

Trend of Project-Based Learning Research (2012-2024) in Chemistry Education

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Article Info	Abstract
Article history: Received: October 30, 2025 Accepted: March 24, 2026 Published: May 24, 2026 Keywords: Chemistry education PjBL Research trends Systematic literature review This article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. © 2026 Journal of Mathematics, Science, and Computer Education	This study aims to identify trends in the project-based learning literature through a systematic review. The study examines global scholarly contributions to the SCOPUS database from 2012 to 2024, sampling 398 papers with the keywords "project-based learning" AND "chemistry," "project-based learning" OR "chemistry," and "project-based learning." Data obtained in annual publications and journal articles were analyzed in Excel. PjBL trends showed yearly increases in publication, confirmed by Vos Viewer software analysis. The highest index in 2021. The top 28 publications review found that PjBL is effective for chemistry across education levels, with substantial research in secondary and higher education emphasizing interdisciplinary links in engineering and computer science. This approach fosters hands-on, inquiry-based learning relevant to STEM fields. The study emphasizes PjBL's importance in preparing students for tech careers, fostering collaboration, and shaping future research trends among global researchers.
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INTRODUCTION

Project-Based Learning (PjBL) emphasizes the 4Cs and soft skills essential for 21st-century education (Aldabbus, 2018), focusing on student-centered, in-depth investigations of relevant topics. It promotes constructive learning through a research-based approach to meaningful problems and interactive learning (Philen, 2016; Tamim & Grant, 2013). The model enhances learning through project-oriented experiences, generating valuable outcomes and a high-quality learning experience (Handrianto & Rahman, 2019; Syahril et al., 2021). Teachers facilitate classroom management by incorporating complex tasks related to real-world questions and challenges. PjBL promotes design, problem-solving, decision-making, and collaboration for critical and creative thinking (Almulla, 2020; Issa & Khataibeh, 2021; Prajoko et al., 2023; Rahmania, 2021). Through PjBL, students gain knowledge, analyze, solve problems, innovate, and pioneer (Wang, 2021). Overall, PjBL cultivates deep learning by linking theoretical knowledge with practical project work.

The 2022 PISA report shows that Indonesian students' creative thinking, scientific literacy, and self-regulation are still below the international average (Damayanti et al., 2021; OECD, 2024). Therefore, educators need to innovate with PjBL models that enhance creative thinking skills (Diawati et al., 2017; Lestari & Sumarti, 2018; Ningsih et al., 2020) and scientific literacy (Adriyawati et al., 2020). PjBL enables students to build their own knowledge while teachers facilitate the process (Brassler & Dettmers, 2017; Kokotsaki et al., 2016; Pujiriyanto et al., 2017; Žerovnik & Nančovska Šerbec, 2021).

Key features of the PjBL model include confronting real-world problems, collaboratively developing solutions, and working in teams of students to address these

challenges ([Juntunen & Aksela, 2014](#); [Krajcik & Czerniak, 2018](#); [Rofik et al., 2022](#)). This approach ensures that students not only grasp content but also cultivate essential skills for societal participation ([Wahbeh et al., 2021](#)). The emphasis is on nurturing both knowledge and practical competencies in students. PjBL boosts critical thinking, creativity, communication, and teamwork among learners, focusing on planning, organizing, and monitoring to develop skills in presenting ideas and negotiating tasks effectively ([Crespi et al., 2022](#)). It empowers students to independently design activities, schedules, and tools, enhancing their overall competencies and preparing them for active participation in society.

PjBL enhances student learning, but its impact on chemistry learning outcomes is inconsistent due to its diverse implementation. Bibliometric analyses of project-based science learning have been conducted ([Kadirhanogullari & Kose, 2023](#); [Kurt & Akoglu, 2023](#)), but none specifically for chemistry exists. Understanding the impact of PjBL is crucial, and this analysis is needed to uncover trends in PjBL, its effectiveness in student engagement, and its impact on critical thinking, problem-solving, and academic achievement in chemistry.

Furthermore, the research will outline the literature's primary subjects and themes, indicating areas that have gotten substantial attention and those that need further investigation. Synthesizes findings from existing studies to identify knowledge gaps and suggest future research to fill them, improving chemistry education through more effective and novel PjBL methodologies. Journals on PjBL in chemistry education were analyzed to determine implications and research gaps. This study investigates the originality of PjBL in chemistry education by (1) assessing annual publication trends from 2012 to 2024, (2) identifying the 28 most important writers by citations, and (3) exploring future practices in this teaching method.

METHODS

Systematic literature review (SLR) was employed to systematically collect, synthesize, and evaluate study findings, aiming to minimize bias from single studies and unsystematic reviews, ensuring transparency in research outcomes ([Azarian et al., 2023](#); [Cabrera et al., 2023](#); [Mengist et al., 2020](#)). This research uses literature-based data collection. Information was obtained through journals or scientific articles from Scopus, covering the topic or concept being studied. The journals used spanned the years 2012 to 2024. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram outlines a data-gathering method (Figure 1) with four stages: identification, screening, eligibility, and inclusion ([Qiu et al., 2017](#); [Page et al., 2021](#)). Researchers refine search results and employ bibliometric analysis involving criteria selection, data retrieval and cleaning, analysis, and conclusions, as detailed in studies by [Danvila et al. \(2019\)](#) and [Rojas-Sánchez et al. \(2023\)](#).

In the first stage, information was searched as a database using the Publish or Perish (PoP) application version 8.17.4863.9118. Search metric data is shown in Table 1. The results obtained were a total of 600 journal references, saved in RIS format (*Reference Manager file extension*), which were then used as a database. It is then imported into the application reference manager, Zotero, for further processing. Inclusion criteria comprised (1) peer-reviewed publications, (2) published from 2012 to 2024, (3) authored in English, (4) accessible in full text, and (5) specifically focusing on trends in publications on PjBL in chemistry education. Articles were excluded if they were solely abstracts, editorials, opinion pieces, or not relevant to the topic.

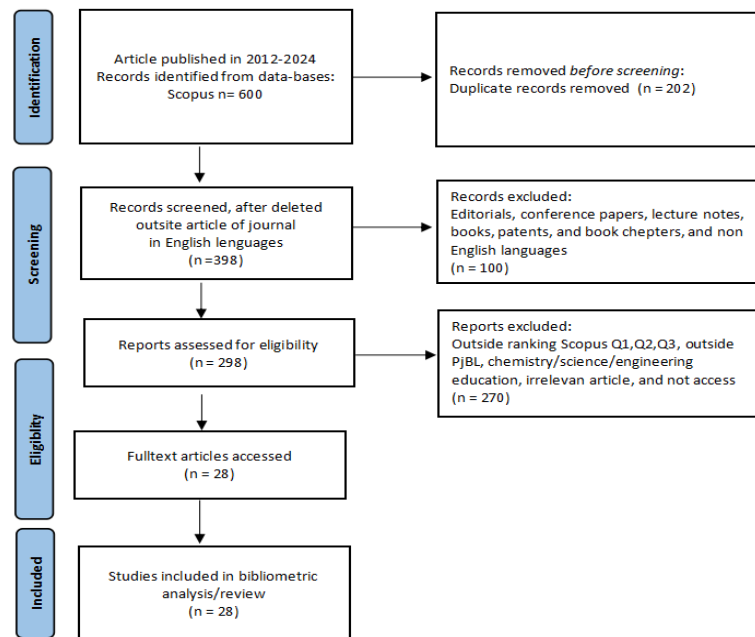


Figure 1 Research step chart

Table 1 Search metrics data

Query	Source	Papers	Citations	Cites/year	H index	HI annual
"Project-based learning" OR "chemistry"	Scopus	200	23.577	1.813,62	94	7.23
"Project-based learning" AND "chemistry"	Scopus	200	1.752	134.77	21	1.62
"Project-based learning" OR "PjBL"	Scopus	200	23.577	1.813,62	94	7.23

The study analyzes scientific publications on PjBL from Scopus indexers, offering freely accessible publications and citations for personal, non-commercial use, with a comprehensive linked dataset available. The study includes Scopus-indexed journal articles from 2012 to 2024 only. The first step of PRISMA is to identify and determine the search criteria with keywords "project-based learning" AND "chemistry," "project-based learning" OR "chemistry," and "project-based learning" OR "PjBL" for data collection and obtain as many as 600 articles indexed by Scopus. The next step in screening was to group the data from the 398 articles, sort them based on the journals that published articles on "project-based learning" using VOSviewer software, and link the groupings. VOSviewer was used to create a map based on the network data and to visualize and explore the map. Of the 398 articles screened, 298 were assessed for eligibility; 28 full-text articles were accessed and reviewed, meeting the eligibility criteria, and then analyzed and synthesized. The data were examined through narrative synthesis to identify significant trends in the development of publications on project-based learning.

RESULTS AND DISCUSSION

For answering RQ 1: *What are the trends in PjBL for chemistry education from 2012 to 2024?*

PjBL research shows consistent yearly growth, with article searches reaching 398 (Figure 2). The trend of PjBL publications increased annually from 2012 to 2021. This increase has been particularly rapid over the past five years. In 2020 (46 articles), with the peak in 2021

(61 articles), followed by 2022 (55 articles), 2023 (48 articles), and 2024 (43 articles). The study reveals a 610% rise in global PjBL research from 2014 to 2021, indicating increased interest (Kokotsaki et al., 2016).

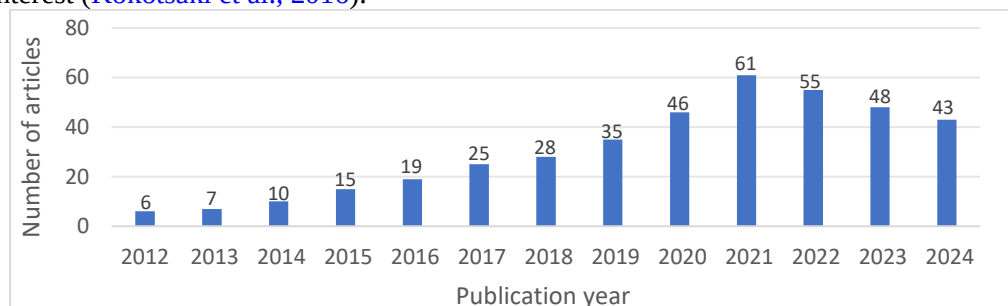


Figure 2 Number of PjBL Publications from 2012 to 2024

Research on PjBL in chemistry education between 2012 and 2024 has experienced significant growth, transforming from a primarily pedagogical novelty into a widespread, evidence-based approach for improving 21st-century skills and conceptual understanding. The field has shifted from general implementations to specialized, technology-integrated, and contextualized approaches, with research output peaking around 2021-2022. This growth is particularly evident in STEM and engineering education, where active, collaborative learning is emphasized (Han et al., 2015; Hanif et al., 2019). Increased publications indicate a shift towards student-centered pedagogies, enhancing thinking skills (Anazifa & Djukri, 2017; Chu et al., 2017a). Table 2-3 provides a summary of the final articles.

Table 2 Citations in journals and authors annually

Publication Year	Journal Name	Level of Scopus	Citations Annual
2012	<i>Educ. Technol. Soc.</i>	Q1	17.23
2013	<i>Int. J. Technol. Des. Educ.</i>	Q1	23.22
2014	<i>Int. J. Sustain. High. Educ.</i>	Q1	18.88
2015	<i>Int. J. Sci. Math. Educ.</i>	Q1	30.14
2016	<i>Improving Schools</i>	Q2	102.69
2016	<i>Computers & Education</i>	Q1	45.33
2017	<i>Jurnal Pendidikan IPA Indonesia</i>	Q3	17.50
2017	<i>Interdiscip. J. Probl. Based Learn.</i>	Q3	40.00
2017	<i>Internet and higher education</i>	Q1	124.00
2018	<i>J. Comput. Assist. Learn.</i>	Q1	17.75
2019	<i>Educ. Res. Rev.</i>	Q1	68.83
2019	<i>J. Res. Sci. Teach.</i>	Q1	33.17
2020	<i>Int. J. Educ. Res.</i>	Q1	45.50
2020	<i>Sage Open</i>	Q1	56.40
2020	<i>Thinking Skills and Creativity</i>	Q1	27.00
2020	<i>Sustainability</i>	Q1	207.00
2021	<i>Eur. J. Eng. Educ.</i>	Q1	75.50
2021	<i>Int. J. Educ. Technol. High. Educ.</i>	Q1	31.25
2021	<i>J. Sci. Teach. Educ.</i>	Q1	61.00
2022	<i>Learning and Motivation</i>	Q2	95.00
2022	<i>Discip. Interdiscip. Sci. Educ. Res.</i>	Q1	31.33
2022	<i>Int. J. Sustain. High. Educ.</i>	Q1	85.00
2023	<i>Frontiers in Psychology</i>	Q2	109.50
2023	<i>Educ. Technol. Res. Dev.</i>	Q1	26.60
2024	<i>Comput. Educ.: Artif. Intell.</i>	Q1	70.00

2024	<i>Educ. Psychol. Rev.</i>	Q1	43.40
2024	<i>Educ. Inf. Technol.</i>	Q1	48.50

Table 2 lists the journals with the highest citation rankings. In 2020, sustainability achieved 207 citations per year. In 2023, *Educational and Information Technology* achieved 109.50 citations/year. In 2016, *Improving Schools* had 102.69 citations/year. In 2022, *Learning and Motivation* achieved 95 citations/year. In 2021, the *European Journal of Engineering Education* achieved 75.50 citations/year. In 2024, *Computers and Education: Artificial Intelligence* achieved 70 citations per year. Meanwhile, in 2019, *Educational Research Review* achieved 68.83 citations/year.

For answering RQ 2: *Who are the 28 most impactful authors in PjBL for chemistry education?*

Table 3 displays that the references cited in the selected articles predominantly include foundational works on education and PjBL, notably by Kokotsaki et al. (2016), Guo et al. (2020), Chen & Yang (2019), Wijnia et al. (2024), Miller et al. 2021, and Wu & Wu (2020) assert PjBL enhances motivation via real-world problems, emphasizing project design and collaborative, student-centered implementation. Anazifa & Djukri (2017) emphasize PjBL's role in developing students' thinking skills.

Table 3 Trends PjBL in chemistry education for the period 2010-2024

Author (Year)	Level of education	Key finding	Cites	Cites/Year
Hung et al. (2012)	Elementary Education	Project-based storytelling enhances motivation, problem-solving, and achievement.	224	17.23
Tseng et al. (2013)	Higher Education	Attitudes towards STEM in a PjBL environment	325	27.08
Edström & Kolmos (2014)	Higher Education	PjBL and CDIO enhance engineering education.	270	24.55
Han et al. (2015)	Secondary Education	STEM-PjBL influences achievement variably among high, middle, and low achievers.	335	33.50
Kokotsaki et al. (2016)	Elementary to higher education	PjBL's importance in digital and AI-focused education.	930	103.33
Sáez-López et al. (2016)	Elementary Education	PjBL enhances motivation and commitment in primary education efficacy	408	45.33
Brassler & Dettmers (2017)	Secondary Education	Enhance competence through PBL and PjBL.	140	17.50
Chu et al. (2017b)	Higher Education	Wikis enhance project-based learning across various disciplines.	242	124.00
Anazifa & Djukri (2017)	Secondary Education	Project-based and problem-based learning effectively enhances students' thinking skills.	136	17.00
Vogler et al. (2018)	Secondary Education	Enhancing PjBL through interdisciplinary teamwork and soft skills.	191	27.29
Chen & Yang (2019)	Secondary Education	PjBL positively impacts students' academic achievement significantly.	415	69.17
Beier et al. (2019)	Higher Education	Authentic project-based learning influences STEM attitudes and aspirations.	199	33.17
Hanif et al. (2019)	Secondary Education	Enhancing students' creativity through STEM-PjBL	352	75.80
Guo et al. (2020)	Higher Education	Project-based learning improves student outcomes in education.	651	130.20

Author (Year)	Level of education	Key finding	Cites	Cites/Year
Almulla (2020)	Secondary Education	PjBL effectively engages students in active learning experiences.	282	56.40
Wu & Wu (2020)	Higher Education	PjBL and SCAMPER enhance creativity's impact on cognition, motivation, and personality in engineering education.	135	27.00
Granado-Alcón et al. (2020)	Higher Education	Project-based learning enhances competencies and knowledge transfer.	67	20.70
Chen et al. (2021)	Higher Education	Project-Based Learning in Engineering: Implementation Challenges.	303	75.75
Kumar (2021)	Higher Education	Educational chatbots improve learning outcomes in design.	125	31.25
Miller et al. (2021)	K-12 Science Education	Motivating teaching, sustaining change in PjBL contexts	179	36.00
Birdman et al. (2022)	Higher Education	Key competencies in sustainability via PjBL programs.	293	85.00
Saad & Zainudin (2022)	Elementary to K12 or higher education	PjBL and computational thinking enhance education.	95	31.47
Markula & Aksela (2022)	K-12 Science Education	Project-based learning: teachers engaging students through projects.	94	31.33
Zhao & Wang (2022)	Secondary Education	A case study of student development across project-based learning units in middle school chemistry.	87	29.00
Zhang & Ma (2023)	Elementary to higher education	PjBL positively influences student learning outcomes significantly.	135	67.50
Meng et al. (2023)	K-12 to tertiary learning	Survey study on PBL e-learning platforms' implementation challenges.	133	26.60
Kong et al. (2024)	Secondary Education	AI literacy framework evaluation for senior secondary students' PjBL course.	147	44.25
Wijnia et al. (2024)	K-12 or higher education	Problem-based, project-based, and case-based learning enhance motivation.	217	43.40
Zhang et al. (2024)	K-12 or higher education	The efficacy of project-based learning in enhancing computational thinking among students.	124	41.00

The high citation counts of select articles indicate significant impact within the PjBL literature, with three studies emphasizing the roles of digital technologies. These studies suggest a trend towards using technology to support collaborative learning, especially in hybrid settings, demonstrating PjBL's relevance as education increasingly incorporates digital tools and artificial intelligence literacy ([Kokotsaki et al., 2016](#) ; [Meng et al., 2023](#); [Kong et al., 2024](#)). [Hung et al. \(2012\)](#) propose digital storytelling to enhance students' motivation and achievement in science learning, while [Saad & Zainudin \(2022\)](#) and [Sáez-López et al. \(2016\)](#) highlight the importance of computational practice in PjBL environments.

The analysis is limited to the secondary and K12 levels, higher education/tertiary education, because it is more dominant than chemistry education implemented at the elementary school level. The top 28 publications review found that PjBL is effective for chemistry across education levels, with substantial research in secondary and higher education (Figure 3) emphasizing interdisciplinary links in engineering and computer science.

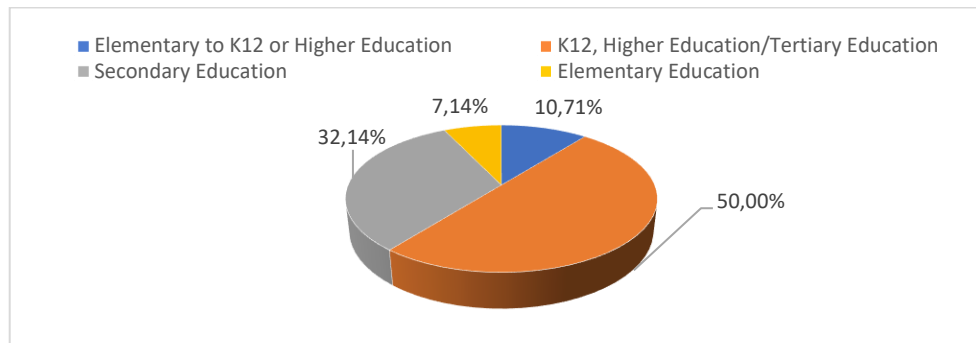


Figure 3 PjBL in level education

As project-based learning becomes more common in the classroom, it is important to consider which academic section, subject, and course type are best taught; whether there is a group size that is optimal for facilitating student learning outcomes (Zhang & Ma, 2023; Wei et al., 2020); and the effect of academic achievement (Al Mulhim & Eldokhny, 2020). The stages in PjBL are (1) identifying the objectives and scope of the project, (2) assigning a project plan, (3) implementing the project, (4) monitoring project progress and solving problems, and (5) completing the project and conducting presentations and evaluations. Better collaboration with project-based learning. This research shows that PjBL in secondary education, K-12, and higher education is promising and helps students intellectually and professionally. Zhao & Wang (2022) suggest that PjBL fosters cognitive (key ideas, scientific practices, problem-solving, critical thinking, and creativity) and non-cognitive (desire to learn chemistry, teamwork, environmental awareness, and perseverance) skills in students. Growth in all three sections boosted thinking skills, academic achievement, and emotional attitude (Zhang et al., 2024). Project-based learning encourages creativity, critical thinking, collaboration, and computing (Saad & Zainudin, 2022; Hanif et al., 2019; Anazifa & Djukri, 2017). Learning with PjBL and academic milestones is going well.

To address RQ 3: *What possibilities exist for future implementation of PjBL in chemistry education?* Visualization of research trends in PjBL studies using Vos Viewer software from the Scopus database in Figure 4.

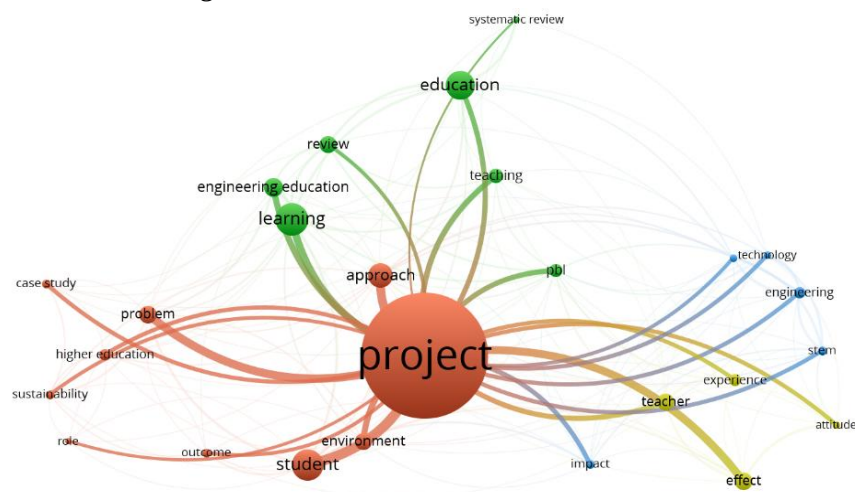


Figure 4 PjBL in the framework of curriculum and higher education

Figure 4 shows that researchers worldwide have generated 4 clusters. The first cluster (10 items) focuses on PjBL's relationship with various factors in higher education, while the second cluster (7 items) explores its connection to education and engineering teaching methods. The third cluster (5 items) relates to engineering, impact, mathematics, STEM, and technology. The fourth cluster (4 items) explores the relationship between PjBL and attitude, effect, experience, and teacher, focusing on PjBL's role in curriculum development and its impact on learning in higher education through inquiry-based and collaborative methods (Chu et al., 2017a). While PBL starts with problems, PjBL begins with guiding questions. PjBL tends to give students greater control over learning, with teachers adopting more supportive roles (Wijnia et al., 2024). PBL focuses on applying knowledge to abstract cases, whereas PjBL centers on practical, real-world tasks and creating tangible artifacts, especially in engineering. Literature shows comparative and simultaneous applications of PBL and PjBL, highlighting their distinct yet overlapping features in educational practices. PjBL researchers utilize quantitative analysis linking achievement with moderating variables like problems, experience, and technology.

PjBL transforms the university from a place that simply delivers information into a living laboratory of ideas, experimentation, and real-world impact. In this approach, students learn by actively exploring meaningful questions and creating solutions. Effective PjBL is guided by several core principles: a driving question or problem that frames the learning, authentic contexts connected to real-world issues, inquiry through investigation and exploration, student voice and choice in shaping their learning, reflection on their progress and understanding, critique and revision through feedback and iteration, and a public product that shares the results with audiences beyond the classroom. Together, these elements ensure that PjBL is not just about "doing projects" but about engaging in rigorous and meaningful learning.

However, research by Sánchez-García & Reyes-de-Cózar (2025) reveals an important challenge in practice. Many projects successfully produce visible outputs such as presentations or final products, but the deeper learning processes—especially reflection and metacognitive thinking—are often overlooked. As a result, projects may appear successful on the surface while failing to fully develop students' self-regulated learning, critical inquiry, and meaningful collaboration. Their findings also show that key PjBL elements such as task design, scaffolding, collaboration, and assessment are implemented unevenly across studies, highlighting a gap between the ideal model of PjBL and its classroom implementation.

This suggests that effective PjBL requires more than assigning projects or showcasing final results. The real value lies in how educators design and guide the learning process. Teachers need to support students in planning their strategies, monitoring their progress, reflecting on their thinking, and revising their work through multiple cycles of feedback. When reflection and metacognitive practices are embedded throughout the project—not only at the end—PjBL becomes a powerful approach for deep, inquiry-driven learning rather than simply product-oriented tasks.

Furthermore, the success of PjBL also depends on how projects are structured and supported institutionally. Studies show that well-designed projects with clear stages, reflection opportunities, and continuous feedback can significantly improve student engagement and critical thinking (Guo et al., 2020). In contrast, inconsistent task design and weak assessment structures may hinder students' ability to regulate their learning (Sánchez-García & Reyes-de-Cózar, 2025). Therefore, effective PjBL requires institutional support, adequate resources, and strong curriculum alignment. Cross-disciplinary collaboration, dedicated planning time, and professional development for educators are

essential to unlock PjBL's full potential and enable universities to address complex real-world challenges through transformative learning.

PjBL emphasizes technology and connects to STEM, engineering, and technology, mediating STEM education development through relevant research, as shown in Figure 5. STEM project-based learning prepares students for challenges. Keywords such as "STEM project," "technology," "students' achievement," "problem," and "environment" are central in the PjBL research network, enhancing conceptual understanding through experimentation and project design. The STEM project-based learning enhances students' creativity (Hanif et al., 2021), achievement (Han et al., 2015), and students' attitudes (Tseng et al., 2013).

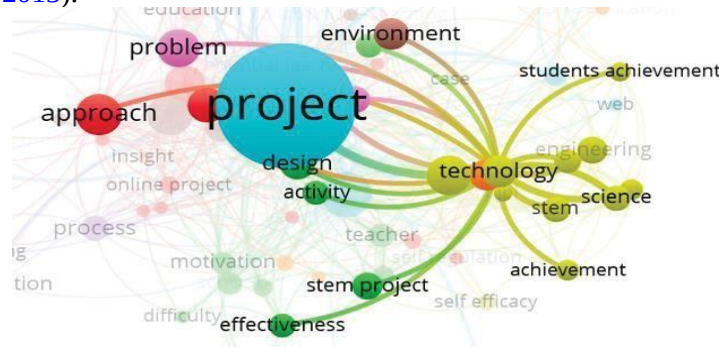


Figure 5 PjBL Regarding STEM and Technology

Teachers' education level is essential for successfully implementing STEM-PjBL in classrooms, as they create lesson plans, assessments, and evaluate project outcomes. Effective assessment tools are crucial for measuring students' understanding of STEM. Integrating real-life issues fosters authentic questions that resonate with learners' backgrounds and experiences. Continuous professional development and a grasp of content theory are vital for effective teaching. Collaboration among educators boosts communication and problem-solving skills, addressing challenges in STEM education. Regular interdisciplinary practice is necessary for teachers to blend various subjects, enhancing STEM learning environments. Overall, strong teacher education ensures educators are equipped to deliver impactful STEM education and cultivate students' comprehension of complex applications.

Research topics on PjBL are increasing because its methodology is rooted in constructivism, which supports experiential learning carried out through projects within a predetermined timeframe, with steps that include preparation/planning, implementation, reporting, and communicating the results of activities and evaluation (Handrianto & Rahman, 2019). PjBL, with its constructivist approach, exposes students to decision-making, problem-solving, and various types of investigative activities through generating questions and designing projects (Sasson et al., 2018). Among higher-order thinking skills, analysis is the most developed, while evaluation is the least developed, although still effective. The reflection methodology at the end of project-based learning encourages students to assess their achievements and weaknesses comprehensively. This enables students to think critically and analytically. Through project-based learning, inquiry processes develop as students study real topics to engage students' interest in learning (Wijayati et al., 2019).

Furthermore, PjBL is an effective learning method for mastering essential 21st-century skills in students (González-Pérez & Ramírez-Montoya, 2022). Each stage of PjBL facilitates the development of soft skills in students. Problem formulation encourages critical analysis, while designing a plan fosters creativity and communication through

negotiation. Setting a completion schedule promotes independent work at varied paces. Monitoring enables group collaboration and progress assessment. Presenting the final product builds confidence and communication skills. The critical final stage, reflection and evaluation, allows students to view the project comprehensively, emphasizing the importance of monitoring progress alongside project completion, ensuring a deeper understanding of their learning journey.

The findings offer practical insights for both educators and curriculum developers to design learning experiences that are more relevant to 21st-century demands. By integrating PjBL with STEM and digital technologies such as augmented reality, teachers can create more engaging, interactive, and context-rich learning environments. Projects connected to real-world sustainability issues allow students not only to understand chemistry concepts more deeply but also to see how scientific knowledge can be applied to solve real problems in everyday life. For curriculum developers, these insights highlight the importance of designing curricula that intentionally promote critical thinking, creativity, collaboration, and scientific literacy through authentic project work. Curricula can become more flexible and interdisciplinary by embedding STEM integration and digital tools, enabling students to learn concepts while actively applying them in meaningful contexts. Ultimately, integrating PjBL with STEM and emerging technologies strengthens both the academic value of learning through deeper conceptual understanding and its practical value by equipping students with the skills and experiences needed to address real-world challenges and succeed in future scientific and technological environments.

CONCLUSION

This study proves that the topic of PjBL is still a trend today. Research publications are increasing annually, with four clusters worldwide. The results of PoP's acquisition and screening show there are 398 Scopus publications on the implementation of PjBL in chemistry education between 2012 and 2024. Based on PoP and VOS viewer overlay visualization, it showed the highest index in 2021. The top 28 publications review found that PjBL is effective for chemistry across education levels, with substantial research in secondary and higher education emphasizing interdisciplinary links in engineering and computer science. This approach fosters hands-on, inquiry-based learning relevant to STEM fields. The study highlights PjBL's educational significance and its role in preparing students for technological careers, encouraging collaboration and future research.

The SLR has limitations, including reliance on a single database, which restricts the article range but is typical in bibliometric research. Merging metadata from various databases poses methodological challenges, with varied standardization. While WoS and PubMed are notable, Scopus was chosen for its extensive educational coverage, its inclusion of reputable journals, and its quality. Some analyses could be improved by using multiple databases, especially for incomplete temporal data. Implications for research include strategic direction for emerging scholars to identify key literature and collaborators and to inform policy and curriculum development based on evidence-backed practices. There's a need for inclusivity in international and multilingual scholarship, alongside interdisciplinary integration of educational theory with technology and cognitive science. Complementing current trends with longitudinal studies and qualitative inquiry can deepen understanding of research impact.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

The following statement should be used: “Conceptualization, SS and KK; methodology and formal analysis, SS; writing—preparation of the original draft, MK and SS; reference manager, citation, and language, RNA; finishing article, SS and KK.

AI DISCLOSURE STATEMENT

The author used ChatGPT to help improve the language and organization of this manuscript. All suggestions generated by the tool were carefully reviewed and edited by the author. Apart from this language assistance, no other artificial intelligence (AI) tools were used in the research, analysis, writing, or preparation of this study.

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