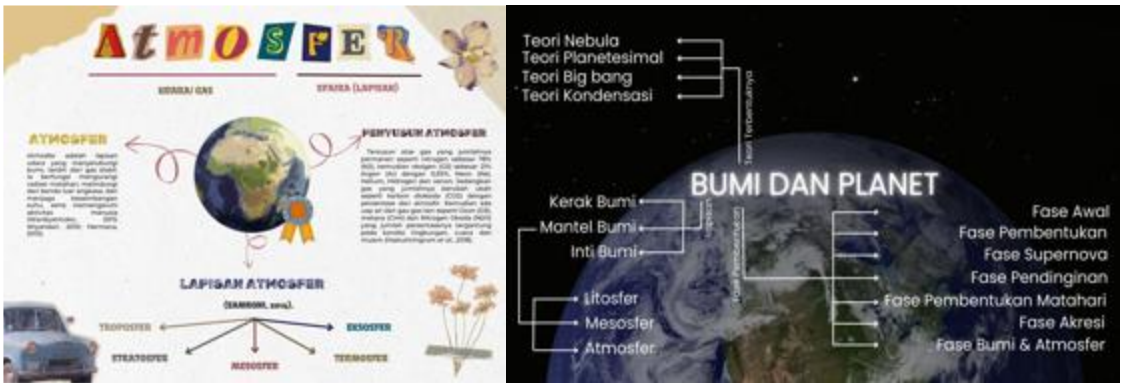

Figure 4. Test Results Of Students' Practice In Making Digital Mind Maps

In addition, as stated by Ng & Fergusson (2019) digital mind maps have been shown to help deepen understanding in science. This was evident in our study, where students demonstrated a better grasp of the material, especially in areas they initially found challenging. The ability of digital mind mapping to help students who struggled with learning and show improved comprehension is also reflected in our findings, as we observed significant improvements in their understanding and problem-solving abilities (Alt et al., 2023; Hazaymeh & Alomery, 2022). The use of digital mind maps not only supports creative thinking skills but also improves overall learning effectiveness (Diniyyah et al., 2022). This method provided students with the freedom to explore various ideas and find potential solutions relevant to SDG 4. We believe this is due to the visual and collaborative nature of digital mind maps, which allows students to engage more actively with the material and with each other, fostering a more dynamic learning environment.

This study provides insight into the profile of students' creative thinking skills in learning biological control materials that are relevant to efforts to develop creative skills in the era of technology-based education. The majority of students being in the moderately creative to less creative category indicates that their potential has not been fully developed. This can be attributed to several factors, such as limited exposure to creative thinking exercises, the nature of the subject matter, and perhaps a lack of engagement with innovative learning tools. These students may have difficulty applying abstract concepts in creative ways due to a lack of experience in thinking divergently or organizing ideas in novel ways. This underdevelopment of potential emphasizes the need for an educational approach that encourages more dynamic, interactive learning experiences. Optimizing the learning process with a more interactive and technology-based approach, such as the use of digital mind maps, is essential. Tools such as MindMeister or Canva can help students organize ideas and enhance creativity (Sun et al., 2022).

In addition, the findings of this study emphasize the critical role of enhancing creative thinking skills in the context of SDGs through quality education. Better creative thinking skills will help students in

designing innovative solutions to complex environmental problems and creating more effective strategies for achieving SDGs (Leong et al., 2024). Therefore, the development of these skills has a major role in preparing students for global challenges through an approach based on creative thinking (Dilekçi & Karatay, 2023). This research also offers a deeper understanding of the linkages between creative thinking skills and solutions to ecological problems and sustainable development goals. One novelty in this research is the assessment of biology students' creative thinking skills in the context of biological control materials. However, this study has limitations, namely a small sample, so the results may not be fully representative. Research with larger samples is needed for more accurate results.

CONCLUSION

This study aimed to assess the creative thinking skills of biology students in Ecology courses, specifically in the context of Biological Control materials, and to explore how digital mind maps can support the development of these skills. The findings reveal that students' creative thinking skills require significant improvement. A majority of students fall into the moderately creative (57.14%) and less creative (28.57%) categories, with the highest score observed in the elaboration indicator (69.04%) and the lowest in flexibility (35.71%). This indicates that while students demonstrate the ability to provide detailed and comprehensive answers, they face challenges in thinking from diverse perspectives and generating flexible solutions.The study highlights that digital mind maps can play a crucial role in enhancing students' creative thinking skills, especially by helping them organize information more effectively, engage in active learning, and develop their creativity through collaboration and the generation of diverse ideas and solutions. The use of digital mind maps can address the challenges observed in the flexibility and fluency indicators, offering a more dynamic way to approach learning and problem-solving. For future research, it is recommended to use larger sample sizes to verify the effectiveness of digital mind maps in improving creative thinking, particularly in the flexibility and fluency indicators. Researchers should also explore the potential of digital mind maps in other subject areas and with different student populations to assess their broader applicability. In addition, further studies could focus on refining the instruments used to measure creative thinking skills and adapting them to better capture the nuances of creativity in various contexts. By doing so, future researchers can provide deeper insights into how digital tools can support sustainable development goals through enhanced education.

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