

Review Article

Cite this article: Suyono, S., Tukiran, T., & Yuliaturosida, E. (2025). Exploring Project-Based Learning for Enhancing Creative Thinking in High Schools: A Bibliometric Analysis and Literature Review. *Educational Process: International Journal*, 18, e2025480. <https://doi.org/10.22521/edupij.2025.17.480>

Received July 10, 2025

Accepted September 4, 2025

Keywords: Project-Based Learning (PjBL), Creative Thinking Skills, Bibliometric Analysis, Literature Review

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Exploring Project-Based Learning for Enhancing Creative Thinking in High Schools: A Bibliometric Analysis and Literature Review

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Abstract

Background/purpose. This study aimed to map the application of the Project-Based Learning (PBL) model to enhance creative thinking skills in high schools (HS), including junior, senior, and vocational high schools. The research explored the trends of PjBL application, identified the characteristics of PjBL that are suitable for HS students, determined appropriate creative thinking indicators, and examined the influencing factors related to PjBL for the development of students' creative thinking. This study provided recommendations to optimize the implementation of PjBL for enhancing creative thinking in the HS context.

Materials/methods. A bibliometric analysis was conducted using publication data retrieved from the Scopus database. The study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 protocol to systematically filter and select relevant articles. Visualization and co-occurrence mapping were performed using VOSviewer software. Out of 258 identified documents, 44 articles met the inclusion criteria and were analyzed through bibliometric techniques and literature review.

Results. The findings indicated that PjBL improves students' creative thinking abilities in HS significantly, particularly in developing fluency, flexibility, originality, and elaboration. Factors such as the integration of real-life issues, STEM-based approaches, technology utilization, and active, student-centered learning environments play a crucial role in enhancing creative thinking. The results also highlight that while research on PjBL for HS is increasing, there remains a need for more studies that focus on diverse subjects and interdisciplinary approaches.

Conclusion. The application of PjBL in HS demonstrates potential in improving students' creative thinking skills, supported by contextual and interdisciplinary projects. To maximize its effectiveness, educators should integrate PjBL with STEM and real-life issues which is relevant to students' developmental stages. Future research should focus on expanding PjBL models across subjects and investigating long-term impacts on students' creativity and learning outcomes.



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1. Introduction

Creative thinking is an essential 21st-century competence that enables students to solve problems, generate diverse ideas, and approach challenges from multiple perspectives (Suherman & Vidákovich, 2022). When integrated into learning activities, PjBL has been shown to strengthen students' ability to think flexibly, recognize opportunities, and adapt to the demands of a rapidly changing world (Rahardjanto *et al.*, 2019; Sari *et al.*, 2023). Compared to other instructional approaches, such as cooperative learning, PjBL has consistently demonstrated greater effectiveness in developing students' creative capacities (Mursid *et al.*, 2022). By situating learning in authentic contexts, PjBL provides students with opportunities to investigate problems, propose solutions, and produce meaningful outcomes that reflect their creative lives (Hussein, 2021; Andini & Rusmini, 2022).

In recent years, PjBL has gained significant attention across various levels of education, from primary to higher education, due to its capacity to cultivate essential 21st-century skills, particularly creativity and innovation. Through project-based tasks, students engage in inquiry, exploration, and reflection—processes that stimulate idea generation and creative synthesis (Sari *et al.*, 2023). The emphasis on authentic problem-solving not only enriches classroom experiences but also connects learning with real-world relevance (Hussein, 2021).

In response to the increasing importance of 21st-century skills, creativity has become a key focus in education, as defined by the Partnership for 21st Century Learning. HS must adopt learning models that enhance students' ability to generate new ideas, explore different perspectives, and apply their knowledge in real-life situations. Despite the growing evidence supporting the effectiveness of PjBL, there remains a lack of research that specifically maps the characteristics of PjBL that are most suitable for the junior HS context. In particular, there is limited understanding of which creative thinking indicators are appropriate for this age group, and which factors within PjBL influence the development of students' creative thinking skills in HS settings.

Based on this background, this study is expected to contribute to the design of effective and contextually relevant learning models that support the development of 21st-century students. This study employed a bibliometric analysis and literature review to examine the trends, subject mapping, influencing factors, and recommended characteristics of PjBL for enhancing creative thinking in HS. Through data extracted from the Scopus database and analyzed using PRISMA 2020 guidelines and VOSviewer visualization tools, this research seeks to answer the following questions:

What are the research trends of PjBL in HS?

What are the characteristics of PjBL that are appropriate for HS students?

What creative thinking indicators are suitable for the HS level?

What PjBL-related factors influence the development of creative thinking in HS students?

By addressing these questions, the study proposed the design of more adaptive, integrative, and future-oriented learning strategies suitable for general education settings, particularly at the HS level.

2. Literature Review

HS play a pivotal role in shaping students' cognitive and creative capacities during a formative stage of adolescence. As the demand for 21st-century competencies grows, educational reforms increasingly emphasize the cultivation of creative thinking alongside academic achievement. Creativity has been conceptualized through several frameworks. Torrance (1966) extended these dimensions for educational contexts, emphasizing idea generation, deep exploration, openness, empathy, and ownership of ideas, highlighting the importance of both cognitive and affective processes in collaborative environments. Similarly, Runco and Jaeger (2012) underscored the dual

criteria of originality and effectiveness as essential for creativity, noting that ideas must be both novel and useful. Together, these perspectives provide a solid foundation for selecting indicators of creative thinking that are appropriate for adolescents and applicable within PBL contexts at the high school level.

Project-Based Learning (PBL) has emerged as a pedagogical model well-aligned with these creative processes. Grounded in constructivist theory, PjBL emphasizes authentic tasks, collaboration, and iterative problem-solving. It immerses students in real-world challenges that require them to design, create, and reflect on activities shown to stimulate and expand creative capacities (Basri *et al.*, 2024). This approach is particularly relevant in HS, where students benefit from engaging, hands-on experiences that connect classroom knowledge with meaningful applications. Empirical studies provide further support for the effectiveness of PjBL. For instance, Siew and Ambo (2018) reported that science-based projects enhanced students' creative thinking by fostering enthusiasm, healthy competition, prototyping, and presentation skills. These experiences encouraged students to generate multiple ideas, refine original concepts, and seek diverse sources of information. Similarly, Setyarini *et al.* (2020) found that PjBL facilitated the integration of logical and divergent thinking, enabling students to construct knowledge through independent inquiry, collaborative presentations (Setyarini *et al.*, 2020), and the creation of tangible products. Such findings suggest that PjBL helps familiarize students with real-world problem-solving and inquiry-based learning.

It is essential to identify which features of PjBL align most closely with the developmental needs of adolescents to optimize its effectiveness. At the HS level, structured yet flexible environments are particularly beneficial, offering guidance while allowing autonomy. Core characteristics include authentic problem-solving (Jalinus *et al.*, 2019), collaborative group work, student voice and choice (Al-Kamzari & Alias, 2025), interdisciplinary integration, clear goals with real-world relevance, and reflection-driven learning (Stozhko *et al.*, 2015). These elements provide opportunities for students to engage in meaningful decision-making, connect learning with everyday life, and sustain creative engagement.

Moreover, PjBL models that incorporate sustained inquiry, iterative planning and revision, and public presentation have been shown to deepen cognitive processing and enhance creative synthesis (Culclasure *et al.*, 2019). For HS students, whose cognitive abilities are transitioning toward abstract and critical thinking, these components provide both structure and challenge, enabling them to internalize knowledge while developing original ideas. Importantly, allowing students to select project topics based on their interests has been linked to higher intrinsic motivation and greater creative expression (Al-Kamzari & Alias, 2025).

Regarding indicators of creative thinking, several frameworks can be adapted for HS students. Torrance's (1966) four classic indicators of fluency, flexibility, originality, and elaboration remain developmentally appropriate and observable within project-based contexts. These indicators are often activated when students are asked to generate multiple ideas (fluency), explore various problem-solving strategies (flexibility), propose unique or unconventional solutions (originality), and expand on ideas with detailed development (elaboration). Furthermore, Treffinger *et al.* (2002) offer a complementary model that includes cognitive and affective dimensions, such as idea generation, digging deeper into ideas, openness to explore, empathy, and ownership of ideas, all of which are well-suited for PjBL tasks that emphasize teamwork, inquiry, and iterative feedback. Other researchers, such as Runco and Jaeger (2012), have emphasized that creativity is defined by two essential components: originality and effectiveness. This means that for an idea to be considered truly creative, it must not only be novel but also appropriate and valuable within a given context. In the PjBL setting, this dual requirement encourages students to develop ideas that are both imaginative and feasible, especially when projects are linked to real-world challenges. This definition

aligns well with project work, where creativity must be translated into concrete outcomes that solve problems or address genuine needs.

Multiple factors influence the effectiveness of PjBL. First, the teacher's role is central, not only as a facilitator of inquiry and dialogue but also as a guide in helping students manage time, resources, and group dynamics. Some teachers have not been skilled in applying scientific approach learning models such as PjBL (Wijayati *et al.*, 2019). Teachers who encourage risk-taking, tolerate ambiguity, and provide constructive feedback are more likely to nurture creative behavior (Yu *et al.*, 2022). Second, the design of learning tasks must allow for open-handedness, challenge, and relevance. Tasks that are overly scripted or limited in scope may restrict divergent thinking, whereas authentic, complex problems encourage students to explore multiple pathways and take intellectual risks. The development of students' creative thinking depends on their aesthetic tastes, intellectual potential inherent in man by nature. Creativity is formed by external factors, thanks to the introduction of modern, newest creative methods, but it is quite possible to teach students to think in stereotyped, clichéd formulas, and individually, outside the box (Kryshtanovych *et al.*, 2021). Third, the learning environment, both physical and psychological, must support collaboration, experimentation, and resilience. Studies showed that a supportive classroom culture that values curiosity, divergent viewpoints, and respectful dialogue enhances both student motivation and creativity (Al-Thani & Ahmad, 2025). Fourth, assessment strategies also play a role. When assessments focus solely on final outcomes, students may prioritize correctness over creativity and innovation. However, formative assessment practices (assessment for learning) that include peer feedback, reflection journals, and process-oriented rubrics have been shown to better support creative development (Duda *et al.*, 2023). Lastly, access to resources and time for project development is critical. Creative thinking thrives when students are given adequate time to explore ideas, revise their work, and learn from mistakes. Schools that build flexible schedules and provide access to technology, materials, and expert mentors tend to see more robust creative outcomes from PjBL initiatives (Mutanga, 2024).

The literature suggests that PjBL can be a highly effective model for developing creative thinking in HS students when it is carefully adapted to their developmental needs. By intentionally designing projects that align with validated indicators of creative thinking, incorporating supportive pedagogical practices, and addressing key contextual factors, educators can create rich learning experiences that cultivate students' creative potential. Moreover, school culture and curriculum flexibility greatly influence the success of PjBL in nurturing creativity. Schools that allow cross-subject collaboration and project days or weeks are more likely to see sustained creative engagement among students (Skrbinjek *et al.*, 2024). However, rigid exam-oriented systems often limit the depth and originality of student work. Therefore, future implementation of PjBL in JHS should also involve systemic reform efforts, including assessment redesign, teacher training, and supportive policies. The creative thinking outcomes from PjBL are best captured not only through traditional tests but through performance-based assessments such as project exhibitions, learning journals, peer reviews, and reflective portfolios (Ngereja *et al.*, 2020). These assessments provide richer data on how students generate, develop, and communicate creative ideas.

3. Methodology

This study employed a systematic literature review and bibliometric analysis to map the implementation of PjBL in enhancing creative thinking skills at the HS level. The process followed the PRISMA 2020 guidelines to ensure transparency and rigor in article identification, screening, and selection (Page *et al.*, 2021). Data collection by utilizing article and journal search applications, namely Scopus. Search for articles by following the rules of words that match the subject and meet the conditions. The keywords used are project-based learning, creative thinking, and HS. The minimum requirements for articles collected were open access, published within the last 10 years, in the education domain, journal article publication type, and relevant to HS education. There were 174

unqualified documents in the identification phase and 158 unqualified documents in the screening phase. The Scopus search displayed 44 relevant documents. The article analysis search did not limit the country of origin or global search.

PRISMA 2020 is intended for use in systematic reviews that include synthesis (such as pairwise meta-analysis or other statistical synthesis methods) or do not include synthesis (for example, because only one eligible study is identified). PRISMA 2020 can be used for original systematic reviews, updated systematic reviews, or continually updated (“living”) systematic reviews (Page *et al.*, 2021). The criteria for the identification stage do not align with the title, as the type of study does not match the topic, and there is no peer review. The screening stage criteria were met, but the data did not meet the inclusion and exclusion criteria in the aspects of title, keywords, abstract, place, introduction, conclusion, and full text.

3.A. Data Sources and Search Strategy

Data were collected through a structured search on the Scopus database, which is widely recognized for indexing high-quality peer-reviewed journals. The search utilized keywords such as:

- “project” and “based” and “learning”
- “creative” and “thinking”,
- “secondary” and “school”, to capture variations in terminology.

The search was limited to articles published between 2015 and 2025, to ensure recent and relevant findings. Only open-access, peer-reviewed journal articles were included, and all articles were filtered for relevance to education and learning domains. No restrictions were placed on the country of origin of the studies to allow for a global perspective.

3.B. Inclusion and Exclusion Criteria

Bibliometric analysis can identify research gaps and suggest future studies in various emerging fields. Data analysis uses analysis through the Scopus web page and VOSviewer. VOSviewer, a freely available software package used to construct and display bibliometric relationships between a variety of variables. To refine the dataset, the study applied the following criteria are listed table 1:

Table 1 Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Published from 2015 to 2025	Published before 2015
Type of publication: journal article, conference proceeding, systematic review	Type of publication: books, book chapters
Written in English	Non-English articles
Focused on HS	Focused on primary or higher education
Discussed Project-Based Learning and/or Creative Thinking	Not focused on PjBL or creative thinking
Indexed in Scopus	Not indexed in Scopus

3.C. PRISMA 2020 Flow Process

The article selection process was conducted systematically in four PRISMA 2020 stages: identification, screening, eligibility, and inclusion.

- Identification Stage: A total of 258 documents were retrieved using the keyword combinations. After removing duplicates and documents not aligned with the theme, 150 articles were excluded.
- Screening Stage: Titles, abstracts, and keywords were examined for alignment with HS context and creative thinking. Sixty-eight documents were excluded because they did not meet the criteria.
- Eligibility and Inclusion: A final set of 44 articles were deemed relevant and included for full-text review and bibliometric analysis.

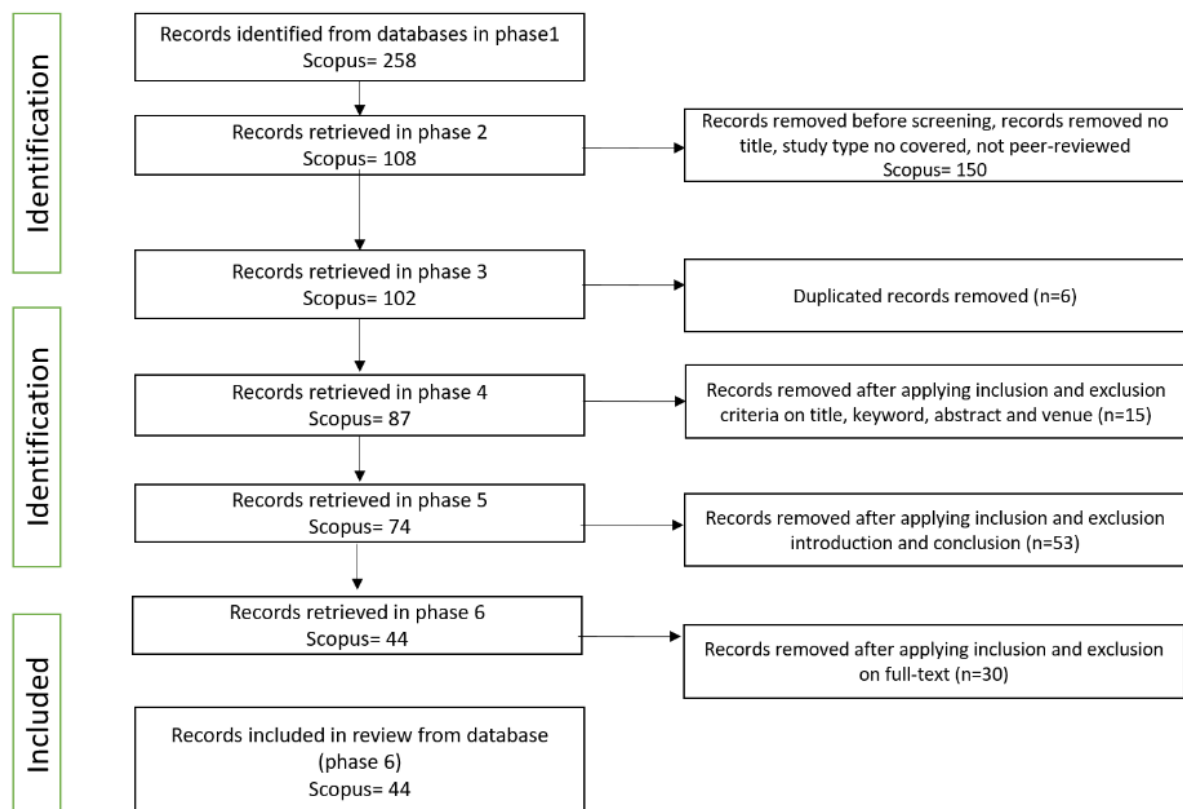


Figure 1. PRISMA 2020 Flow Diagram Illustrating the Identification and Search Processes

The methodology of this study is strong and systematically aligned with the PRISMA 2020 framework; however, several limitations must be noted. First, the data collection relied solely on the Scopus database. While Scopus is widely recognized for its rigorous indexing of peer-reviewed journals, this reliance may exclude potentially relevant studies indexed in other databases such as Web of Science, ERIC, or Google Scholar. Second, although the process of article selection followed PRISMA 2020 stages (identification, screening, eligibility, and inclusion), the procedure for thematic coding during the content analysis requires further clarification. Specifically, the process by which categories were constructed, merged, and validated should be elaborated to enhance methodological transparency. Third, the PRISMA 2020 flow diagram should be explicitly included in the article to represent the identification, screening, and inclusion processes visually. Finally, to strengthen reliability and transparency, examples of extracted studies—including their focus, method, and key findings—should be presented in a table or appendix. These additions would provide clearer evidence of how data were synthesized and how conclusions were drawn.

3.D. Data Analysis Tools

1. Bibliometric Analysis (Primary Focus)

To explore the research landscape related to PjBL and creative thinking at the HS level, a bibliometric analysis was conducted using VOSviewer (Van Eck & Waltman, 2010). The analysis provided insights into publication patterns and research trends by examining:

- Keyword co-occurrence networks, which revealed dominant research themes such as “creative thinking,” “PjBL,” and “21st-century skills,” directly aligning with the characteristics and objectives of PjBL for HS students.
- Author collaboration networks, highlighting key contributors and collaborative clusters in the field, which may reflect shared frameworks or methodologies relevant to middle school contexts.
- Country and institutional productivity, identifying countries such as Indonesia, the United States, and China as leading contributors to PjBL and creativity research in HS education.
- Source density maps showed that journals such as Scopus and Eric Journal are influential in disseminating findings on PjBL and creative thinking.

These bibliometric findings provided a macro-level view of how PjBL is conceptualized, implemented, and studied globally in relation to creative thinking, particularly at the HS level.

2. Content Analysis (Supporting Analysis)

To enrich and validate the bibliometric trends, a thematic content analysis was conducted on the full texts of 44 selected studies. The analysis addressed the core research questions by identifying:

- Characteristics of PjBL suitable for HS students, such as problem orientation, collaboration, real-world relevance, and multi-disciplinary integration.
- Creative thinking indicators, including fluency, flexibility, originality, and elaboration, as commonly used across educational research for this age group.
- Influential PjBL-related factors, such as instructional design, assessment methods, subject context, and challenges in classroom implementation, which collectively influence the development of creative thinking.

This dual analysis approach enabled both quantitative mapping of research trends and qualitative insight into pedagogical practices.

4. Results

4.A. Research Trends of PjBL for Enhancing Creative Thinking in HS

The trend of PjBL for enhancing creative thinking studies showed fluctuations from 2017 to 2025. In 2017, there were 2 Scopus-indexed documents. The number increased slightly to 3 documents in 2018 and continued to rise in 2019, reaching 6 publications. The highest number of documents was recorded in 2020, with 10 publications primarily sourced from science and education. However, after this peak, the number of publications decreased to 5 in 2021 and further declined to 3 documents in 2022. In 2023, the number of PjBL-related publications increased again to 5 documents, followed by 6 documents in 2024. However, in 2025, the publication rate declined to 4 documents.

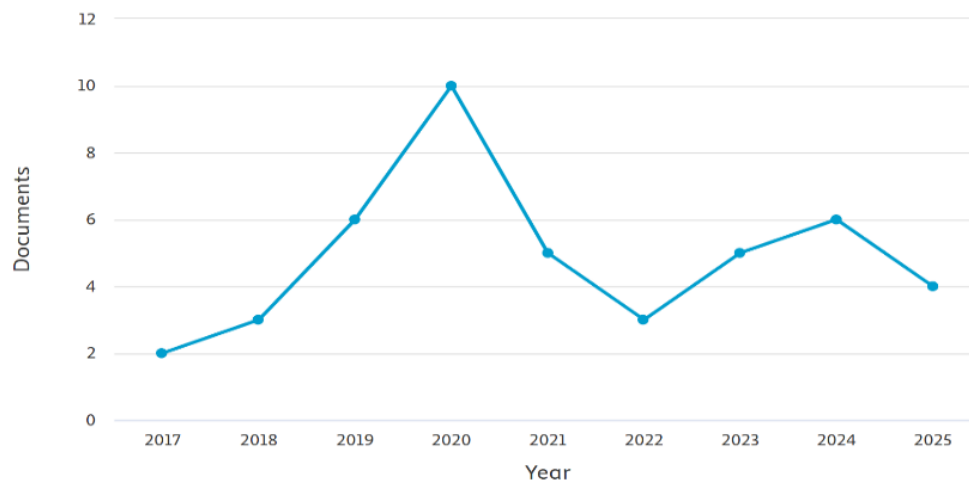


Figure 2. Documents by Year

The highest publication peak occurred in 2020, with 10 documents focusing on the application of project-based learning, particularly in the context of science and education journals, such as the Journal of Physics: Conference Series, and other international conference proceedings. Although the number of publications declined in the following years, a resurgence was observed in 2023 and 2024. Most of these documents are dominated by journals and conference proceedings with a strong focus on STEM fields, indicating that the implementation of PjBL is still concentrated in physics and science education areas.

4.B. Subject Mapping of PjBL for Enhancing Creative Thinking in HS

The application area of PjBL for enhancing creative thinking in HS is dominant in physics and astronomy as many as 21 documents (30.9%). Furthermore, the social sciences comprise as many as 16 documents (23.5%), and the engineering disciplines comprise 10 documents (14.7%). In addition, computer science is represented by 6 documents (8.8%), and mathematics by 3 documents (4.4%). Disciplines with a percentage below 3% include business, management, and accounting (2.9%), environmental science (2.9%), and materials science (2.9%). Other disciplines with a percentage below 2% include arts and humanities, energy, psychology, and others.

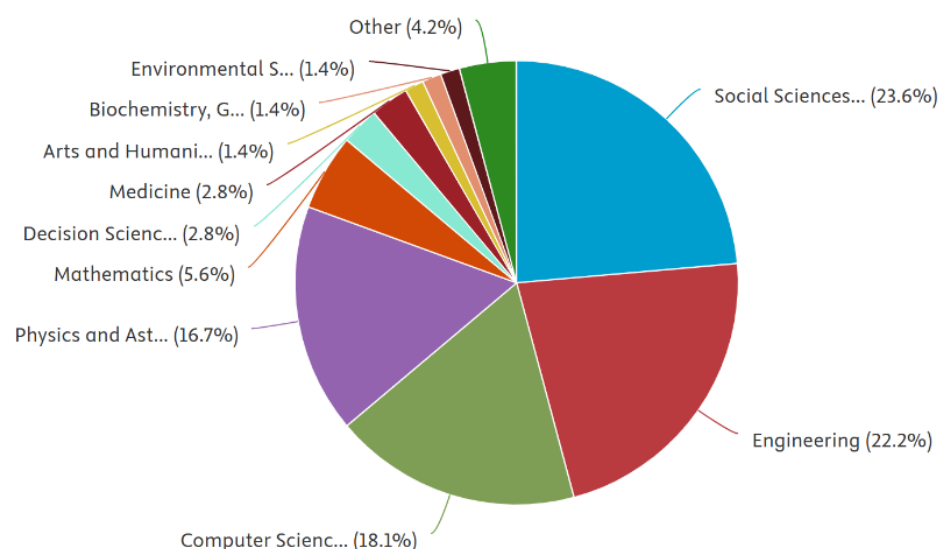


Figure 3. Documents by Subject Area

Articles on the application of PjBL in vocational schools in the last 10 years showed the highest research interest in 2019 and 2023. The most journal sources in 2019 were from Journal of Physics Conference Series with 5 documents. In 2023, most of them originated from AIP conference proceedings, comprising 4 documents. The number of article documents decreased in 2017 and 2022. Journals published in 2017 are AIP conference proceedings 1 document and journals published in 2022 are International Journal of Evaluation and Research In Education 1 document and AIP conference proceedings 3 documents

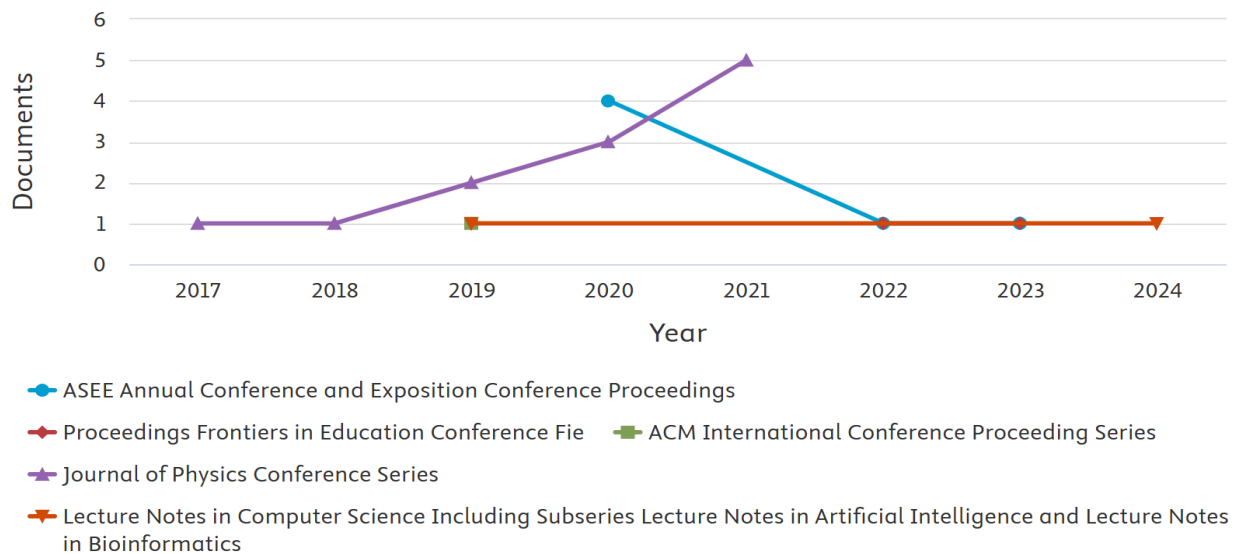


Figure 4. Documents Per Year by Source

Four publication sources contributed documents within the last eight years. The Journal of Physics Conference Series has the highest number of documents with a total of 13 publications. The ASEE Annual Conference and Exposition contributed 5 documents, while Lecture Notes in Computer Science, Including Its Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, and the Proceedings of the Frontiers in Education Conference each contributed 1 document. The Journal of Physics Conference Series reached its peak publication in 2021 with 5 articles. The ASEE Annual Conference and Exposition Conference Proceedings had its highest publication year in 2020, with 4 articles.

Some evidence also highlights the application of PjBL in non-STEM domains. For example, studies in social sciences have implemented PjBL in civic education and entrepreneurship projects to foster collaboration and creative problem-solving. Similarly, in the arts and humanities, PjBL has been applied in artistic education and literature-based projects, which encouraged students to express originality and develop creative narratives. These findings, although still limited in number, indicate that PjBL has cross-disciplinary potential that extends beyond science-related contexts.

4.C. Opportunities for Appropriate PjBL Studies and Interconnected PjBL and Creative Thinking

Bibliometric mapping was conducted using VOSviewer, with data imported in CSV format based on the results of the PRISMA 2020 screening process. The VOSviewer settings considered both the frequency of term occurrence and the co-occurrence relationships between keywords. Through this process, VOSviewer grouped terms into thematic clusters, calculated the size of each node (reflecting frequency), and measured the proximity between nodes (indicating their level of relatedness). The visualization generated consists of 30 items, divided into 6 clusters, with 229 links and a total link strength of 482.

Cluster 1 consists of 7 items, including creative thinking, HS students, community engagement, collaborative learning, scamper, artistic education, and physics education. Cluster 2 contains 5 items, namely project-based learning, artificial intelligence, HS, cognitive ability, and e-learning. Cluster 3 contains 6 items, including design thinking, critical attitude, deeper learning, creativity, elaboration, and vocational education. Cluster 4 consists of 5 items, including 21st-century skills, education level, competency, motivation, and CAD 3D. Cluster 5 comprises 4 items: project-based learning, STEM, engineering, and elaboration. Cluster 6 comprises three items: physics education, collaborative learning, and community engagement, which are interconnected across clusters.

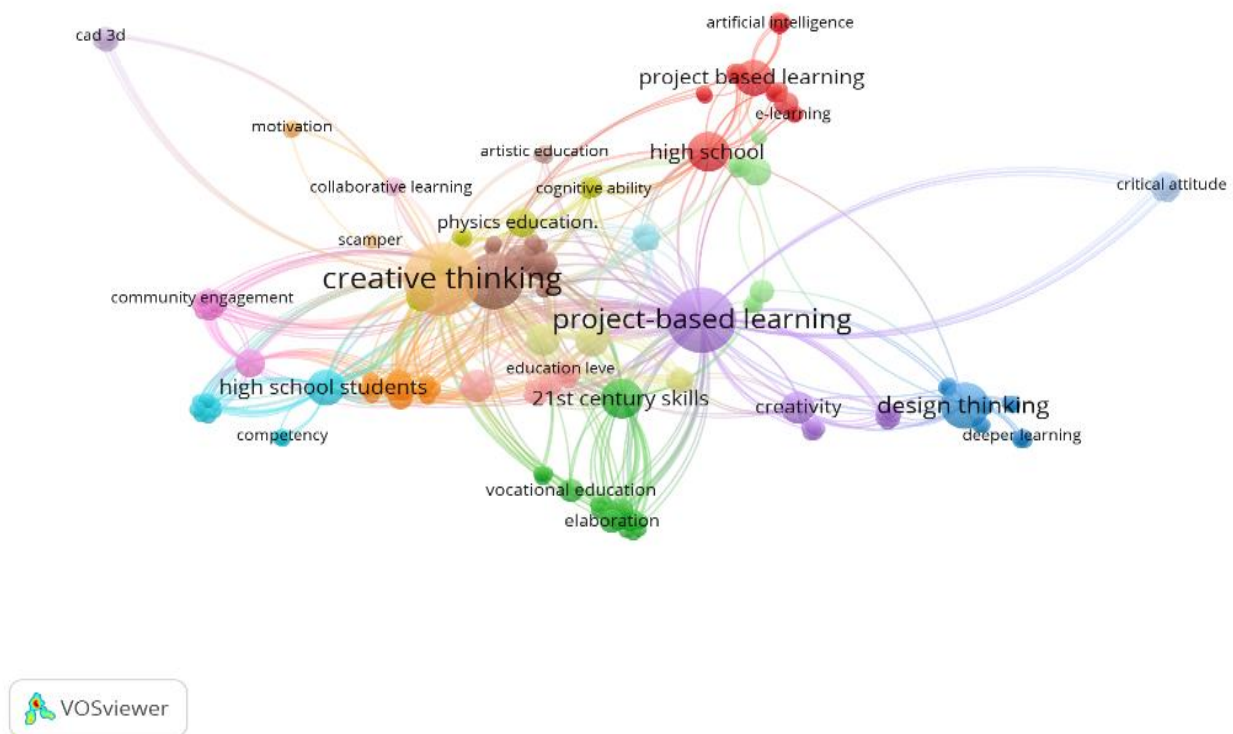


Figure 5. Occurrences PjBL and Creative Thinking

The term PjBL appeared as the most dominant keyword, present in 2 clusters, with 42 links, a total link strength of 97, and 15 occurrences. The term 'creative thinking' is distributed across 3 clusters, with 39 links, an average link strength of 84, and 13 occurrences. Meanwhile, HS students appeared in 2 clusters, forming 27 links, a link strength of 59, and 10 occurrences. The combined link between PjBL and creative thinking comprised 66 links, with a total link strength of 181, indicating a strong conceptual relationship between these two terms in the analyzed literature.

The clustering results highlight not only the centrality of PjBL and creative thinking but also the fragmentation of research themes. While STEM- and technology-related terms (e.g., STEM, engineering, artificial intelligence, e-learning) dominate some clusters, terms related to social or artistic aspects (such as artistic education and community engagement) appear less represented. This imbalance suggests that research on PjBL and creative thinking has been heavily concentrated in science and technology domains, whereas broader interdisciplinary contexts remain underexplored. Therefore, the keyword co-occurrence analysis reveals both the strong conceptual linkage between PjBL and creative thinking and the need for future research to expand beyond STEM-dominated clusters.

4.D. Characteristics of PjBL Suitable for HS Students

Table 2. Overview of the Most Cited Publications

Author(s)	Year	Research Focus	Method	Subject	Key Findings	Relevance to PjBL and Creative Thinking	Limitations
Fadhil M Kasli, E Halim A Evendi, Mursal Yusrizal	2021	Impact of PjBL on Creative Thinking Skills and Student Learning Outcomes	Experimental	JHS (Junior HS)	The PjBL learning model can improve the CTS of experimental class students in the high category compared to the control class.	Supports PjBL as an effective model for enhancing creative thinking skills	Limited to JHS context; not tested across different subjects or broader educational settings.
Widyasmah, M Abdurrahman Herlina, K	2020	Implementation of STEM Approach Based on PjBL to Improve Creative Thinking Skills of HS Students in Physics	Experimental	SHS (Senior HS)	The application of the PjBL and STEM learning approach to Pascal's Law has significantly increased creative thinking skills.	Shows how STEM strengthens PjBL's impact on creative thinking	Focused only on physics (Pascal's Law); generalization to other subjects is limited.
Safitri, A D Suparwoto	2018	Enhancing senior HS students' creative thinking skills using PjBL	Experimental	SHS	Students' creative thinking The skills in the experiment class are higher than those in the control class. This indicated that project-based e-learning is effective in improving students' creative thinking skills in relation to Newton's laws of motion.	Supports PjBL as an effective model for enhancing creative thinking skills	Restricted to Newton's Law topic; lacks evidence for other science or interdisciplinary areas.
Fatimah Sarbaini	2022	Using-PjBL Coupled with Mobile Learning Technologies to enhance Students Cognitive Skills: How the Approach Shapes	Experimental	Vocational HS (VHS)	The use of PjBL through mobile learning technologies can enhance students learning, hence a successful approach to learning	Supports PjBL as an effective model for enhancing creative thinking skills	Conducted in vocational HS; generalization to general HS students may be limited.

Author(s)	Year	Research Focus	Method	Subject	Key Findings	Relevance to PjBL and Creative Thinking	Limitations
Creativity among Students in Higher Education							
Wibowo, G J Purwianingsih, W Kusnadi	2021	Analyse of creative thinking ability of vocational students after waste management project-based learning	Experimental	SHS	PjBL is quite influential in improving the students creative thinking abilities, especially in contextual teaching material such as waste management learning	Supports PjBL as an effective model for enhancing creative thinking skills	Focused on environmental projects; may not represent broader subject areas.
Aryanti, Y Afandi Wahyuni, E S Putra, D A	2021	Torrance Creative Thinking Profile of Senior HS Students in Biology Learning: Preliminary Research	Experimental	SHS	The ability to think creatively remains low. Further research requires a learning model to improve creative thinking skills such as the Creative Problem Solving (CPS) or PjBL model	Confirms that further research about PjBL requires to improve creative thinking	Preliminary study; not direct evidence of PjBL implementation.
Yusuf, Arief Rahman Marji Sutadji, Eddy Sugandi, Machmud	2023	Integration of STEM PjBL into 21st Century Learning and Innovation Skills (4 Cs) in Vocational Education Using SEM Model Analysis	Experimental	VHS	There was a correlation between STEM PjBL and 4 Cs competencies, creativity	Supports PjBL correlate for enhancing creative thinking skills	Conducted in vocational schools; not directly generalize to general HS contexts.

The reviewed studies also reveal a distinction between JHS and SHS contexts. At the JHS level, as highlighted by Fadhil *et al.* (2021) students are generally in the early stage of formal operational thinking, which makes them more responsive to PjBL projects that are concrete, contextual, and closely related to their daily experiences. In contrast, SHS students, as shown in studies by Widyasmah *et al.* (2020) and Safitri & Suparwoto (2018), demonstrate greater cognitive readiness to engage in abstract, interdisciplinary, and technology-enhanced projects. This suggests that while PjBL is beneficial across both levels, its design and complexity should be adapted to the learners' developmental stage.

The existing literature shows that PjBL is an effective model for enhancing students' creative thinking skills, especially when implemented through active, student-centered learning approaches. Fadhil *et al.* (2021) demonstrated that the application of PjBL significantly improved the creative thinking abilities in JHS students. Although the majority of studies have been conducted at the senior HS and vocational levels, similar trends were consistently observed. For example, Widyasmah *et al.* (2020) and Yusuf *et al.* (2023) emphasized that integrating PjBL with a STEM-oriented approach effectively supports the development of creativity, critical thinking, and other 21st-century competencies. Furthermore, the incorporation of technology into PjBL, as discussed by Fatimah & Sarbaini (2022) and Safitri & Suparwoto (2018), has been shown to enhance student engagement further and improve creative learning outcomes. Characteristics of PjBL suitable for HS students include its alignment with real-world problems, integration with STEM disciplines, the use of technology, and a focus on student-centered project development. These aspects are considered crucial for enhancing students' creative thinking skills in the context of HS education. PjBL implemented through contextual projects, particularly those related to environmental issues, was found to be influential in developing creative thinking, as highlighted by Wibowo *et al.* (2021). Aryanti *et al.* (2021) noted that despite the positive impact of PjBL, the creative thinking skills of HS students remain relatively low, indicating a need for further research and more systematic implementation of PjBL to optimize its effectiveness.

The literature also reveals several challenges and limitations. PjBL requires significant teacher preparation and pedagogical expertise, which can be a barrier in schools where teachers are less familiar with student-centered or inquiry-based approaches (Wijayati *et al.*, 2019). The implementation of PjBL is often time-intensive and resource-dependent, making it difficult to sustain in exam-oriented systems or in schools with limited access to materials and technology (Mutanga, 2024). While many studies report improvements in creativity, the gains are not uniform across all indicators. For example, aspects such as originality and elaboration often remain weak, suggesting that PjBL may need to be complemented with targeted instructional strategies (Aryanti *et al.*, 2021). Most of the literature highlights PjBL within STEM contexts, with relatively limited exploration in humanities, arts, or social science domains, which narrows its perceived applicability.

4.E. Creative Thinking Indicators Appropriate for HS Level

The development of creative thinking at the HS requires measurable indicators that are relevant to students' cognitive and developmental stages. Referring to widely recognized frameworks such as Torrance's Creative Thinking indicators, several core aspects can be identified as suitable benchmarks for evaluating students' creative thinking skills. According to Aryanti *et al.* (2021), the indicators of creative thinking consist of fluency, flexibility, originality, elaboration, and problem sensitivity. These indicators have been effectively applied in assessing the creative thinking abilities of HS students in various science learning contexts, especially in biology and environmental education. Their study emphasized that while indicators such as fluency and flexibility showed moderate levels of achievement, aspects like originality and elaboration still required improvement, highlighting the need for targeted instructional models.

Research by Fadhil *et al.* (2021) on HS students demonstrated that PjBL is capable of significantly enhancing students' creative thinking when measured through these indicators. Their findings support the relevance of applying Torrance's framework at the HS level, as it provides a structured way to capture the diverse dimensions of students' creative abilities. Other studies emphasize the importance of aligning creative thinking indicators with real-life, contextual problem-solving activities. For instance, Wibowo *et al.* (2021) and Widyasmah *et al.* (2020) highlighted that creative thinking indicators can be more effectively developed when integrated within project-based or STEM-oriented learning environments. This approach allows students to engage with problems that require generating original ideas, considering multiple perspectives (flexibility), refining solutions (elaboration), and being sensitive to the existence of problems in real-world contexts. Indicators such as fluency, flexibility, originality, elaboration, and problem sensitivity are considered appropriate and effective for measuring creative thinking among HS students, especially when applied within active, project-based, and contextually relevant learning models.

4.F. PjBL-Related Factors that Influence the Development of Creative Thinking in HS Students

Several interconnected factors strongly influence the effectiveness of PjBL in enhancing creative thinking among HS students. Literature suggests that the design and implementation of PjBL must consider these elements to achieve optimal development of students' creative skills. One significant factor is the integration of real-life contexts into project themes. Fadhil *et al.* (2021) emphasized that when students engage with authentic problems, especially those related to their daily lives or environment, their ability to generate original and practical ideas improves significantly. Wibowo *et al.* (2021) found that contextual projects, such as those focused on environmental issues, have a positive impact on students' creative thinking abilities, particularly when the projects encourage exploration and problem-solving that extends beyond theoretical knowledge. Contextual projects also require more resources, time, and teacher expertise, which can limit their feasibility in schools with constrained conditions.

Building on these insights, it becomes essential to link the phases of PjBL with validated indicators of creative thinking. Torrance (1966) proposed four key indicators (fluency, flexibility, originality, and elaboration) that remain relevant for HS contexts. By mapping these indicators onto the stages of PjBL, a more transparent framework can be established to illustrate how creative skills are activated and developed throughout the learning process.

Table 3. Framework PjBL and Creative Thinking (Torrance)

Torrance Creative Thinking Indicator	Definition	How PjBL Develops It
Fluency	Ability to generate many ideas or solutions	In the brainstorming and inquiry phase of PjBL, students explore multiple possibilities for solving authentic problems.
Flexibility	Ability to shift perspectives or approaches	During the design and collaboration phase, students adapt and modify strategies when they face challenges.
Originality	Ability to create unique or novel ideas	In the design and creation phase, students develop innovative products or solutions.
Elaboration	Ability to expand and refine ideas with detail	In the revision and presentation phase, students refine their projects based on feedback and add meaningful details.

Another critical factor is the incorporation of STEM (Science, Technology, Engineering, and Mathematics) components into PjBL activities. Widyasmah *et al.* (2020) and Yusuf *et al.* (2023) combine PjBL with STEM approaches, providing students with structured opportunities to innovate, experiment, and apply interdisciplinary knowledge. Nevertheless, studies also suggest that STEM-oriented PjBL can be challenging to implement consistently across non-science subjects, potentially narrowing its application in more diverse curricula. This integration not only enhances creativity but also develops students' broader 21st-century competencies, including critical thinking and collaboration. Technology integration within PjBL is also a notable factor influencing the development of creative thinking. Research by Safitri & Suparwoto (2018) and Fatimah & Sarbaini (2022) demonstrated that the use of digital tools and mobile learning in project-based environments can increase student engagement and motivation, which are essential for stimulating creative output. Technological resources also provide diverse platforms for students to express ideas, collaborate, and prototype innovative solutions. Disparities in access to digital tools and inconsistent levels of teacher preparedness for technology integration present substantial barriers, especially in resource-limited educational settings.

The learning environment and teacher facilitation play crucial roles in this process. Studies indicate that when teachers adopt student-centered approaches and provide sufficient autonomy, students are more likely to take intellectual risks, experiment with ideas, and develop their creative thinking (Aryanti *et al.*, 2021). This is particularly important for HS students, who are at a developmental stage where guided exploration and encouragement significantly influence cognitive growth. The development of creative thinking through PBL in high school students is influenced by factors such as project relevance to real-life contexts, the integration of STEM elements, the use of technology, and the supportive role of teachers. These components collectively enhance an active learning environment where creativity can flourish. Without adequate training and institutional support, teachers may struggle to strike a balance between autonomy and guidance, and projects may become superficial rather than fostering deep, creative engagement.

5. Discussion

The bibliometric and literature review findings reveal important insights regarding the implementation of PjBL. First, the research trend analysis indicates that interest in PjBL for enhancing creative thinking has experienced fluctuations over the past eight years. However, a significant peak occurred in 2020, with ten publications focusing on PjBL. The trend shows a decline in the following years before experiencing a resurgence in 2023 and 2024. This suggests that while PjBL remains a relevant topic, its research development is still concentrated in specific areas such as physics and STEM education, with fewer studies explicitly focusing on HS levels.

An additional insight concerns differences between JHS and SHS applications of PjBL. In JHS, projects that are context-based and tied to familiar issues (e.g., environmental problems, health, or community life) are more effective for nurturing fluency and flexibility in creative thinking. Meanwhile, SHS students are generally able to handle more complex projects involving STEM integration, abstract problem-solving, and digital tools, which stimulate originality and elaboration. Recognizing these developmental differences is important, as it highlights that PjBL effectiveness is not uniform but needs to be tailored according to students' cognitive maturity and educational level.

The subject mapping further confirms this pattern. Physics, astronomy, social sciences, and engineering dominate the PjBL discourse, with relatively limited representation from broader interdisciplinary applications, especially those tailored to early secondary education. Most sources originate from conference proceedings such as the Journal of Physics: Conference Series and AIP Conference Proceedings, indicating that discussions around PjBL and creative thinking are still heavily tied to specific academic forums. From the literature review, several key characteristics of PjBL were

identified as suitable for high school students. These include an emphasis on real-world problem-solving (Fadhil *et al.*, 2021; Wibowo *et al.*, 2021), integration with STEM elements (Widyasmah *et al.*, 2020; Yusuf *et al.*, 2023), and the use of technology to support student engagement (Fatimah & Sarbaini, 2022; Safitri & Suparwoto, 2018). These components align with the cognitive and developmental needs of high school students, as they promote critical thinking, creativity, and collaboration in a structured yet flexible learning environment.

In terms of measurable outcomes, Torrance's creative thinking indicators —such as fluency, flexibility, originality, elaboration, and problem sensitivity —are considered suitable benchmarks for evaluating students' creative thinking (Fadhil *et al.*, 2021). Studies show that these indicators can be effectively developed through PjBL, particularly when projects are contextualized and aligned with students' everyday experiences. The influencing factors identified include the authenticity of project themes, STEM integration, technology adoption, and teacher facilitation. The presence of these factors fosters a learning environment that is conducive to exploration, innovation, and the development of students' creative potential. Importantly, the teacher's role in providing autonomy and guiding students through inquiry-based processes is crucial, where students require structured support to nurture their creative capabilities. The novelty of this review lies in linking bibliometric patterns with pedagogical implications, providing a comprehensive view of how PjBL aligns with established frameworks of creativity.

Despite these positive findings, several gaps remain. The number of studies focusing explicitly on HS contexts remains limited compared to those on senior high school and vocational education levels. Moreover, although technology and STEM are recognized as enhancers of PBL effectiveness, their implementation in diverse school settings remains limited to a specific context and requires further investigation. The findings highlight that while PjBL holds significant promise for enhancing creative thinking among high school students, its success is contingent upon thoughtful design, contextual relevance, and the integration of interdisciplinary and technological elements. Future research should aim to expand the scope of PjBL applications beyond science-dominated fields, ensuring that its benefits can be maximized across various educational contexts. PjBL's potentials are in arts, humanities, and interdisciplinary fields, ensuring that its benefits extend across diverse learning environments

6. Conclusion

The research trend analysis indicates that the implementation of PjBL enhances creative thinking in high schools, is still in development, but has not yet reached optimal dissemination, particularly in diverse educational contexts beyond STEM and science-focused subjects. Although several studies confirm the positive impact of PjBL in improving students' creative thinking, most research is still concentrated at the senior high school and vocational levels. The literature also indicates that appropriate characteristics of PjBL for HS students include real-life project integration, STEM elements, and technology use, all of which are effective in enhancing creativity. However, the application of PjBL in JHS remains limited, especially regarding cross-disciplinary projects, contextual environmental themes, and broad integration across school subjects.

Bibliometric mapping confirms a strong conceptual link between PjBL and creative thinking. However, research output is still dominated by conference proceedings in specific scientific fields, with minimal representation from broader educational journals, particularly those focusing on early adolescent development. Therefore, there is a significant opportunity to expand PjBL research for HS students, primarily to support the development of creative thinking across diverse learning domains, including social sciences, arts, and humanities.

7. Suggestion

Future studies should further explore the implementation of PjBL in HS settings beyond physics or STEM-based subjects. Applying PjBL in interdisciplinary projects, such as environmental education, the social sciences, or the arts, can provide broader benefits to students' development of creative thinking. Integrating PjBL with 21st-century skill frameworks (particularly creative thinking) is essential to align learning with students' developmental needs. Teacher training should move beyond general workshops and focus on practical, classroom-oriented competencies. For example:

- a. Training on designing interdisciplinary and real-world projects that connect science with social and cultural contexts.
- b. Workshops on using digital tools and mobile learning platforms to support PjBL implementation and enhance students' creativity.
- c. Capacity-building in assessment practices, such as developing rubrics for creative thinking (fluency, flexibility, originality, elaboration) and incorporating formative feedback strategies.
- d. Coaching or mentoring programs to strengthen teachers' facilitation skills in guiding inquiry, managing group dynamics, and fostering student autonomy.

Furthermore, research should assess the long-term impact of PjBL on students' creative thinking through more comprehensive approaches, such as mixed methods designs, longitudinal studies, and the inclusion of affective factors like motivation, engagement, and self-confidence. Expanding publication outputs in reputable educational journals focusing on HS learning and adolescent cognitive development is also crucial to disseminate findings more effectively. By implementing targeted teacher training, interdisciplinary projects, and innovative assessment practices, future research and practice can ensure that PjBL becomes a sustainable and effective approach for enhancing creative thinking across diverse educational settings.

Declarations

Author Contributions. Suyono, Tukiran, Eka Yuliaturosida. Suyono: The first draft of the manuscript and all authors commented on earlier versions of the manuscript. Tukiran: The conception and design of the study. Eka Yuliaturosida: Data analysis, drafting, and revising work. All authors read and approved the final manuscript.

Conflicts of Interest. The authors declare that they have no conflict of interest.

Funding. This research received no external funding.

Ethical Approval. This study did not require approval from an ethics committee.

Data Availability Statement. The data supporting the findings of this study are available from the first, second, or third author upon reasonable request.

Acknowledgments. The authors would like to acknowledge that there are no additional contributors to this work.

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