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Creative Thinking Skills in Science Education: A PRISMA-based Systematic Literature Review

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Abstract

Creative thinking skills are widely discussed in science education research, yet their conceptualization, pedagogical treatment, and measurement still show methodological diversity. This study systematically synthesizes recent studies on creative thinking skills in science education, focusing on learning strategies, learning media, and assessment instruments. A systematic literature review (SLR) using the PRISMA framework was conducted on 23 Scopus-indexed publications from 2019–2022. The results indicate that most studies position creative thinking skills as a learning outcome embedded in instructional innovation rather than as an independent construct. STEM-oriented learning, technology-assisted learning, problem-based learning, and inquiry-based learning are the most frequently explored contexts. However, the literature is dominated by qualitative and descriptive research, with limited comparative or experimental evidence. Variation in definitions and measurements also persists, often overlapping with related constructs such as critical thinking. Overall, this review reveals rich pedagogical innovation but limited methodological consistency and analytical rigor. The findings highlight the need for clearer construct boundaries, more robust research designs, and better alignment between learning strategies and validated instruments. This review contributes to mapping research patterns and identifying gaps for future empirical studies in creative thinking skills in science education.

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INTRODUCTION

Creative thinking skills have become a primary area of study in science education, particularly in response to the demand for mastery of higher-order thinking competencies required in the 21st century (OECD, 2019; Puspita, Retno, et al., 2025; Puspita, Solviana, et al., 2025; Trilling & Fadel, 2009). Within the widely adopted 4C framework (critical thinking, creativity, communication, and collaboration), creative thinking is increasingly recognized as a key competency that supports innovation, problem-solving, and scientific inquiry processes (Kennedy & Sundberg, 2020; Weng et al., 2022). In the context of science education, creative thinking is not limited to artistic expression, but includes the capacity to generate hypotheses, design experiments, interpret data innovatively, and generate various solutions to open-ended problems (Beghetto & Kaufman, 2014; Hu & Adey, 2002)

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Creativity, as a complex and multidimensional construct, has been a subject of extensive research and theoretical exploration. Initial frameworks, such as Guilford's Structure of Intellect model, emphasized the cognitive aspects of creativity, proposing that it comprises various cognitive abilities that can be systematically measured (Guilford, 1950; Kim, 2006; Suherman & Vidákovich, 2022). Guilford's approach laid the groundwork for future researchers to delve deeper into the nuances of creative thinking. For example, Torrance expanded this understanding by identifying four critical dimensions of creativity: fluency, flexibility, originality, and elaboration. These dimensions serve not only as indicators of creative potential but also as vital components within educational contexts, guiding assessments and pedagogical strategies aimed at enhancing student creativity (Farida et al., 2023; Supriadi et al., 2025). Building on Torrance's work, broader models like Rhodes' "4Ps of creativity" provided a more holistic view, emphasizing the interplay between the person, process, product, and press within the creative domain (Lucifora et al., 2025). This approach acknowledges that individual characteristics, cognitive processes, and contextual factors all significantly influence creative output (Kaufman, 2009; Suherman et al., 2025).

In contemporary educational research, the Torrance Tests of Creative Thinking (TTCT) have emerged as a standard method for assessing creative thinking. These tests are recognized for their ability to capture the essence of creative thought and behavior, while studies examining their predictive validity have reinforced their significance as measures of both individual and group creativity (Runco et al., 2010; Torrance, 1988). Moreover, recent investigations underscore the influence of pedagogical strategies and learning environments, which can enhance or inhibit students' creative capacities. For instance, integrating digital technologies and encouraging divergent thinking within curricula have proven effective in fostering creativity among students (Lu, 2025). Taken together, these frameworks establish creative thinking not only as a cognitive skill but also as a complex interaction of personal, contextual, and motivational factors, an understanding that is essential when examining its role in educational settings.

Science education inherently provides fertile ground for fostering creative thinking skills, as it emphasizes inquiry, experimentation, and the resolution of open-ended problems. This environment extends beyond traditional notions of creativity associated with the arts, instead encompassing essential scientific practices such as hypothesis formulation, experimental design, and innovative data interpretation (Barrow, 2010; Xu & Fan, 2025). According to Barrow (2010) the incorporation of creativity within K-12 science instruction cultivates an inquisitive mindset, allowing students to face scientific challenges with novel solutions. This pedagogical approach underscores the notion that creativity is integral to scientific inquiry, facilitating a deeper engagement with the material.

Several previous studies have also emphasized the pedagogical relationship between creative thinking skills and conceptual understanding in science learning. Conceptual understanding serves as a cognitive foundation that enables students to apply knowledge flexibly, transform ideas, and engage in problem-solving creatively (Chi & Wylie, 2014; Duit & Treagust, 2012) Therefore, contemporary learning approaches such as STEM/STEAM education, inquiry-based learning, problem-based learning, and technology-assisted learning are often claimed to be capable of developing creative thinking skills through the presentation of authentic and complex learning contexts (Bybee, 2013; Kelley & Knowles, 2016; Putranta, 2019). Nonetheless, the way creative thinking skills are conceptualized and treated as a learning construct shows considerable variation across studies (Sternberg, 2018).

Although the number of studies on creative thinking in science education continues to increase, the existing literature still shows conceptual and methodological fragmentation. In many studies, creative thinking skills are often discussed together with or used interchangeably with other constructs such as critical thinking, representational abilities, or higher-order thinking skills, without clear conceptual boundaries (Facione, 2011; Kozma & Russell, 2005). While the overlap among these constructs is acknowledged in cognitive and educational theory, the lack of clear conceptual boundaries makes cross-study comparisons difficult and hinders the accumulation of coherent evidence(OECD, 2019). In the context of systematic literature reviews, this ambiguity becomes a serious issue because the synthesis process heavily relies on clear definitions of constructs and analytical focus (Snyder, 2019).

Moreover, previous reviews in this field tend to use narrative or scoping review approaches, which provide a general overview of creativity or 21st-century skills, but have not systematically analyzed how creative thinking skills are operationalized, taught, and specifically measured in science education (Ramírez-Montoya et al., 2022). As a result, understanding of dominant research themes and trends, methodological patterns, learning strategies, media, as well as instruments for measuring creative thinking skills remains partial and fragmented (Linnenluecke et al., 2020). This gap becomes even more apparent in recent literature, where the rapid development of technology-based and STEM studies has not been fully matched by systematic and evidence-based analytical synthesis efforts (Kelley & Knowles, 2016).

Based on these issues, the PRISMA framework was used in this study's Systematic Literature Review (SLR) to synthesize research on creative thinking skills in science education published between 2020 and 2022 (Page et al., 2021). It is simpler to analyze the primary literature that has to be extracted and examined to respond to inquiries about media, tactics, and tools when the SPIDER-type literature research is used. Rather than advocating a specific pedagogical approach, this review aims to map research patterns, clarify how creative thinking skills are conceptualized and studied, and identify methodological and theoretical gaps in the existing literature. By explicitly focusing the review on creative thinking skills as the main construct, this study is expected to provide a clearer analytical foundation for empirical research and instructional design in science education. In contrast to previous research, in this study, not only learning strategies but also congruence between learning strategies and instruments for measuring skills of creative thinking for science education are systematically identified. In line with this objective, this review is aimed at answering the following research questions: (1) What research topics are most frequently studied in relation to creative thinking skills in science education? (2) What research methods and designs are most commonly used? (3) What learning media are utilized to support the development of creative thinking skills? (4) What teaching strategies are applied? (5) What instruments are used to measure creative thinking skills in science education?

METHOD

This study uses a Systematic Literature Review (SLR) approach to map research on creative thinking skills in science education. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) principles are followed throughout the review process to guarantee the traceability and transparency of the literature search and selection approach (Page et al., 2021). This SLR is positioned as a descriptive-analytical mapping, not as a comparative evaluation of intervention effectiveness, considering the limited number and heterogeneity of the studies analyzed (Haq & Roesminingsih, 2024; Snyder, 2019). Although an official risk-of-bias tool was used, the quality of the study was considered based on research design, clarity of methodology, and transparency of reporting.

This systematic review of literature follows the structure recommended using the SPIDER framework, concentrating on students from different levels (primary, high, and higher education) and teaching staff, as well as future teachers, as subjects. The examined issue concerns the skills of creative thinking within science education for fluency, flexibility, originality, and elaboration skills, as well as their development, assessment, and incorporation within context-based science education. The literature has used different study designs, like quasi-experimental, mixed-methods designs, descriptive designs, case study designs, and qualitative research, as well as designing learning tools using STEM education, problem-based education, project-based education, and technology-enhanced education. The assessment of the skills for creative thinking has been done using both test and non-test methods, depending on each study context.

Literature searches were conducted in Scopus, ScienceDirect, SAGE Journals, Google Scholar, and Semantic Scholar databases, as well as reputable national journals. Search keywords included "creative thinking skills," "science education," "learning strategies," "learning media," and "assessment instruments." The publication period was set from 2019 to 2022 to represent the latest developments in technology-based science education research. The included articles are empirical studies in English. The study selection was carried out through the stages of identification, title and abstract screening, and full-text eligibility assessment, which were documented in a PRISMA flow diagram. This process resulted in 23 articles that met the criteria and were further analyzed. Table 1 outlines the inclusion and exclusion criteria applied to select studies for this systematic literature review.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
- Philosophical, theoretical and educational practices on creative thinking skills. - The population/research subjects included toddlers, preschool children, college students, teachers, prospective teachers, and males and females. - The literature has been published in a reputable journal, Scopus, for 2019–2022. - The literature compares contexts, learning methods, and measurement of creative thinking skills. - Strongly valid empirical data and research techniques support the literature. - The literature is published in English.	- Incomplete literature. - The The literature has been published for more than 2019–2022. - Literature in the form of books.

Collection and acquisition of research data

Figure 1 depicts the search process and the quantity of material found using the PRISMA framework. Four phases comprised the literature selection process: keyword searching and literature selection based on title and abstract, inclusion and exclusion criteria, and text completion, which will yield the cited literature.

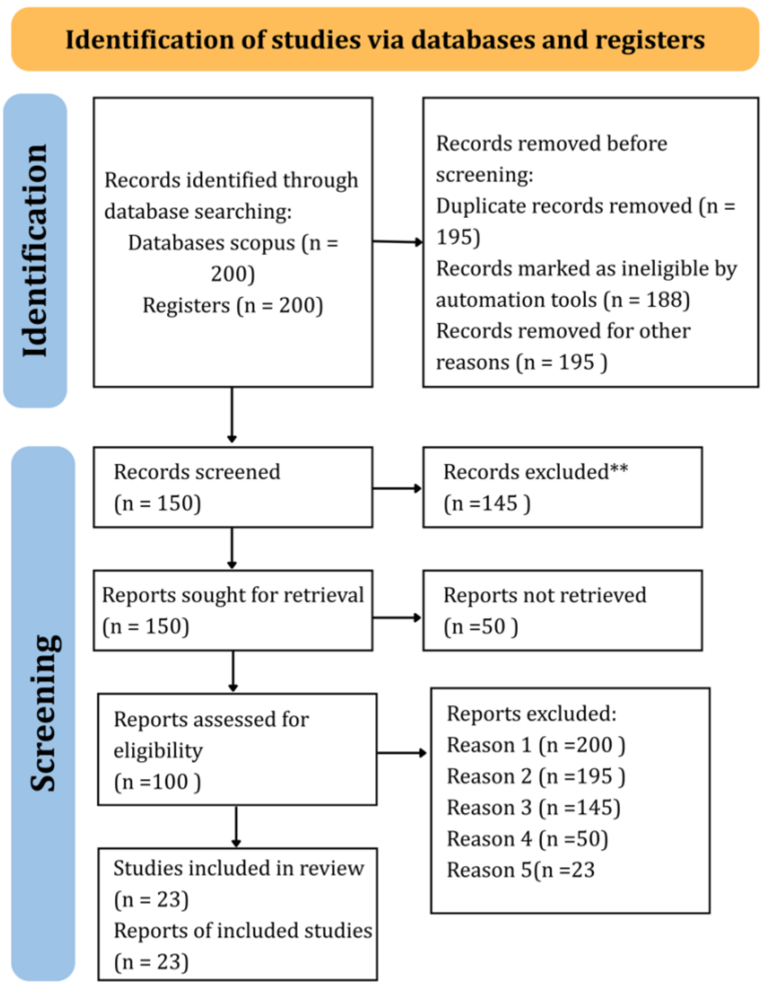

Figure 1. The PRISMA Procedure

Based on the image above, the PRISMA framework was obtained from 200 Journals to be filtered by title and abstract from I95 journals until January 2024. Based on the inclusion and exclusion criteria filtering, 145 journals were obtained. With a full-text philtre, 50 were obtained. 23 of the 50 journals were relevant. 24 major publications were chosen for additional analysis at the end of the selection process. In order to gather information that helps address the predefined research questions, the chosen primary literature was then retrieved. Data extraction qualities in connection to the study topics are compiled in Table 2.

Table 2. Properties of Data Extraction Mapped to Research Questions

Property Research Questions	Research Questions
Research Topics and Trends	RQ1
Research Methods/Design	RQ2
Research Media	RQ3
Research Strategy	RQ4
Research Instruments	RQ5

The process outlined in the generated SLR serves as a guide and compass for seeking and analyzing literature to conduct a review and reduce the likelihood of bias, and it is referenced in the search of major literature across various journal databases (see Figure 2).

After the data had been extracted, they were classified, assessed, compared, analyzed, combined, and concluded. Data extracted and analyzed from the main articles were used to answer the literature study questions. For the record, statistical methods and search engine searches were used in this article's analysis. The SLR aimed to analyze literature on creative thinking skills based on statistical methods and search string searches rather than by hand reading papers published in different journals. Therefore, the SLR may miss several articles on creative thinking skills in several journals.

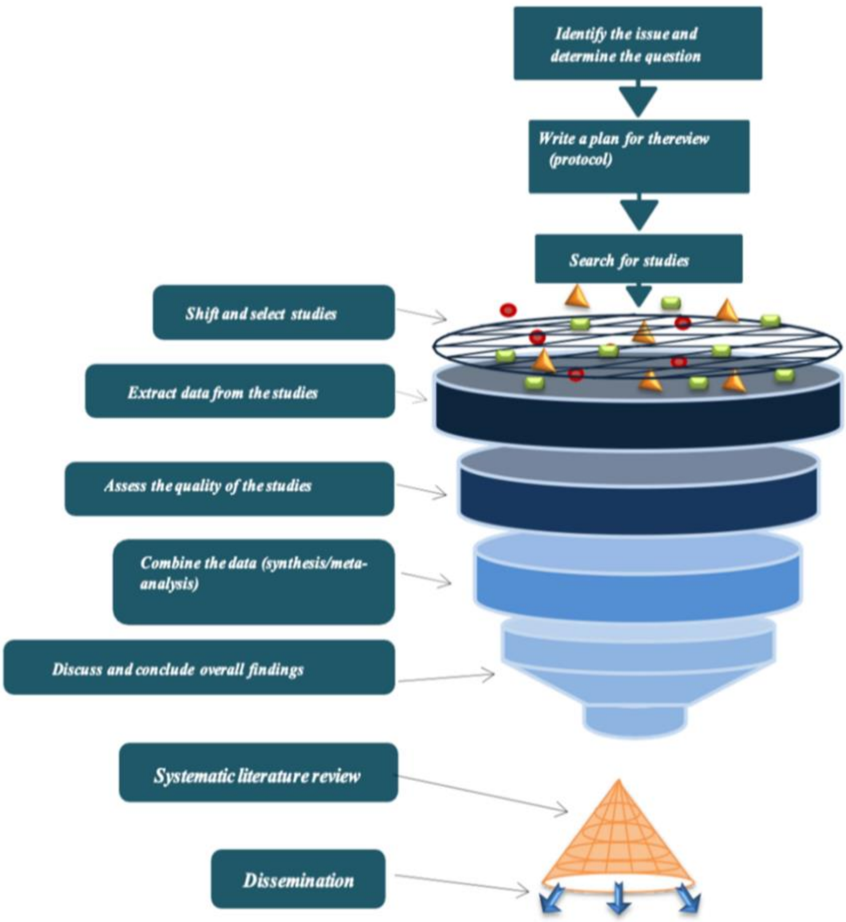

Figure 2. Systematic Literature Review Procedure

Data analysis was conducted using the SPIDER framework (Sample, Phenomenon of Interest, Design, Evaluation, Research type), which is suitable for synthesizing qualitative and mixed evidence in educational research (Cooke et al., 2012). Extracted data included the research context, design and methods, learning media and strategies, as well as instruments for measuring creative thinking skills (Wahyu et al., 2023). The analysis was performed descriptively and thematically, without a meta-analysis, to avoid overgeneralization and to maintain alignment between the research objectives and the available data. Although consistency in terminology was maintained by focusing the analysis on creative thinking skills, this review has limitations, including a relatively small corpus size and variations in definitions and instruments across studies. Therefore, the findings of this study are positioned as an initial mapping and analytical foundation for future research, rather than as definitive conclusions regarding the effectiveness of specific learning approaches.

RESULTS AND DISCUSSION

This study will mainly explain and analyse the literature review, how far research has progressed regarding creative thinking skills over 2019–2022. These dimensions include research topics and trends, research methods and designs, learning media, instructional strategies, and the instruments used to measure creative thinking skills, which are systematically mapped to the formulated research questions. Table 3 presents a summary of selected studies addressing creative thinking skills in science education, including their research focus and main findings.

Table 3. Research Related to Creative Thinking Skill

Authors & Year	Journal	Research Result
(Blatti, 2019)	Journal of Chemical Education	This has made a huge impact on community college students and students they teach in outreach programs. It is very important to nurture their imagination and aid in developing creative ideas and creative thinking skills that can be used to solve societal problems. They empower students, especially those not very well-represented in science-related fields, to pursue science-related careers.
(Sumarni, 2020)	Jurnal Pendidikan IPA Indonesia	This research found that by consistently practicing critical thinking and creative thinking strategies, there could be improvement in more meaningful concepts being developed. High-level thinking strategies enhanced students' thinking capabilities in terms of learning things such as cause-and-effect thinking, making predictions about rational outcomes, understanding data from diverse perspectives, and evaluating as well as making. Thinking skills demonstrated in relevant content learning would ensure development of the students' thinking skills with habits of critical and creative thinking in playing with ideas and content information processing.
(Sternberg, 2020)	Journal: Journal of Intelligence	Our new metrics drew on elements of scientific reasoning that we had previously investigated. However, compared to the test for scientific originality, the factorial composition of the test for the assessment of scientific influence is less obvious. Additionally, we discovered that participants regarded high-impact research as more practically valuable and scientifically rigorous than low-impact studies. However, they also usually rated high-impact studies as less creative, most

Authors & Year	Journal	Research Result
		likely as a result of their titles and abstracts being less innovative to our participants. Replicated findings in studies included the correlation of letter sets with number series (both measures fluid intelligence) and the correlation of scientific creativity with scientific reasoning.
(Fatmawati, 2019)	Journal of Physics: Conference Series	Correlations between (1) critical and creative thinking skills, (2) creative thinking skills and learning accomplishment, (3) creative thinking skills and learning achievement, and (4) creative thinking, critical thinking, and learning achievement were found in the data analysis findings. Enhancing critical and creative thinking abilities may result in improved learning outcomes as these abilities have an impact on learning accomplishment.
(Pacheco, 2021)	Journal: Thinking Skills and Creativity	This study aims to provide a conceptual model that includes operational descriptions of abilities and/or cognitive processes related to complex thinking. In order to do this, a review was conducted of the primary conceptualizations that have been offered in the cognitive sciences and how their processes are approached. Consequently, the synthesis and conjugation of several mental viewpoints is suggested as a new conceptualization for complicated thinking.
(Hsia, 2021)	Journal: British Journal Of Educational Technology	The current study suggests a flipped learning strategy based on creative problem-solving (CPS-based flipped learning) to help students understand the pre-class materials and cultivate their creativity through creative thinking. Future research can investigate more strategies that can improve students' learning efficacy from the standpoint of improving students' collaborative learning.
(Latorre-Cosculluela, 2020)	Journal: Revista Electrónica de Investigación Educativa	The results show that the work teams were able to design innovative approaches to the real problems they faced, becoming actively involved in a shared search for solutions. This active methodology increases the confidence of students' in their creative abilities and the development of empathic skills
(Calavia, 2021)	Journal: ThinkingSkills and Creativity	Think-Create-Learn employs open, approachable, and user-friendly design-based tools to overcome obstacles by using a creative, problem-solving approach, making connections between the material and the student's interests and realities, and creating new opportunities for competence development. The methodology's favorable integration into current teaching curricula, its validity to support the elements indicated, and its capacity to assist instructors in producing more creative individuals are all demonstrated by the assessment conducted with both teachers and students. In summary, this study demonstrates how the field of design and the suggested approach may be pertinent to the growth of creativity in educational institutions.

Authors & Year	Journal	Research Result
(Rahimi, 2021)	Journal: Computers & Education	Science education increasingly position creative thinking skills as a core learning outcome embedded within instructional innovation. Excuses like the complexity and difficulty of defining and measuring creativity are no longer acceptable. With the help of developments in computer science, psychology, learning sciences, and technology, we can develop the instruments required to fulfill this responsibility we only need to be inventive.
(Meyer, 2020)	Journal: The Journal of Design, Economics, and Innovation	Skills for developing creative solutions to complex problems are increasingly essential. It will require a study group to recommend a list of design and educational practices to create a curriculum that aligns with their skills and objectives. To fully realize the potential of design in the twenty-first century, it will be necessary to make a deliberate effort to bootstrap the design profession toward a strong practitioner community and an effective professoriate. In this piece, we outline that route.
(Mason, 2019)	Journal of Psychoactive Drugs	Creative thinking and empathy are crucial for everyday interactions and subjective well-being. Studies show a reduction in these skills in populations where social interaction and subjective well-being are significantly compromised.
(Ramírez-Montoya, 2022)	Journal of Open Innovation: Technology, Market,and Complexity	The area of education has major obstacles in creating competences for reasoning for complexity in today's complex, dynamic, and linked environment ("Education 4.0"). Critical, systemic, scientific, and inventive thinking are sub-competencies of complex thinking, which is a macro-competency in educational settings. In order to determine educational practice and research potential, this study examined the literature on complex thinking related to Education 4.0. The findings include the following: (a) features of studies that connect complex thinking, critical thinking, and creative thinking; (b) the qualitative approach predominates in the studies; (c) the research has focused most on critical thinking competency; (d) teaching methods and techniques are the main components of Education 4.0; and (e) project feasibility, research opportunities, and various skills are the three challenges that stand out for educational research.
(Jawad, 2021)	Journal: International Journal of Interactive Mobile Technologies (IJIM)	The research aims to comprehend how education in STEM fields science, technology, engineering, and mathematics affects mathematical success and creative thinking.
(Aguilar, 2019)	Journal: Frontiers I Psychology	Improving creativity and developing technology skills in the classroom is the future of education, and such skills could be useful tools in ensuring that inequalities remain smoothed in a classroom setting. The paper discusses a study that is a systematic scoping review of literature that focuses on social creativity and

Authors & Year	Journal	Research Result
		technology in science subjects.
(Kwangmuang, 2021)	Journal: Heliyon Journal Heliyon	The learners cognitive process: the level of cognitive load, scientific thinking, concept shift, and mental representation with innovation learning. Learning innovation components: implication on student higher order thinking skills and learner cognitive process, cognitive load, scientific thinking, concept change mental representation with learning innovation.
(Großmann, 2019)	Journal: International Journal of Science Education	Experimentation is a complex problem-solving process. In biology lessons, experiments involve creative thinking and open discovery; however, they still require some instructional guidance. Regarding all students' conceptual and procedural knowledge, incremental scaffolds showed no additional benefit regarding students' knowledge in the post-test compared to working with no scaffolds or worked-out examples. Under the teaching learning conditions of this study, students with low prior knowledge learned more concept and procedure knowledge after the teaching unit from working under incremental scaffolds compared to worked out examples.
(Amponsah, 2019)	Journal: Thinking Skills and Creativity	a qualitative concept of the different items studied at school and in this context it is important for schools to support pupils in developing creative learning strategies.
(Yılmaz, 2021)	Journal; Participatory Educational Research (PER)	This study aimed to investigate prospective teachers with science education in pedagogy fields' critical and creative thinking, multifacted 21st – century skills as well as academic results due to technology integration. The results of the study reveal that the student teachers' 21st – century skills, critical and creative thinking and academic achievements have significantly enhanced as a result of incrementally incorporating technology in teaching-learning process.
(Huang, 2019)	Journal: Universal Access in the Information Society	This research creates a new learning paradigm in an outdoor co-space and implements a mobile augmented reality system for a creative design course unit. The proposed system is expected to improve access to other subject domains such as language learning, eco-education, and social science education.
(Adawiyah, 2019)	Journal of Physics: Conference Series	The findings of this research have shown the effectiveness of interactive e-books in improving student creative thinking skills in learning rotational dynamics concept. The enhanced creative capabilities related to the design and features of the e-book.
(Parra-González, 2020)	Journal: EDUCAR Education for Sustainable Development	The findings showed a strong activation and creative thinking score, implying that students and teachers score high on activation and creativity obtained through gamification.
(Kusumawati, 2019)	Journal of Physics: Conference Series	Creative thinking skills were very important in the era of the Industrial Revolution, especially in the 21st century. Since everyone needs to have 4C (Creative, Critical thinking, communication, Collaborative), it

Authors & Year	Journal	Research Result
		means that in the first cycle, students experienced elevated levels of creative thinking. This illustrates how students' creative thinking skills are enhanced by inquiry-collaborative learning interventions informed by lesson study for the learning community.
(Israel-Fishelson, 2021)	Journal of Educational Computing Research	Two forms of creativity that have been studied are those of creative thinking and computational creativity. Computational Thinking (CT) and creativity are viewed as essential skills needed in the 21st century and are advocated for integration into curricula across the globe.
(Sun, 2022)	Journal: Computers& Education	Innovation is considered one of the essential "21st – century skills." The growing importance of scientific inquiry in science education at schools is in developing and problem-solving skills with the aid of technology, while paying insufficient attention to developing creative thinking skills to produce innovative ideas or solutions. These findings have implications for design of technology-based interventions for science education to foster and enhance group creativity.

After analysing the data in the 23 selected articles, we discussed the three pillars supporting creative thinking skills: theory, strategy, and measurement. We also revealed the kinds of research gaps that are essential to creating future research possibilities.

Research Topics and Trends

Most of the studies analyzed focus on creative thinking skills in the context of STEM/STEAM approaches, problem-based learning, and inquiry-based learning. These approaches are generally positioned as learning environments that support idea exploration, open-ended problem solving, and the integration of cross-disciplinary knowledge (Bybee, 2013; Kelley & Knowles, 2016). However, this review also shows that many studies are still descriptive and exploratory in nature, with varying definitions of creative thinking skills that are not always explicitly formulated as a main construct (Sternberg, 2018). This variation in focus indicates that the conceptual consensus on creativity in science education is still evolving.

Research Methods and Design

From a methodological perspective, quantitative research and mixed methods are more dominant compared to purely qualitative research. Quasi-experimental and pre-experimental designs are often used to examine the implementation of certain learning strategies in classroom contexts (Creswell & Clark, 2017). However, differences in research design, sample size, and intervention duration limit the possibility of direct comparisons between studies. This condition aligns with Snyder (2019) the finding that methodological heterogeneity in educational studies often limits comparative synthesis in small-scale SLRs.

Media and Learning Strategies

The learning media reported in the reviewed studies include e-modules, digital simulations, virtual laboratories, and technology-assisted worksheets. The most frequently mentioned learning strategies are problem-based learning, project-based learning, and the STEM approach. These strategies are theoretically considered to support creativity because they provide authentic problems and encourage the exploration of diverse solutions (Hmelo-Silver, 2004; Putranta, 2019). Nevertheless, most studies do not conduct adequate comparative analysis between strategies, so the existing findings tend to indicate the use of certain strategies rather than evidence of their relative effectiveness.

Measurement Instruments

Measurement instruments for creative thinking skills show considerable variation, both in terms of format and the indicators used. Some studies adapt previously developed creative thinking tests, while others develop contextual instruments tailored to specific science content and learning objectives (Beghetto & Kaufman, 2014; Hu & Adey, 2002). This variation reflects the absence of established measurement standards and underscores the challenge of directly comparing results across studies (OECD, 2019).

Discussion and Implications

Overall, the results of this systematic literature review indicate that research on creative thinking skills in science education still shows considerable conceptual and methodological fragmentation. Differences in operational definitions, measurement indicators, and learning approaches used make it difficult to conduct comparative synthesis across studies. These findings are consistent with previous reviews highlighting that creativity in education is often treated as a broad and multidimensional construct, which risks conceptual ambiguity if it is not explicitly defined at the outset of the research (Beghetto & Kaufman, 2014; Sternberg, 2018). Although various learning strategies, such as problem-based learning, project-based learning, and the STEM approach, are often reported to have the potential to support the development of creative thinking skills, most of the reviewed studies were not designed to compare the effectiveness of different strategies. This is consistent with the findings of Linnenluecke et al., (2020) and Snyder (2019), who emphasized that SLRs with limited corpora and heterogeneous study designs are more appropriate for mapping research trends and identifying literature gaps rather than for generating normative pedagogical recommendations or causal claims. Therefore, the results of this SLR cannot be used to conclude the superiority of any particular learning approach, but rather to understand how these approaches are positioned in the literature.

From a methodological perspective, the dominance of quantitative designs and mixed methods with quasi-experiments indicates a tendency in research to measure the impact of learning in real classroom settings, but often with limitations in variable control and short intervention durations. This condition has the potential to affect the internal and external validity of research findings (Creswell & Clark, 2017). In addition, the variation in measurement instruments used, both those adapted and those developed independently, indicates that there is not yet a widely agreed-upon standard for measuring creative thinking skills in science education, as also reported in the OECD report (OECD, 2019). This lack of standardization limits the possibility of accumulating more coherent evidence across studies.

The theoretical implications of these findings highlight the need for more systematic efforts to clarify the boundaries of the construct of creative thinking skills, particularly in relation to creative thinking skills and other higher-order thinking skills. Although the overlap between these constructs is acknowledged in cognitive literature, conceptual clarity remains necessary so that future research can have a consistent analytical focus and be more meaningfully comparable (Facione, 2011; OECD, 2019). From a methodological perspective, future research needs to develop more consistent research designs, with more detailed reporting of procedures and the use of measurement instruments that have undergone rigorous validation processes. This approach is important to enhance the reliability of empirical findings and support the development of stronger research syntheses in the future (Hu & Adey, 2002; Page et al., 2021). By positioning the results of this study as an initial mapping, this SLR contributes by identifying dominant research patterns, methodological trends, and existing gaps in the literature. These findings are expected to serve as a foundation for further empirical research that not only focuses on the implementation of learning strategies but also on strengthening the conceptual and methodological basis in the study of creative thinking skills in science education.

This systematic review of the literature reveals how far research has progressed in creative thinking skills in 2019–2022. Several research results show that the development of creative thinking skills has reached various areas of study, including creativity and technological skills in the classroom. They are the future of education and can become powerful tools to smooth out inequalities in class. The perspective that considers creativity complex and hard to define, measure, and enhance is no longer acceptable. With advances in psychology, science learning, technologies, and computer science, we can create the tools we need to meet this obligation by being creative. Learning in the 21st century has also been highlighted to address challenges posed by the Industrial Revolution 4.0. 21st – century skills are defined as "skills for working collaboratively to address globalization and partnership for 21st – century skills." They encompass skills such as working collaboratively, technological literacy, critical thinking, and problem-solving abilities to address (Kennedy & Sundberg, 2020). The skills of graduates in terms of learning should be in information, communication, critical thinking, and problem-solving. Thus, teaching higher-order thinking skills such as problem-solving in realistic problems has great significance. Rich revealed that "21st – Century Learning demands that students be able to produce, synthesize, and evaluate knowledge in a variety of cultures."

They thereby exhibit civic duty and digital literacy. Open-source software and virtual tools enable students to learn anywhere. The learning experiences in the classroom should be connected to the students' skills in this type of learning environment in the 21st century. Furthermore, the learning experiences should empower students as individuals and as citizens. So, this is because using digital literacy as e-learning has a favourable influence on teaching and learning processes (Wicaksono et al., 2023). The reason is that e-learning is something both the instructor and the student are comfortable with and are capable of utilising. Technology could be utilized in education in the future. E-learning can break the limitations of the traditional learning method in the classroom, which offers more flexible teaching and learning methods.

This study can be a reference for determining learning and research on creative thinking skills in the future by deepening how communication and representational skills can be improved, where students need to be more accustomed to being introduced to mathematics problems with the help of relevant techniques from other areas of creative thinking skills. In the 21st century, creativity and digital skills play a crucial part in coming up with solutions for everyday problems and are part and parcel of basic competencies for developing any valuable product or service (Athanassios & Vasiliki, 2019). The skill of creative thinking is relevant to all because evidence for the truth of stating the formulation of assessment can be promoted by creative thinking (Sirajudin & Suratno, 2021). This skill is therefore one of the alternatives for the learning activity that can be employed to enhance basic skills for this 21st-century era in terms of STEM education.

In addition, the findings of this review indicate that contemporary pedagogical approaches such as STEM/STEAM education, inquiry-based science education, problem-based learning (PBL), and project-based learning (PjBL) are predominantly positioned in the literature as contexts for fostering creative thinking skills in science education (Boom-Cárcamo et al., 2024; Marini et al., 2025; Suherman et al., 2025; Wu et al., 2025). These approaches are commonly characterised by the use of authentic, real-world problems that encourage divergent and higher-order thinking. However, consistent with the overall findings of this SLR, most studies do not provide comparative or causal evidence regarding the relative effectiveness of these pedagogies. Instead, they reflect a broader tendency in the literature to conceptualise creativity as an embedded outcome of learner-centred and context-based instructional designs rather than as a directly measurable effect of a specific teaching strategy.

LIMITATIONS

There are several limitations in this systematic literature review, which must be kept in mind while interpreting the results. Firstly, this review is founded on a fairly small body of research, specifically the studies published in the time range of 2019 to 2022, and perhaps does not comprehensively cover the previous research in the area and the latest trends post the mentioned time range. Furthermore, the difference in research design, the context in which the subjects were made to learn, the instruments used to determine the measurements, and so forth in the studies covered in the review is rather extensive, making any sort of direct comparison or causality rather difficult. Therefore, the results obtained in this review can be seen as an initial insight into the research trends and gaps.

CONCLUSION

This systematic literature review examines research on creative thinking skills in science education published between 2020 and 2022. The results show that studies in this area generally associate creative thinking skills with innovative learning methods, such as STEM/STEAM, problem-based learning, and the use of technology-based tools. However, these findings mostly reflect research trends and patterns rather than comparative evidence on the effectiveness of specific approaches. The review also highlights considerable conceptual and methodological diversity, especially in how creative thinking skills are defined, research designs, and measurement tools used. Therefore, the main contribution of this study is to provide an initial overview of research focus, methodological approaches, and gaps in the literature. These findings are expected to serve as a basis for further research that develops a more consistent construct definition, stronger methodological design, and validated measurement instruments in the study of creative thinking skills in science education.

AUTHOR CONTRIBUTION

Conceptualization, LP, AA, TJ, and DM. Methodology, LP, KK, and SS. Software, LP, and KK. Validation, LP, and NFL. Formal analysis, LP, KK, SS, and NFL. Investigation, LP. Resources, LP. Data curation, KK and SS. Writing original draft preparation, LP. Writing, review and editing, LP, and KK. Visualization, LP, KK, and NFL. Supervision, AA, TJ, and DM. All authors have read and agreed to the published version of the manuscript.

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