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Teachers' Strategies to Foster Students' Creative Thinking Skills in Biology Learning: A Systematic Literature Review

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Abstract

Teachers play a pivotal role in designing innovative biology learning strategies that cultivate students' creative thinking, a core 21st century skill. This ability is essential for generating novel ideas, solving complex problems, and making interdisciplinary connections. By integrating real world scenarios and inquiry based approaches, teachers can further enhance students' engagement and creative capacity. This study aims to conduct a systematic literature review to identify and analyze the pedagogical strategies employed by teachers to foster students' creative thinking skills in the context of biology learning. Employing the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) methods, a comprehensive literature search was executed using the Google scholar and Scopus database, with a publication scope from 2016 to 2025. The keywords used were *("Teacher Strategy") AND ("Creative thinking" OR "Creativity") AND ("Biology Learning" OR "Biology Education")*. From an initial identification of 371 articles, 25 met the predefined inclusion criteria and were subsequently subjected to an in-depth content analysis. The review's findings indicate that a range of effective strategies were implemented by teachers, including Problem Based learning (PBL), Project Based Learning (PjBL), flipped classroom, blended-learning, the RQA model, Reading-concept mapping (Recamp) integrated with Group Investigation (GI), Creative Responsibility Based Learning (CRBL), and approaches grounded in ethnoscience and the Habits of Minds (HoM) profile. The most frequently utilized instructional media were mind maps, 3D learning media (3Ds Max), and inquiry based worksheets. This review recommends that pedagogical competence among biology teachers be enhanced through ongoing professional development and the integration of creative strategies into the curriculum. This will empower them to design innovative learning models that effectively foster students' creative thinking skills, addressing the demands of 21st century education.

Keywords: biology learning; creative thinking; novel idea; solving problem; teaching strategies

INTRODUCTION

Global developments in science and technology in the 21st century require students to master various global competencies, one of which is creative thinking skills. Creative thinking is a highly essential 21st century skill. This skill is crucial for students to generate original ideas, solve complex problems, and connect various concepts in learning (Amriko *et al.*, 2022; Sari *et al*., 2024). This skill encourages innovation and problem solving abilities, enabling students to continuously develop and adapt in an increasingly complex world (Wardhany & Muhid, 2024; Ramadhan *et al*., 2025). Creative thinking skills involve the ability to think in new, original, and flexible ways to generate novel ideas, while also being multifaceted as they encompass both innovative aspects that generate new ideas and adaptive aspects that modify existing ones (Nkosi & Mtshali, 2024; Samaniego *et al*., 2024). Furthermore, creative thinking also encompasses the capacity to evaluate the quality of the ideas produced.

Creative thinking skills, demonstrated when students effectively address problems in ways that are both accurate and divergent from conventional approaches, encompass four key dimensions which are fluency, flexibility, originality, and elaboration (Alabbasi *et al*. 2022; Al-Qadri *et al*., 2025). Fostering these four dimensions is crucial for equipping students with the tools to approach complex challenges creatively within an educational context. This emphasis on creativity has increasingly become a primary focus in contemporary educational policies, as it is a crucial factor in enhancing student learning outcomes (Fitriyyah *et al*., 2024; Setiamurti & Kurniawati, 2024). Consequently, there is an urgent need for educators to integrate teaching methods and strategies that explicitly aim to develop these abilities in students. These approaches not only nurture students' creative potential but also prepare them to navigate future challenges with greater adaptability and innovation.

In the context of biology learning, creative thinking skills are indispensable for students. This is because biology learning not only necessitates a profound comprehension of core concepts but also their application in authentic contexts. Therefore, conventional instructional methods focused solely on content delivery are inadequate for preparing students to tackle complex biological problems. Consequently, an ideal biology pedagogical approach should systematically cultivate students' creative thinking abilities to foster inquiry, generate innovative ideas, design novel solutions for scientific challenges, and effectively connect abstract biological principles with real world phenomena (Fahmi & Jumadi, 2023; Khayitov & Kholmurodova, 2023). Extensive scholarly literature consistently demonstrates that these skills are pivotal for enhancing both student engagement and academic achievement (Julianto *et al*., 2022; Sucilestari *et al*., 2023).

Various studies have unveiled the profile of creative thinking skills among students in Indonesia within science education, including biology. Evidently, the majority of Indonesian students' creative thinking skills remain relatively low. Programme for International Student Assessment (PISA) test results indicate that the creative thinking domain of Indonesian students falls below the average of other OECD member countries, such as Singapore, Malaysia, Brunei Darussalam, and Malaysia (OECD, 2024). According to the PISA test results, only 31% of Indonesian students attained at least a baseline proficiency in creative thinking, while the other 69% performed below this level. A similar finding was revealed that students encounter difficulties in demonstrating creativity during science learning (Wati *et al*. 2021; Cahyaningsih *et al*., 2023). Therefore**,** further research is imperative to enhance students' creative thinking skills.

To address the previously identified challenges, teachers play a crucial role in developing innovative learning strategies. Efforts to enhance creative thinking skills in biology learning can be implemented by teachers through various innovative approaches, models, and instructional strategies (Laurenza *et al*., 2023; Yonanda *et al*., 2023). Therefore, this research focuses on diverse innovative strategies applied by teachers in teaching and learning process to empower students' creative thinking skills. Through a systematic literature review, this study aims to conduct a systematic literature review to identify and analyze the pedagogical strategies employed by teachers to foster students' creative thinking skills in the context of biology learning. Consequently, the findings of this study are expected to serve as a valuable reference for teachers and stakeholders in Indonesia in selecting appropriate strategies to improve students' creative thinking skills.

METHOD

This research employs a Systematic Literature Review (SLR) methodology. SLR is a systematic research method utilized to identify, evaluate, and synthesize existing literature to address specific research questions (Ritterbusch & Teichmann, 2023; Kasim *et al*., 2024). It also provides a structured and rigorous approach to identify, evaluate, and synthesize existing research. Since the study aims to investigate teacher strategies in enhancing students' creative thinking within biology learning. SLR ensures that the literature collected is relevant, comprehensive, and transparent. The primary focus of this study is to examine teacher strategies in empowering students' creative thinking skills within biology learning. The guidelines used for literature search and analysis are based on PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis). According to Liberati *et al.* (2009), PRISMA consists of four stages, namely identification, screening, eligibility, and included. The first stage, identification, involved searching for articles as primary literature through the Google Scholar and Scopus databases. The keywords used were *("Teacher Strategy") AND ("Creative thinking" OR "Creativity") AND ("Biology Learning" OR "Biology Education")*. At this stage, a total of 371 articles were identified for eligibility assessment. The second stage, screening, involved analyzing the identified articles by evaluating the relevance of their titles and abstracts based on predefined criteria. Subsequently, the articles were categorized according to the inclusion and exclusion criteria, which are detailed in Table 1. Adherence to these criteria was a prerequisite for the inclusion of articles as primary literature in this study. As a result, 76 articles that met the inclusion criteria were selected for further analysis in the next stage, while 295 articles that did not meet the criteria were excluded.

Table 1. Inclusion and exclusion criteria for the research

No.	Inclusion Criteria	Exclusion Criteria
1	Articles were selected from reputable national and international journals.	Articles were not from reputable national and international journals.
2	The subjects in the research were students or university students.	The subjects in the research were not students or university students.
3	Articles were published within the range of 2016-2025.	Articles were published before 2016.
4	Articles were accessible in full-text.	Articles were not accessible in full-text.
5	Articles belonged to the research field of Biology education.	Articles did not belong to the research field of Biology education.

The third stage, eligibility, involved a thorough analysis of the full content of articles that had passed the screening phase to determine their relevance and alignment with the research theme. This stage was essential to ensure that only studies with substantial contributions to the topic were included. Based on this evaluation, 25 articles were found to be eligible and were selected as primary data sources for the study. Finally, the fourth stage, inclusion, consisted of synthesizing and analyzing these 25 eligible articles in depth. The insights obtained from this synthesis were then used to formulate the research findings and draw conclusions. This step ensured that the final analysis was based on high quality, relevant, and thematically consistent literature. The overall process of article selection and analysis is illustrated in Figure 1.

The collected articles that met the established criteria for this research analysis were subsequently exported in RIS format and analyzed using VOSviewer software. VOSviewer was utilized to generate three distinct types of bibliometric maps: namely network visualization, overlay visualization, and network based density visualization among the existing items. These visualizations provided both structural and temporal insights into the existing literature. These results were employed to map research trends, identify research gaps, and understand the evolution of research concerning the development of creative thinking skills within the context of biology learning. This visual mapping approach enabled a comprehensive and systematic overview of how scholarly attention has shifted and expanded over time.

The use of VOSviewer in this context also facilitated the identification of key authors, influential publications, and frequently occurring keywords within the dataset, allowing for a deeper understanding of the intellectual structure of the field. By examining the co-occurrence of terms and the strength of citation linkages, the analysis shed light on the most prominent themes and the interconnections between different research areas. This bibliometric approach not only highlighted dominant research clusters but also revealed emerging areas that warrant further exploration, thereby offering valuable direction for future studies in the realm of creative thinking development in biology education. Moreover, the visualization of these patterns supported a data-driven interpretation of how concepts such as innovation, problem solving, and critical thinking have been integrated into biology learning. Through this lens, researchers and educators can better grasp how pedagogical strategies have evolved and how they align with the competencies required in 21st century education.

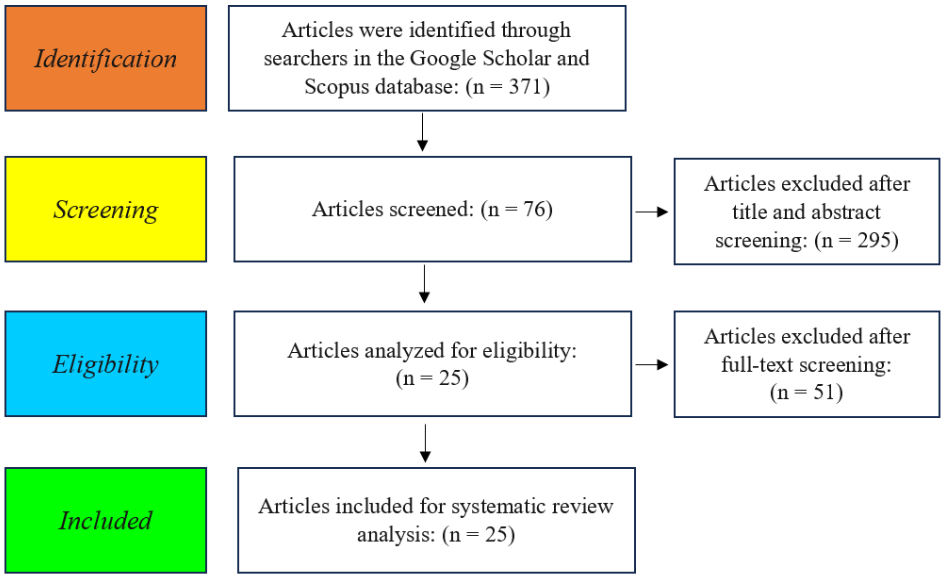

Figure 1. PRISMA flow chart

RESULT AND DISCUSSION

The SLR review reveals key research and publication trends concerning teacher strategies in fostering students' creative thinking skills over the past decade. By analyzing 25 articles that met the inclusion criteria, this study provides a comprehensive overview of the scholarly output in this field. The analysis findings indicate that the volume of research published annually lacks uniformity. The distribution exhibits significant variation, indicating a fluctuating academic focus on the topic. This pattern underscores the need for more sustained and consistent research to provide a more stable foundation for future pedagogical strategies. The specific trends from this research are presented in detail in Figure 2.

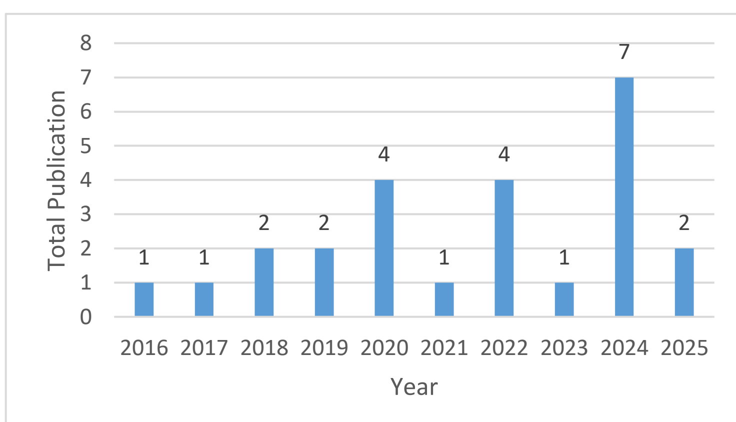

Figure 2. Research and publication trends in the last decade

An analysis of publication trends reveals a fluctuating pattern from 2016 to 2025. The number of publications gradually increased from one publication in 2016 and 2017 to four in 2020. Following a decline in 2021, the number rose again to four in 2022. The peak was observed in 2024, with a total of seven publications, before decreasing to two in 2025. This pattern indicates that the issue of developing creative thinking skills in biology education has received growing attention, particularly in the post pandemic period. According to Zulhafizh & Permatasari (2020) there emerged a need for teachers to develop digital and PjBL innovations post COVID 19 pandemic. Antika *et al*. (2022) and Cheung *et al*. (2023) also explain that the shift in learning modes from conventional to online or blended learning in the 21st century necessitates teachers to design creative biology learning, such as developing interactive digital media to foster students' creativity. The distribution of publications presented in Figure 3 indicates a significant dominance by Indonesia, which accounts for a total of 20 publications. A considerable number of researchers in Indonesia appear to be motivated to explore and evaluate the effectiveness of various instructional models that emphasize the development of students' creative thinking skills. In contrast, other countries such as China contributed only two publications, while Beirut, Nigeria, and Rwanda each recorded just one publication. This reveals a substantial disparity in the level of interest and research focus across countries regarding the topic under investigation.

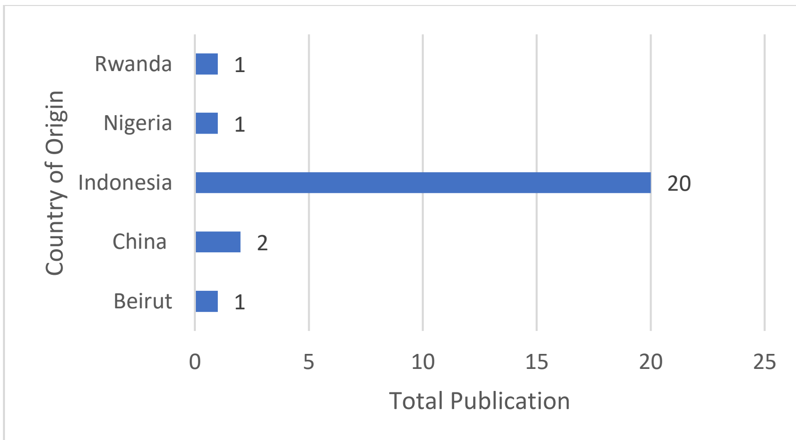

Figure 3. Distribution of research and publications by country of origin

Figure 3 also underscores that research on teacher strategies for developing creative thinking skills in biology education is a highly significant issue in Indonesia. This aligns with the implementation of the Merdeka Curriculum, which emphasizes the enhancement of students' creativity and critical thinking. The Merdeka Curriculum requires teachers not only to deliver content through conventional instruction but also to serve as facilitators in fostering students' higher-order thinking skills. This focus reflects a paradigm shift in education toward a more adaptive approach in response to 21st century demands. As highlighted by Meisuri *et al*. (2025), creative thinking skills are essential for preparing students to navigate the complexities of the modern world. Consequently, a growing body of research has emerged to evaluate teaching strategies that support the achievement of these educational goals. Furthermore, It emphasizes that creative thinking skills are highly relevant within contextual and applied biology learning (Safitri *et al*., 2024; Sari *et al*., 2025) . These studies reflect a collective awareness in Indonesia of the urgent need for educational transformation. This represents a positive indication of efforts to improve the overall quality of education at the national level. Based on educational level, the distribution of publications indicates a dominance at the university level (52%) and senior high school level (40%), while junior high school and elementary school levels each contribute only 4%, as illustrated in Figure 4. This distribution highlights a notable imbalance, where research on the development of creative thinking skills in biology learning is predominantly concentrated on adolescent and adult learners. In contrast, the elementary level remains significantly underrepresented, indicating a need for more extensive and focused research at the foundational stages of education in the future.

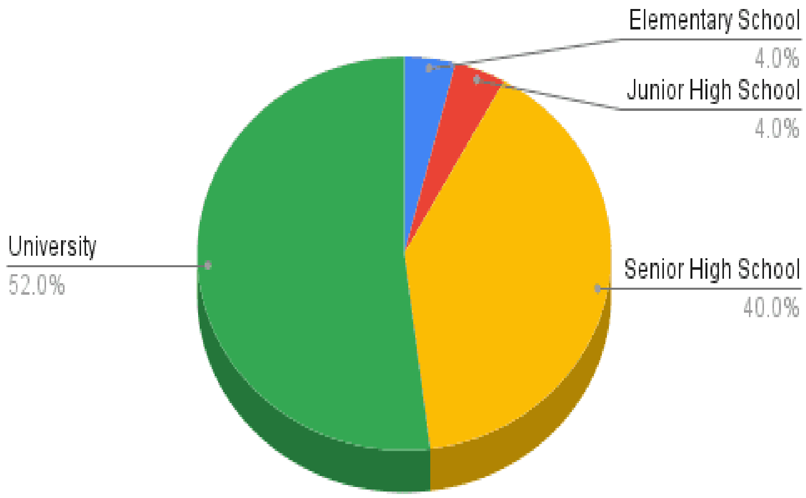

Figure 4. Distribution of research and publications by educational level

Figure 4 demonstrates that the development of creative thinking skills in biology learning is more extensively researched in the context of adolescent and adult learners. This aligns with Piaget's theory of cognitive development, which posits that students at these ages are in the formal operational stage. At this stage, learners possess abstract thought and hypothetical reasoning, enabling sophisticated creative problem-solving. This is crucial for honing creativity as it allows students to explore, imagine, and innovate effectively (Rabindran & Dharsini, 2020; Khayitov & Kholmurodova, 2023). As such, the predominant research focus on older learners is not only practical but also theoretically justified. Nevertheless, this emphasis may inadvertently overlook the potential to nurture creative thinking from an early educational stage. Encouraging research across all developmental levels may support a more comprehensive and inclusive approach to educational reform.

Instructional strategies are a primary determinant of teacher success in empowering students' creative thinking skills. A systematic literature review reveals a wide variety of teacher implemented strategies designed to foster these skills specifically within the context of Biology learning, as presented in Supplementary File 1. The findings highlight a diverse set of instructional approaches that have been applied to stimulate students' creative thinking, supported by empirical findings indicating their effectiveness (Hidayati *et al*., 2019; Rahardjanto *et al*., 2019; Angraini *et al*., 2022). This effectiveness is attributed to the strong philosophical and theoretical foundations underlying these strategies, which enable educators to engage students in learning processes that cultivate their creative and innovative thinking abilities.

As indicated in Supplementary File 1, PjBL and PBL are among the most frequently utilized instructional strategies. Teachers apply these methods in both conventional formats and through innovative modifications to enhance their effectiveness (Saepul *et al*., 2023). Both models emphasize active, student-centered learning, yet differ in their focus and implementation. PBL involves students in solving complex real-world problems and encouraging them to conduct research and apply knowledge to find creative and innovative solutions (Yustina *et al*., 2020; Putriyani *et al*., 2023; Xiong & Ren, 2024). Conversely, PjBL focuses on students completing projects that require planning, execution, and presentation, often culminating in a tangible product (Hussein *et al*., 2024; Muliadi *et al*., 2025). In their implementation, both models can be combined with various biology learning media to further enhance creative thinking skills, such as digital mind maps and 3D animations and other like the use of virtual laboratories (Suprapto *et al*., 2018; Hidayati & Idris, 2020; Uwitonze & Nizeyimana, 2022). Furthermore, in terms of learning content, these models can also be linked with ethnoscience contexts prevalent in the students' local areas (Herak *et al*., 2025; Muliadi *et al*., 2025).

Other strategies also employed by teachers include the implementation of blended learning and flipped classroom models. Both models are highly suitable for the current digital era as they integrate technology to support the learning process (Baytiyeh, 2017; Yustina *et al*., 2020). Blended learning, which combines online and offline instruction, allows students to connect various information sources, build knowledge networks, and develop creativity through digital exploration and direct collaboration (Kumar *et al*., 2021; Sharma *et al*., 2022; Putri *et al*., 2023). Meanwhile, the flipped classroom provides flexibility for students to independently study material before class meetings. This can be integrated with the use of digital technologies such as websites or other platforms to accommodate independent learning activities outside the classroom, thereby dedicating face to face time for exploration, discussion, and idea generation, which significantly supports the growth of creativity (Rodríguez *et al*., 2019; Ridlo *et al*., 2022).

Furthermore, other strategies implemented by teachers include learning models such as Recamp integrated with GI, CRBL, OIDDE, and HoM profile based learning. These models are also quite effective in fostering students' creative thinking skills in biology learning. Recamp integrated with GI creates a more meaningful learning environment centered on students' deep understanding, thereby enhancing creativity and collaboration among students. Meanwhile, CRBL strengthens creative thinking skills by combining autonomy, accountability, and collaborative exploration, enabling students to habitually generate, test, and refine innovative ideas (Zainuddin *et al*., 2020; Safitri *et al*., 2024). Subsequently, the OIDDE learning model cultivates creative thinking skills by guiding students through a structured cycle, starting from problem exploration and idea generation, through critical evaluation, and culminating in real-world application of solutions. This model integrates divergent thinking (generating various alternative ideas) and convergent thinking (selecting the best idea), making it effective in developing creativity within collaborative and inquiry-based learning contexts. These principles bear similarities to the HoM profile-based learning model (Hashim et al., 2018; Husamah *et al*., 2018). The HoM Profile fosters creativity by accustoming students to flexible, reflective, courageous, and open-minded thinking towards new ideas. Through these thinking habits, students are not only capable of generating diverse ideas (divergent thinking) but also able to select, develop, and implement their best ideas (convergent thinking) (Hidayati & Idris, 2020). For example, by engaging with novel biological materials such as land snail mucus or exploring under-studied forest ecosystems such as the Dramaga Protected Forest region, students develop open minded thinking, generate multiple ideas and then converge on the most promising solution (Al Khairina *et al*., 2025; Pertiwi *et al*., 2025).

The scientific mapping results generated by VOSviewer software provide an overview of the research direction and focus within biology learning, specifically concerning the development of creative thinking skills. This mapping comprises three primary visualization types: network, overlay, and density visualizations. Firstly, the network visualization presented in Figure 5 illustrates the interconnections among key concepts evident in publications related to the research topic. As depicted in Figure 5, the terms creative thinking, PjBL, and creativity emerge as central nodes, indicated by their larger circle sizes, signifying their dominant frequency in the literature. The strength of the links demonstrates a close interrelationship among these concepts and other terms such as critical thinking, biology, and active learning. This underscores that research in biology learning consistently positions creative thinking abilities and PjBL approaches as foundational for the development of innovative instruction. This aligns with various studies affirming that project based learning effectively enhances creative thinking skills by engaging students in collaborative, real world projects that cultivate critical thinking and problem solving abilities (Chen *et al*., 2022; Hao *et al*., 2024). Consequently, this network map reaffirms the central role of creative thinking skills within integrated Biology learning. Subsequently, the overlay visualization presented in Figure 6 illustrates the temporal development of research, providing insights into the chronological progression of publications on this topic.

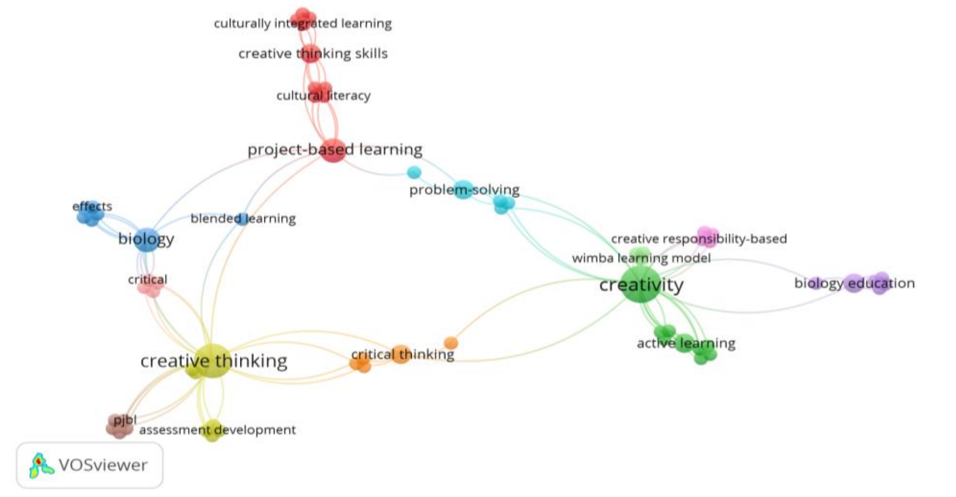

Figure 5. Network visualization

In the overlay visualization Figure 6, the color spectrum indicates the temporal evolution of frequently used terms in research. Terms such as biology and creative thinking appeared earlier (marked with bluish hues, approximately 2018–2020), whereas terms like culturally integrated learning and creative thinking skills are more recent (marked with yellowish green hues, approximately 2023–2025). This shift signifies a reorientation in research focus, moving from general creative thinking skill development towards the integration of creative thinking skills with cultural contexts and PjBL. This trend suggests that current research increasingly emphasizes the relevance of socio cultural context in fostering students' creativity particularly within biology learning innovations (Honra & Monterola, 2024; Beknazarova, 2025). Finally, the density visualization presented in Figure 7 elucidates the primary themes associated with creative thinking skills in biology learning, providing a comprehensive overview of the key focus areas in this field.

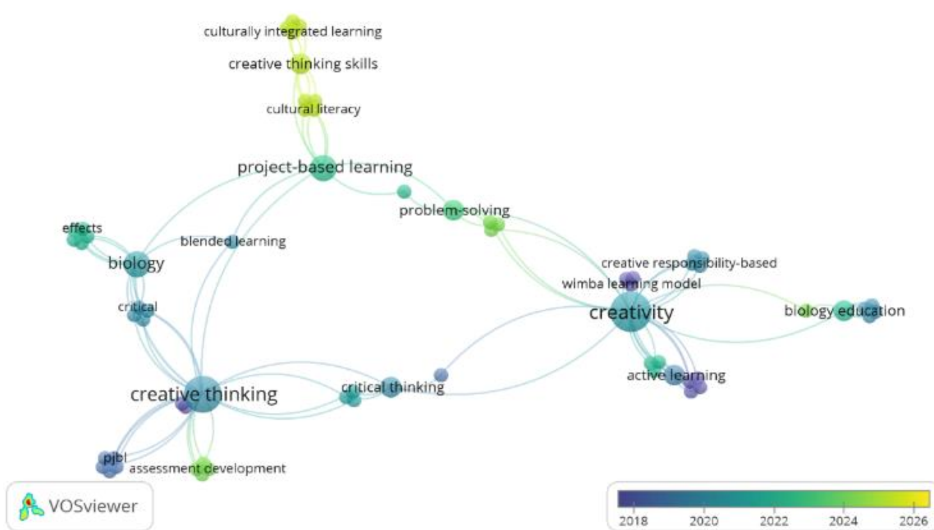

Figure 6. Overlay visualization

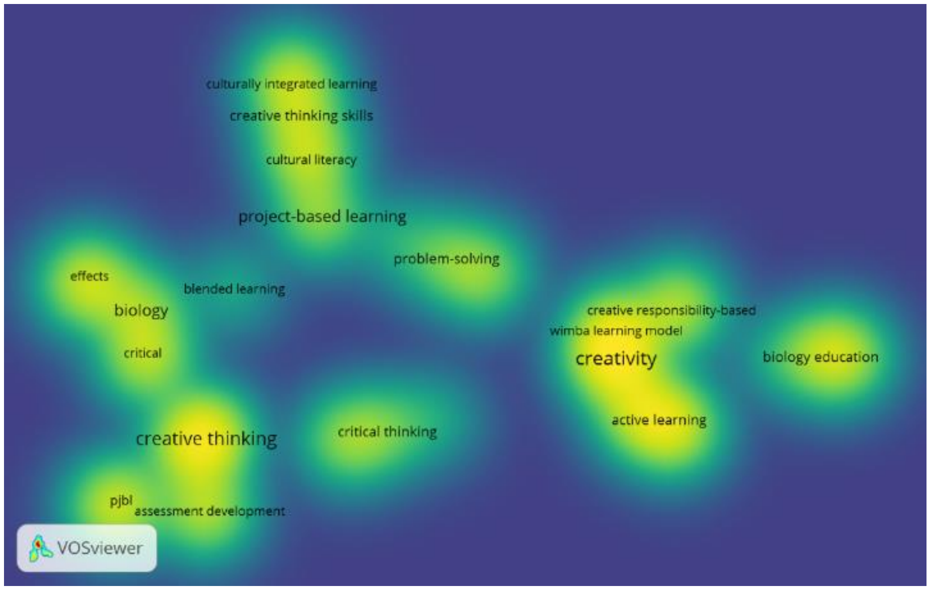

Figure 7. Density visualization

The density visualization results in Figure 7 highlight the research intensity in specific areas. The terms creative thinking and creativity appear as areas with the brightest color intensity (yellow), indicating a dominant research focus. Meanwhile, other terms such as PjBL, critical thinking, and biology education also show a relatively high density, although not as prominent as the central nodes. This visualization demonstrates that the existing literature consistently links biology learning with the development of creativity and critical thinking through active and PjBL learning approaches. These patterns suggest that while creativity remains a central focus, there is growing interest in integrating diverse pedagogical strategies and interdisciplinary approaches to enhance both critical and creative thinking in biology education. Thus, this density map affirms a strong concentration of research on the development of creative and innovative thinking skills within the context of biology learning. Future research should expand investigations to underrepresented educational levels, particularly primary education, and explore cross-cultural comparative studies to strengthen the generalizability of findings at a national and international scale. Moreover, longitudinal and experimental designs are recommended to examine the sustained impact of these pedagogical strategies on students' creative thinking development in biology learning.

CONCLUSION

This systematic review identifies and analyzes a range of pedagogical strategies employed by teachers to foster students' creative thinking skills in biology learning. The findings reveal that various instructional models have been effectively implemented, including PjBL, PBL, blended learning, flipped classroom, Recamp integrated with GI, CRBL, OIDDE, and HoM profile based learning. These strategies are often integrated with supportive media such as digital mind maps, inquiry level based worksheets, and interactive 3D animations to further enhance creative thinking outcomes. In addition, the review shows that research in this field has undergone dynamic development over the last decade, with diverse contributions across countries and educational levels. Indonesia emerges as a dominant contributor to publications, while most studies are concentrated at the high school and university levels. Overall, the findings provide valuable insights for educators and researchers worldwide, offering evidence based references for designing innovative biology teaching strategies that align with the demands of 21st century education.

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