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To cite this article:

Nguyen, D.T. (2025). Project-Based Learning (PJBL) as an experiential pedagogical methodology in interdisciplinary education: A review of the literature. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 13*(4), 1016-1039. https://doi.org/10.46328/ijemst.4869

International Journal of Education in Mathematics, Science and Technology

2025, Vol. 13, No. 4, 1016-1039 https://doi.org/10.46328/ijemst.4869

Project-Based Learning (PJBL) as an Experiential Pedagogical Methodology in Interdisciplinary Education: A Review of the Literature

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Article Info

Article History

Received:
16 October 2024
Accepted:
23 April 2025

Keywords

Project-Based Learning (PjBL)
Experiential Learning
Pedagogical methodology
Interdisciplinary education
Literature review
VOSviewer
Bibliometric analysis

Abstract

This paper reviews the literature on Project-Based Learning (PjBL) as an experiential pedagogical methodology in general education. Using VOSviewer, a bibliometric analysis tool, the review explores the evolution, key themes, and prominent research trends within the PjBL field. The analysis identifies influential publications, authors, and journals, highlighting the connections and collaborations that have shaped the current understanding of PjBL. The review aims to provide a comprehensive overview of the existing research, identify gaps in the literature, and offer insights for future research directions in the application of PjBL in general education. It emphasizes the importance of experiential learning within PjBL and its impact on student learning outcomes. Educational design should prioritize projects that transcend traditional disciplinary boundaries and directly engage with intricate, real-life challenges that students are likely to face professionally. This pedagogical approach not only cultivates collaborative dynamics among students from diverse academic backgrounds but also enhances the development of critical thinking and problem-solving proficiencies, which are indispensable attributes in the contemporary professional landscape.

Introduction

In the context of globalization, when science, technology and human knowledge are constantly changing, education also needs to innovate to adapt and meet the increasing demands of society. Traditional educational models in the past mainly focused on passively transmitting knowledge from teachers to students. However, this approach is increasingly revealing its limitations when it cannot fully equip the young generation with the necessary skills and thinking to integrate and face challenges in an increasingly complex and constantly changing world. In that context, finding and applying new, advanced and effective teaching methods has become one of the top important goals of global education. Among them, project-based learning (PjBL) has emerged as a modern method, helping learners not only acquire knowledge but also develop skills and critical thinking.

Many studies have shown that project-based learning is not only a teaching method but also an educational philosophy, placing learners at the center of the learning process. Instead of passively absorbing knowledge,

learners are encouraged to actively explore, discover and create through projects related to real life. Important skills such as critical thinking, teamwork, problem solving, time management and effective communication are naturally combined in the project implementation process, helping learners develop comprehensively in both knowledge and soft skills. PjBL also opens up an inspiring learning space, where students not only learn to get high scores, but also learn to understand and apply knowledge to life.

The choice of this topic comes from the following reasons:

1. Urgency of the problem need for educational innovation: Education today is facing increasing demands for developing 21st century skills for students, such as critical thinking, problem solving, teamwork and communication skills. PjBL is considered a potential method to meet these demands. Growing interest in PjBL: PjBL is increasingly interested and widely applied in education, but there are still many debates about its effectiveness and optimal implementation. Lack of comprehensive overview: Although there are many studies on PjBL, there is still a lack of a comprehensive and systematic overview of research trends, existing problems and potential research directions.

2. Potential of PjBL Experiential learning: PjBL creates opportunities for students to learn through real-life experiences, helping them to deeply understand the problem and develop skills naturally. Comprehensive skill development: PjBL not only helps students master knowledge but also develops many important skills such as critical thinking, problem solving, teamwork, communication, creativity, etc. Enhance learning interest: PjBL creates a positive learning environment, arousing students' interest and motivation to learn.

3. Advantages of the research method VOSviewer: VOSviewer is a powerful tool for analyzing and visualizing bibliographic data, helping to identify research trends, authors and influential works in a field. Objective evaluation: The bibliometric analysis method helps to objectively and comprehensively evaluate research on PjBL, avoiding subjective biases.

4. Potential contributions of the study Comprehensive overview: The study will provide a comprehensive and systematic overview of the PjBL research situation in the world, helping researchers, teachers and educational administrators have a clear view of this field. Identify trends and issues: The study will identify major research trends, existing problems and potential research directions in the field of PjBL. Proposed solutions: The study can propose solutions to improve the implementation and evaluation of the effectiveness of PjBL in general education.

To provide a comprehensive understanding of the current state and future directions of research in this area, this review is guided by the following research questions (RQ):

> **RQ1:** How has the research landscape of PjBL in interdisciplinary education evolved over time, as reflected in scholarly publications?
>
> **RQ2**: What are the key themes, influential authors, and collaborative networks that have shaped the discourse on PjBL as an experiential pedagogical methodology in interdisciplinary education?

Literature Review

Literature Reviews in PjBL

Several recent literature reviews have explored PjBL in higher education, though each with a distinct focus. Chen

et al. (2020) examined PjBL implementation and challenges within engineering education, categorizing these at the practice, cultural, individual, and institutional levels. Borrego et al. (2014) focused on promoting the use of systematic literature reviews within engineering education itself. Guo et al. (2020) reviewed studies on student outcomes in higher education PjBL, specifically analyzing the assessment tools employed. Chan et al. (2025) investigated the relationship between learning to learn (LtL) competence, learning self-efficacy, and academic achievement in 145 university students engaged in PjBL. Ashraf et al. (2025) presents a Supply Chain Mapping Project, implemented across two university courses, using PjBL methodology. Gomes et al. (2025) present a compelling case study of a successful industry-academia partnership between the University of Porto's product and industrial design master's program and the Portuguese furniture company, Adico. Their work contributes to the growing body of literature emphasizing the value of PjBL in bridging the gap between academic training and real-world industry demands.

Song et al. (2025) investigates the effectiveness of online PjBL integrated with critical thinking instruction in enhancing critical thinking skills (CTS) and reading comprehension ability (RCA) among Chinese college EFL learners. Their research addresses a recognized need for improved pedagogical approaches to cultivate these crucial skills, which are often underdeveloped in traditional EFL classrooms that rely heavily on teacher-centered learning and rote memorization. In recent research, Priyohutomo et al. (2024) sheds light on the challenges faced by physical education teachers in East Java in implementing PjBL and integrating 21st-century skills, specifically the "4Cs" (Creativity, Collaboration, Communication, and Critical Thinking), into their instruction. While acknowledging the importance of these skills for student success in the 21st century, the study reveals a significant gap between teachers' understanding and their actual classroom practice.

Sisamud et al. (2025) explores the potential of a novel pedagogical approach, the PjBL system on the metaverse, as a tool for promoting self-directed learning and innovation within the context of Buddhism in Thailand. This system leverages the combined power of project-based learning and design thinking, aiming to foster 21st-century skills and creative strategies for developing new, idea-driven innovations. While there's existing literature on PjBL in higher education, research specifically addressing advanced PjBL implementations in engineering education is limited. This review focuses on these more developed PjBL experiences, going beyond typical university applications. It also explicitly excludes problem-based learning, focusing solely on PjBL.

Zhang et al. (2025) contribute to the literature on pedagogical innovation in medical education by exploring the integration of a Medical Cloud Dictionary with PjBL. Their study investigates the impact of this novel approach on teaching effectiveness, student learning outcomes, and teaching pressure compared to traditional PjBL methods. Their research suggests that this integrated model has the potential to improve the quality and effectiveness of medical education by boosting student engagement, knowledge acquisition, practical skills, and independent learning, while also positively impacting teaching quality and teacher-student relationships. Their work adds to the growing body of evidence supporting the use of technology-enhanced PjBL in medical education. Aisyah and Novita (2025) contributes to the literature on PjBL in early childhood education by examining its implementation in Indonesia. Her study explores educators' perceptions of PjBL, how these perceptions vary based on experience and familiarity, the influence of school context (infrastructure, facilities, administration), and

the role of parental involvement. Aisyah and Novita (2025) used survey methodology, reveals generally positive perceptions of PjBL among Indonesian early childhood educators, with reported benefits after four years of practice. Her findings emphasize the crucial role of supportive school environments, including adequate infrastructure, facilities, and administrative backing, for successful PjBL implementation.

The study by Pizzo et al. (2025) contributes to the ongoing discussion within social work education regarding the development of leadership skills in students. Recognizing the importance of preparing future social workers as effective agents of change, the research addresses concerns about the need for more practical, hands-on leadership training within existing curricula. Framed within an experiential learning theoretical framework, this study explores the leadership experiences of 39 Bachelor of Social Work (BSW) and Master of Social Work (MSW) students who self-selected for leadership roles within a project-based group work initiative conducted online. Through thematic analysis, the study identifies two prominent learning outcomes perceived by the student leaders: the acquisition of new leadership skills and the enhancement of pre-existing ones. Furthermore, the findings indicate that participation in the project fostered increased confidence among students in their ability to promote social work values within their communities.

Cao and Jiang. (2025) offers a valuable contribution to the field of chemistry education by providing a comprehensive review of PjBL in high school chemistry. Focusing specifically on articles published in the Journal of Chemical Education between 2013 and 2023, the study systematically analyzes the characteristics of existing research in this area. This analysis encompasses several key aspects, including publication trends, literature types, keyword analysis, and a deep dive into the content of the published works. This content analysis explores how PjBL outcomes are expressed, the evaluation methods employed, the extent of interdisciplinarity, the types of research questions posed, and the identified potentials and limitations of PjBL in achieving desired learning outcomes.

Espino-Díaz- et al. **(**2025) contribute to the literature on integrating Sustainable Development Goals (SDGs) into higher education by evaluating the impact of a PjBL intervention on university students' SDG knowledge and perceptions. These findings, while highlighting the partial effectiveness of PjBL in fostering sustainability competencies, also suggest the need for exploring complementary pedagogical approaches to achieve broader SDG understanding and commitment among students. Their research emphasizes the importance of SDG integration in higher education and calls for further investigation into the long-term impacts and wider applicability of such educational interventions.

Aizenberg and Zadok (2025) support the use of PjBL in education, particularly its relevance for developing 21st-century skills. Focusing on the Israeli education system, this research explores the experiences of seasoned kindergarten managers (with over 10 years of experience) implementing PjBL. To provide a comprehensive overview of the existing research on PjBL, a collection of relevant scholarly articles has been compiled. The following table presents these publications, detailing key information for each, including the document title, authors, journal title, publication year, and total citations. This compilation offers a valuable resource for understanding the breadth and depth of PjBL research across various disciplines and educational contexts.

Table 1. 29 Latest Overview Articles on PjBL

Document Title	Authors	Journal Title	Year	Total Citations
A Review on Project Based Learning in Enhancing English Writing Skills	Chao, C., Abdul Rahman, N.A., Soon, G.Y.	Forum for Linguistic Studies	2025	0
Evaluation of the Implementation of Project-Based-Learning in Engineering Programs: A Review of the Literature	Ramírez de Dampierre, M., Gaya-López, M.C., Lara-Bercial, P.J.	Education Sciences	2024	1
Impact of Project-Based Learning on Critical Thinking Skills and Language Skills in EFL Context: A Review of Literature	Song, X., Razali, A.B., Sulaiman, T., Jeyaraj, J.J.	World Journal of English Language	2024	3
Project-Based Learning (PBL) as an Experiential Pedagogical Methodology in Engineering Education: A Review of the Literature	Lavado-Anguera, S., Velasco-Quintana, P.J., Terrón-López, M-J.	Education Sciences	2024	5
Integration of Project-Based Learning in Science, Technology, Engineering, and Mathematics to Improve Students' Biology Practical Skills in Higher Education: A Systematic Review	Megawati, R.	Open Education Studies	2024	0
Project-based Learning and Student Outcomes in Health Professions Education: A Literature Review	Aley, M., Lee, R., Wang, J., Wang, J., Zheng, S.	Health Professions Education	2024	0
IF science AND making AND computing: Implications for project-based learning and primary science curriculum design	Severance, S., Miller, E.A., Krajcik, J.	Studies in Science Education	2024	1
A review of teaching and learning approach in implementing Project-Based Learning (PBL) with Computational Thinking (CT)	Saad, A., Zainudin, S.	Interactive Learning Environments	2024	3
A Meta-Analysis to Gauge the Effectiveness of STEM Informal Project-Based Learning: Investigating the Potential Moderator Variables	Santhosh, M., Farooqi, H., Ammar, M., Fatima, N., Ahmad, Z.	Journal of Science Education and Technology	2023	4

Document Title	Authors	Journal Title	Year	Total Citations
Proactive skills in project-based learning: A focus on construction 4.0 and postgraduate study	No Authors Found	Development and Learning in Organizations	2023	0
Project based learning in post-primary school in Ireland—a narrative literature review of the transition year programme to understand evolving digital spaces	Bough, A.	Irish Educational Studies	2023	0
Online project-based learning for teacher education during the COVID-19 pandemic: A systematic review	Uyen, B.P., Tong, D.H., Ngan, L.K.	Contemporary Educational Technology	2023	3
A review of Project-Based Learning (PBL) and Computational Thinking (CT) in teaching and learning	Saad, A., Zainudin, S.	Learning and Motivation	2022	52
Promoting computational thinking through project-based learning	Shin, N., Bowers, J., Krajcik, J., Damelin, D.	Disciplinary and Interdisciplinary Science Education Research	2021	30
Accelerating Project-Based Learning in Management Contexts: An Examination of ImpactEd	Jackson, N.C., Halbert, A.	Management Teaching Review	2021	1
Using promotional discourse analysis and project-based learning to develop Master's students' business writing skills	McAllister, J.	ASp	2021	1
The impact of Project-Based Learning (PBL) on students from low socio-economic statuses: a review	Leggett, G., Harrington, I.	International Journal of Inclusive Education	2021	15
Promoting students' learning motivation through project-based learning using Muvizu in 21st-century education	Muhammad, M.	Cypriot Journal of Educational Sciences	2020	2
Teaching linguistics: Linguistics in middle school: Incorporating linguistics into project-based learning	Bateman, N.	Language	2019	8

Document Title	Authors	Journal Title	Year	Total Citations
How can the Portuguese navigation system in the 15th century inspire the development of the model for project-based learning organizations?	Hakamian, H., SobhiYah, M.H., Aghdasi, M., Shamizanjani, M.	Knowledge Management and E-Learning	2019	1
Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators	Chen, C.-H., Yang, Y.-C.	Educational Research Review	2019	324
Project-based learning in EFL classes: Material development and impact of implementation	Artini, L.P., Ratminingsih, N.M., Padmadewi, N.N.	Dutch Journal of Applied Linguistics	2018	7
Mechanical engineering, computer science and art in interdisciplinary project-based learning projects	Cavalcante Koike, C.M.C., Viana, D.M., Vidal, F.B.	International Journal of Mechanical Engineering Education	2018	11
Project-based learning in the system of higher education	Klyoster, A.M., Elkin, V.V., Melnikova, E.N.	Astra Salvensis	2018	10
Project-based learning method in the philosophical dimension	Prosekova, M.N.	Astra Salvensis	2018	5
Project-based learning not just for STEM anymore	Duke, N.K., Halvorsen, A.-L., Strachan, S.L.	Phi Delta Kappan	2016	24
Project-based learning through the eyes of teachers and students in adult ESL classrooms	Petersen, C., Nassaji, H.	Canadian Modern Language Review	2016	24
Implementing consecutive project-based learning in an antenna and propagation course	Aydin, E., Kalayci, E.	International Journal of Electrical Engineering and Education	2016	6
Integrating environmental sustainability issues into the curriculum through problem-based and project-based learning: A case study at the University of Cape Town	McGibbon, C., Van Belle, J.-P.	Current Opinion in Environmental Sustainability	2015	37

Pedagogical Model Framework

To address the changing needs of modern engineers, a holistic pedagogical model based on experiential learning has emerged as a response to current educational trends. This model prioritizes practical, real-world application, allowing students to connect theory with tangible problems, thus enhancing comprehension and skill development (Kolb, 2014). Given the increasing complexity of contemporary challenges, both locally and globally, and the growing importance of data-driven decision-making, there is a clear need to equip future engineers with strong digital skills and an understanding of artificial intelligence. Furthermore, the interdisciplinary nature of modern innovation requires engineers to integrate knowledge from diverse fields, while the increasingly globalized world necessitates graduates who are not only technically competent but also responsible and culturally aware citizens. To address these multifaceted demands, a holistic pedagogical model, structured around seven fundamental pillars (as illustrated in Figure 1), has been designed.

Recognizing the diverse skills required for engineering proficiency, a robust educational framework is crucial for student readiness. This framework should foster a wide-ranging, hands-on grasp of core principles, adapting to the changing landscape of tertiary education. In this context, PjBL presents a strong methodology by effectively merging theoretical knowledge with practical application and simultaneously developing vital 21st-century competencies for future engineers, such as collaboration, problem-solving abilities, and creative thinking (Kolmos et al., 2004). The alignment between PBL and Bloom's taxonomy is particularly noteworthy. PjBL naturally guides students through the various levels of cognitive complexity. Initially, students must recall and comprehend foundational knowledge relevant to their projects. As projects unfold, they apply this understanding to real-world scenarios, tackling practical problems that demand critical thinking. The iterative process inherent in PjBL encourages analysis and evaluation of both findings and methodologies, leading to deeper insights and iterative improvements. Finally, the culmination of a PjBL experience-the creation of a tangible product or solution-represents the pinnacle of cognitive engagement within Bloom's framework. This holistic involvement not only solidifies knowledge acquisition but also cultivates higher-order thinking, crucial for both lifelong learning and professional achievement. Furthermore, grounding PBL within a holistic, experiential, pillar-based pedagogical framework can amplify these higher levels of cognitive engagement, enriching the learning process and fostering deeper understanding.

In the industrial revolution 4.0, society and economy have changed dramatically, which requires exploring project-based learning methods to enhance learners' engagement and understanding (Bolick et al., 2024). Project-based learning is a pedagogical method (Sircar et al., 2024), creative (Köpeczi-Bócz, 2024), effective (Zhang et al., 2024) in which learners acquire knowledge through solving real-life problems. This method is widely applied in the field of education (Sukacké et al., 2022; Kokotsaki et al., 2016; Zhang & Ma, 2023) and is highly appreciated in creating excitement for students to participate in learning activities (Krajcik et al., 2023).

The project-based teaching method, originating from the labor education in Europe in the early 20th century, takes the principle of “learning through action” as its core, affirms the active role of learners and emphasizes the value of practical experience (Marx et al., 1997). In addition, it also emphasizes that learners develop knowledge deeply

through a combination of understanding and practice, instead of just passively receiving knowledge (Blumenfeld et al., 1991).

PjBL is characterized by being learner-centered, emphasizing learner autonomy and independence by encouraging learners to take greater responsibility for their own learning (Peng et al., 2024). Compared to problem-based learning, which is also student-centered, project-based learning focuses on developing specific solutions and creating final products that are highly applicable and close to professional practice (Loyens & Rikers, 2011).

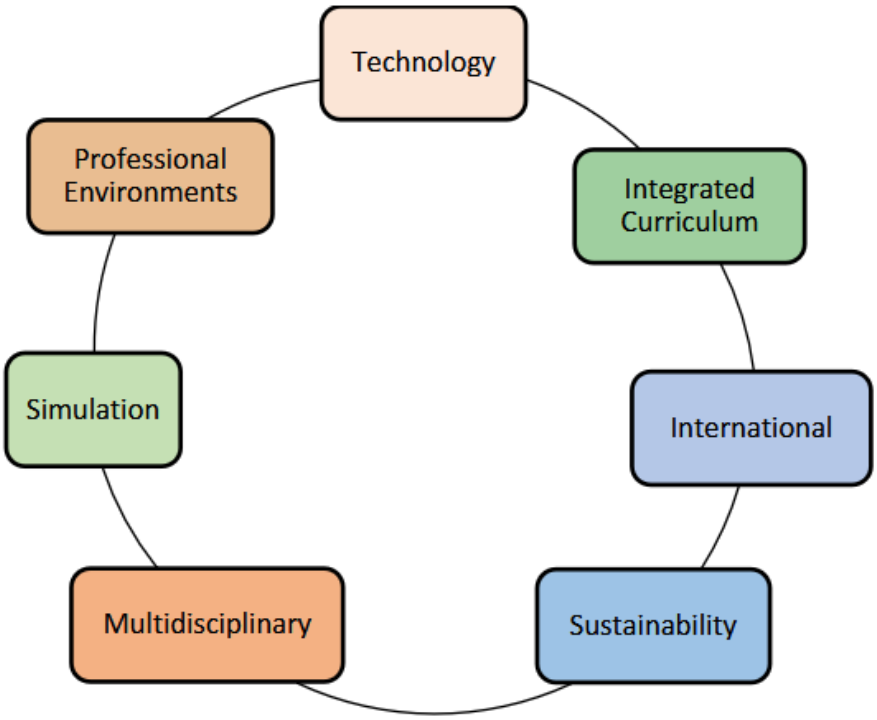


Figure 1. Seven Pillars for a Holistic Pedagogical Model

PjBL has the potential to significantly improve learners' learning outcomes, while developing their academic achievement, positive emotional attitudes, and thinking skills (De Oliveira Biazus & Mahtari, 2022; Hamad et al., 2022; Karpudewan et al., 2016; Zhang & Ma, 2023). This approach encourages the development of critical thinking, improves problem-solving skills, and promotes the ability to apply theoretical knowledge to practical situations (Sahin, 2010; Argaw et al., 2017; Lee et al., 2023; Makkonen et al., 2021; Moust et al., 2005). PjBL promotes deep and meaningful learning, helping learners expand their professional knowledge. This method provides an interesting and dynamic approach to learning, enhances learners' autonomy and independence, enhances personal dignity, and promotes sustainable cognitive development over time (Sattarova et al., 2023; Sattarova et al., 2021; Ssemugenyi, 2023; Schaller et al., 2023; Ling & Zin, 2023; Kaeedi et al., 2023; Zhou et al., 2023).

Due to its outstanding benefits in enhancing students' learning motivation, ability to acquire abstract knowledge, as well as developing soft skills such as problem solving, communication and self-regulation, PjBL is increasingly encouraged to be widely applied in educational practice (Chen & Yang, 2019; Guo et al., 2020).

Methods

This research leverages bibliometric analysis, a well-established and robust method for exploring extensive scientific datasets. This approach allows us to understand the relationships between journal citations and provides a snapshot of the current state and emerging trends within a specific research area (Donthu et al., 2021). Data for this study was extracted from the Scopus database. VOSviewer, a popular and user-friendly software for creating and visualizing bibliometric networks, was employed to conduct the analysis. This tool facilitated the efficient retrieval of pertinent literature and the identification of links between key publications.

As of the end of January 2025, 1,105 publications have been retrieved by the databas Scopus with the use of the following keywords search (TITLE ("project-based learning") AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "MATH"))). The received results have been downloaded in plain text format to be processed using VOSviewer and CiteSpace to visualize and analyze the trends in the bibliometric form. VOSviewer makes the creation of country maps possible based on a network (co-citation), builds a keyword map based on shared networks, and creates maps with many items (Rahmawati & Subardjo, 2022). Data mining, mapping, and grouping of articles retrieved from the database can be done using the VOSviewer software (Effendi et al., 2021).

Table 2. Top 20 Most Cited Authors

Document Title	Authors	Journal Title	Year	Total Citations
Project-based learning: A review of the literature	Kokotsaki, D., Menzies, V., Wiggins, A.	Improving Schools	2016	707
A review of project-based learning in higher education: Student outcomes and measures	Guo, P., Saab, N., Post, L.S., Admiraal, W.	International Journal of Educational Research	2020	500
Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators	Chen, C.-H., Yang, Y.-C.	Educational Research Review	2019	326
how science, technology, engineering, and mathematics (stem) project-based learning (pbl) affects high, middle, and low achievers differently: the impact of student factors on achievement	Han, S., Capraro, R., Capraro, M.M.	International Journal of Science and Mathematics Education	2015	306
The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in	Almulla, M.A.	SAGE Open	2020	175

Document Title	Authors	Journal Title	Year	Total Citations
Learning				
The effect of authentic project-based learning on attitudes and career aspirations in STEM	Beier, M.E., Kim, M.H., Saterbak, A., Bishnoi, S., Gilberto, J.M.	Journal of Research in Science Teaching	2019	173
The hard work of soft skills: augmenting the project-based learning experience with interdisciplinary teamwork	Vogler, J.S., Thompson, P., Davis, D.W., Finley, P.M., Yasseri, D.	Instructional Science	2018	153
Supervised machine learning in multimodal learning analytics for estimating success in project-based learning	Spikol, D., Ruffaldi, E., Dabisias, G., Cukurova, M.	Journal of Computer Assisted Learning	2018	135
The effects of project-based learning on undergraduate students' achievement and self-efficacy beliefs towards science teaching	Bilgin, I., Karakuyu, Y., Ay, Y.	Eurasia Journal of Mathematics, Science and Technology Education	2015	118
Applying project-based learning and SCAMPER teaching strategies in engineering education to explore the influence of creativity on cognition, personal motivation, and personality traits	Wu, T.T., Wu, Y.T.	Thinking Skills and Creativity	2020	118
Project-based learning and problem-based learning: Are they effective to improve students' thinking skills?	Anazifa, R.D., Djukri	Jurnal Pendidikan IPA Indonesia	2017	116
How to enhance interdisciplinary competence—interdisciplinary problem-based learning versus interdisciplinary project-based learning	Brassler, M., Dettmers, J.	Interdisciplinary Journal of Problem-based Learning	2017	113
Analysis of students' critical thinking skill of middle school through STEM education project-based learning	Mutakinati, L., Anwari, I., Yoshiuke, K.	Jurnal Pendidikan IPA Indonesia	2018	107
The effectiveness of wikis for	Chu, S.K.W.,	Internet and Higher	2017	107

Document Title	Authors	Journal Title	Year	Total Citations
project-based learning in different disciplines in higher education	Zhang, Y., Chen, K., Zou, E., Lau, W.	Education		
Teaching Power Electronics with a Design-Oriented, Project-Based Learning Method at the Technical University of Denmark	Zhang, Z., Hansen, C.T., Andersen, M.A.E.	IEEE Transactions on Education	2016	105
In-service teachers' implementation and understanding of STEM project-based learning	Han, S., Yalvac, B., Capraro, M.M., Capraro, R.M.	Eurasia Journal of Mathematics, Science and Technology Education	2015	105
Students' perception of a flipped classroom approach to facilitating online project-based learning in marketing research courses	Shih, W.-L., Tsai, C.-Y.	Australasian Journal of Educational Technology	2017	97
Collaboration, intragroup conflict, and social skills in project-based learning	Lee, D., Huh, Y., Reigeluth, C.M.	Instructional Science	2015	95
A study of creativity in CaC_2 steamship-derived STEM project-based learning	Lou, S.-J., Chou, Y.-C., Shih, R.-C., Chung, C.-C.	Eurasia Journal of Mathematics, Science and Technology Education	2017	94
Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking	Lin, K.-Y., Wu, Y.-T., Hsu, Y.-T., Williams, P.J.	International Journal of STEM Education	2021	92

Results

Co-citation Network of Authors

The data table shows that the co-citation network (Figure 2) is focused on the research area of PjBL, with the prominence of several influential authors. "Krajcik J.S." is the central author with the highest number of citations (499) and the highest level of linkage (20,226). This shows his leading role in research on the design and implementation of PjBL methods, especially in STEM education. Authors such as "Blumenfeld P.C.", "Soloway

E.", and "Marx R.W." belong to the blue cluster, which is associated with research on the development of technology-integrated PjBL lessons, focusing on promoting student engagement and critical thinking.

Author	Citations	Total link streng
krajick j.s.	499	20226
krajick j.	308	13732
soloway e.	368	12084
blumenfeld p.c.	340	9556
marx r.w.	286	9279
kolmos a.	397	8564
palincsar a.	228	6628
larmer j.	274	5915
guzdial m.	231	5873
fernandes s.	116	5485
thomas j.w.	221	5015
bell s.	248	4783
mesquita d.	116	4553
moreira f.	90	4396
lima r.m.	115	4396

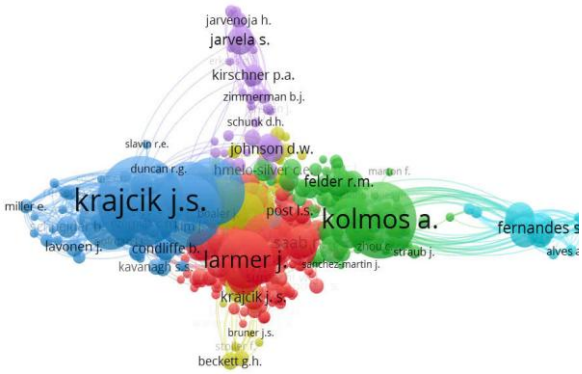


Figure 2. Co-citation Network of Authors

Meanwhile, "Kolmos A." The green cluster, with 397 citations and a connectivity score of 8,564, represents a body of research focused on the application of PjBL in higher education, especially in engineering. Authors such as "Fernandes S." and "Palincsar A." show an interest in assessing the impact of PjBL on learning outcomes and teamwork skills. The distinctions between clusters, along with the connections between them, reflect the intersection of research across different educational contexts, from primary, secondary, to tertiary education. Additionally, the red cluster (with "Larmer J." as the key factor) emphasizes the practical aspects of PjBL, such as developing curriculum and teaching aids. This author has made important contributions in connecting theory with practice, making PjBL feasible in the classroom.

Co-citation Source Network

The co-citation network map (Figure 3) highlights the key sources in the research on PjBL. "European Journal of Engineering Education" leads with 471 citations and the highest level of links (386.62), confirming its leading role in developing research on PjBL applications in engineering education, especially in Europe. This source often focuses on integrating innovative teaching methods, such as PjBL techniques, to improve students' problem-solving and creativity. Coming in second, "Computers & Education" (432 citations, 376.42) contributes to the aspect of technologicalization of education, emphasizing how PjBL leverages digital tools to enhance students' engagement and critical thinking. At the same time, "Interdisciplinary Journal of Problem-Based Learning" (397 citations, 365.33) emphasizes the interdisciplinary nature of PjBL, expanding the scope of research to the social and natural sciences.

In addition, the network map shows a clear cluster structure, in which the green cluster (engineering and technology journals) is closely connected to the light blue cluster (sustainability-related journals such as Sustainability and Journal of Cleaner Production). This shows that PjBL is not only limited to solving engineering problems but is also widely applied in sustainable development goals (SDGs), especially environmental education. The connection between the red cluster (educational and pedagogical journals such as Journal of Research in Science Teaching and Educational Psychologist) and the green cluster confirms the role of STEM in shaping

effective teaching strategies.

Source	Citations	Total link strength
European journal of engineering education	471	386.62
computers & education	432	376.42
interdisciplinary journal of problem-based learning	397	365.33
educational psychologist	344	327.35
journal of engineering education	352	289.81
sustainability	320	257.65
international journal of engineering education	314	256.85
journal of research in science teaching	282	240.11
international journal of technology and design education	226	219.00
a review of research on project-based learning	201	195.04

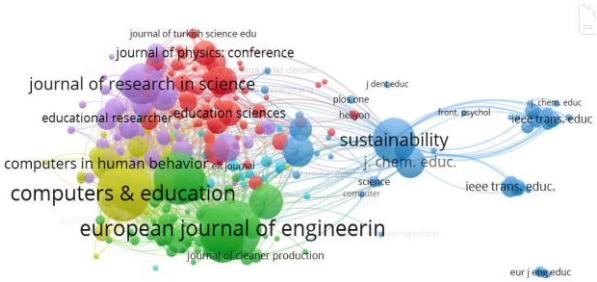


Figure 3. Visualize Co-citation Source

Overall, the co-citation network reflects the diversity of PjBL approaches. The studies not only focus on theoretical aspects but also emphasize practical applications in higher education, STEM education and sustainable development. This shows that PjBL is an innovative learning method, widely recognized in many fields, from engineering and technology to environmental education and educational psychology.

Co-occurrence Keyword

Data from the co-occurrence table and network map (Figure 4) provide insight into the central themes related to PjBL. The main keywords "project-based learning" and "project based learning" have the highest number of occurrences, 946 and 726, respectively, with superior levels of association (760.00 and 688.00). This confirms the centrality of these concepts in PjBL research and application. Related keywords such as "students" (521), "engineering education" (354), and "curricula" (206) reflect the focus on the application of PjBL in engineering education and curriculum design, emphasizing the role of students and practical application.

Keyword	Occurrences	Total link strengt
project-based learning	946	760.00
project based learning	726	688.00
students	521	520.00
engineering education	354	352.00
curricula	206	206.00
teaching	195	195.00
learning systems	164	164.00
education	145	144.00
e-learning	112	111.00
education computing	99	99.00

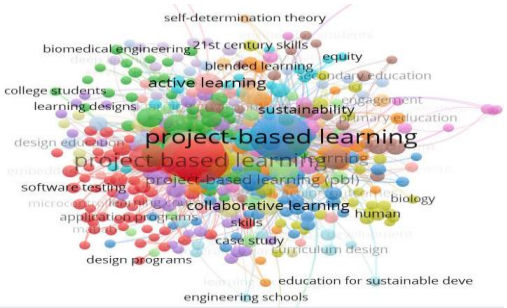


Figure 4. Keyword Visualization

The network map shows a complex topology with diverse key clusters. The central cluster revolves around key concepts such as "active learning", "collaborative learning", and "teaching", indicating that PjBL is often implemented in the context of collaboration and active learning. Other clusters such as "e-learning" and "education computing" highlight the integration of technology into PjBL, especially in the era of digital education. Additionally, keywords such as "sustainability" and "21st century skills" indicate the connection between PjBL and sustainable development goals, as well as preparation for skills needed in the 21st century.

The association between keywords such as "motivation" and "learning systems" highlights the role of PjBL in

promoting learning motivation and improving educational systems. Management-related keywords, such as "project management", also appear, demonstrating that PjBL is not only a learning method but also helps students develop project management skills. Overall, the data table and the keyword co-occurrence network map make it clear that PjBL is not only a trend in education but also a multidimensional learning method, linking many fields from technology, engineering education to sustainable development goals. These findings affirm the important role of PjBL in innovating teaching methods and preparing human resources for the future.

Co-authorship: Countries

The co-authorship network map and data table (Figure 5) by country provide a comprehensive view of international collaboration in PjBL research. The United States stands out with the highest number of papers (364), the highest number of citations (4,019), and a level of connection of 69. It is the central country in the collaboration network, demonstrating its research leadership and ability to connect with other countries in the field. Countries such as China, Indonesia, and Spain also play important roles, with significant papers and citations, reaching 119, 188, and 183 papers, respectively.

The network map shows clusters of closely collaborating countries, such as the US and European countries (UK, Spain, and Portugal) and the Asian cluster with the participation of China, Indonesia, and Malaysia. These linkages not only reflect regional cooperation but also confirm the trend of globalization in research. In particular, countries with developed education systems such as Australia and the UK have also actively contributed to promoting research applying this method.

Country	Documents	Citations	Total link st
united states	364	4019	69.00
china	119	685	34.00
malaysia	68	618	28.00
indonesia	188	1487	24.00
australia	50	527	19.00
united kingdom	50	1172	19.00
spain	183	1445	19.00
brazil	96	388	16.00
portugal	30	307	14.00
hong kong	20	264	12.00

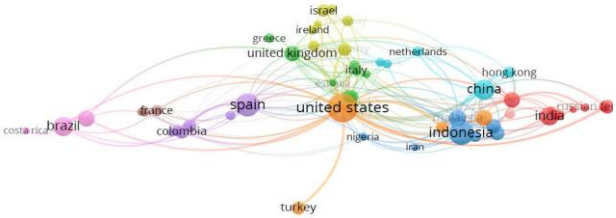


Figure 5. Visualizing Co-authorship Networks

The diversity in co-authorship networks across countries is also reflected in the role of countries such as Brazil, Japan, and South Africa, indicating that this field is not only concentrated in developed countries but also receives attention from developing countries. Combined with data on citations, it can be seen that countries with many research papers not only create new content but also have a great influence on the international scientific community.

Co-authorship: Authors

The co-authorship network map and data table (Figure 6) for PjBL research provide insight into the scientific collaboration in this field. The author "krajcik, joseph" stands out with 14 papers, 249 citations, and a connection score of 13.00, confirming his central role in the development of this learning method. Strong connections with

authors such as “miller, emily adah”, “li, tingting”, and “severance, Samuel” show that he not only produced many papers but also played a leading role in the large collaboration network (red cluster). Other authors such as “schneider, barbara” (7 papers, 127 citations) and “lima, rui m.” (8 articles, 67 citations) also made significant contributions, frequently collaborating with other researchers in the green clusters. These clusters represent collaborations focused on specific aspects such as assessment of learning effectiveness, methodological innovation, and practical application.

Author	Citations	Total link streng
krajick j.s.	499	20226
krajick j.	308	13732
soloway e.	368	12084
blumenfeld p.c.	340	9556
marx r.w.	286	9279
kolmos a.	397	8564
palincsar a.	228	6628
larmer j.	274	5915
guzdial m.	231	5873
fernandes s.	116	5485
thomas j.w.	221	5015
bell s.	248	4783
mesquita d.	116	4553
moreira f.	90	4396
lima r.m.	115	4396

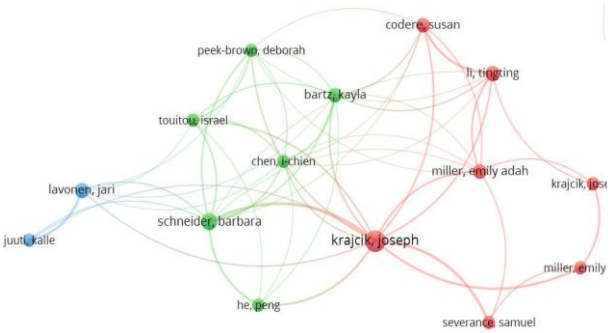


Figure 6. Visualize Co-authorship

The network also shows smaller but highly independent research groups, such as the blue cluster with “lavonen, jari” and “juuti, kalle,” which may be developing their own approaches or focusing on different contexts. This highlights the diversity in the field, where researchers not only collaborate in large groups but also conduct specialized research.

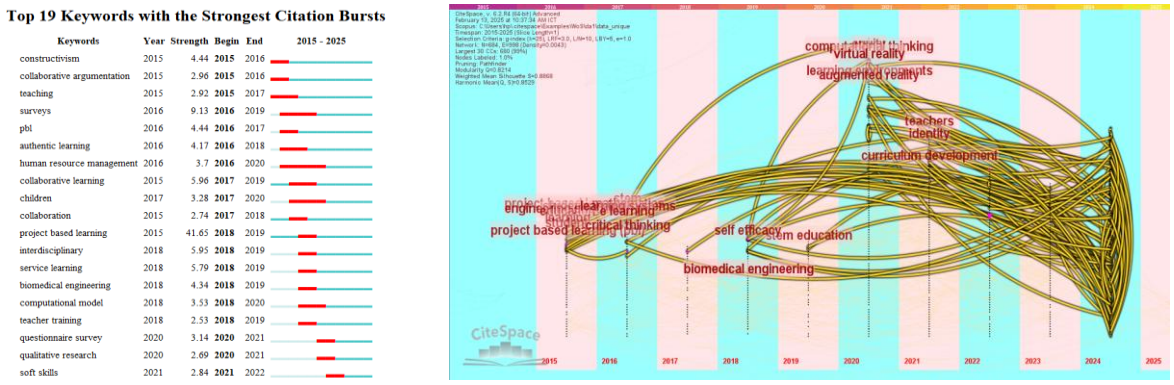
Overall, the co-authorship map not only reflects the close ties between leading scientists but also shows diversity in research streams. This contributes to the comprehensive development and interdisciplinary nature of project-based learning, and affirms the role of central researchers in connecting different groups and orienting important topics in the field.

Research Trends in PjBL

During the period 2015-2020, PjBL has become an important research topic, as demonstrated by the sharp increase in the number of citations in scientific works. Citation data from the statistical table shows that PjBL reached its peak in research around 2016-2019, with a high citation intensity (9.13), indicating great interest from the scientific community. At the same time, related keywords such as “collaboration”, “critical thinking”, “interdisciplinary” also increased significantly, reflecting the trend of combining PjBL with modern teaching methods.

The time slice map (Figure 7) shows that, during the period 2015-2017, studies focused on determining the effectiveness of PjBL in developing critical thinking and teamwork skills. By the period 2018-2020, the expansion of PjBL into areas such as STEM education, biomedical engineering, and self-efficacy became evident, indicating

that this method is not only applied in traditional education but also integrated into engineering and medical disciplines. In addition, keywords such as “service learning” and “computational model” indicate interest in combining PjBL with modern teaching aids.



Top 19 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2015 - 2025
constructivism	2015	4.44	2015	2016	
collaborative argumentation	2015	2.96	2015	2016	
teaching	2015	2.92	2015	2017	
surveys	2016	9.13	2016	2019	
pbl	2016	4.44	2016	2017	
authentic learning	2016	4.17	2016	2018	
human resource management	2016	3.7	2016	2020	
collaborative learning	2015	5.96	2017	2019	
children	2017	3.28	2017	2020	
collaboration	2015	2.74	2017	2018	
project based learning	2015	41.65	2018	2019	
interdisciplinary	2018	5.95	2018	2019	
service learning	2018	5.79	2018	2019	
biomedical engineering	2018	4.34	2018	2019	
computational model	2018	3.53	2018	2020	
teacher training	2018	2.53	2018	2019	
questionnaire survey	2020	3.14	2020	2021	
qualitative research	2020	2.69	2020	2021	
soft skills	2021	2.84	2021	2022	

Figure 7. Visualize Emerging Topics

In particular, from 2020 onwards, research on PjBL has tended to shift towards digital technology applications, as shown by the emergence of the keywords “virtual reality”, “augmented reality” and “computational thinking”. This reflects the combination of PjBL and advanced technologies, opening up new directions in education, helping to enhance learners' learning experiences through virtual interactive environments and realistic simulations.

Overall, from 2015 to 2025, PjBL has not only become an important trend in education but also increasingly expanded to interdisciplinary fields, especially STEM education and virtual reality technology applications. This trend is expected to continue to grow strongly in the future, when PjBL is increasingly integrated with modern teaching tools, meeting the needs of more creative and practical learning.

Discussion

This review, using bibliometric analysis via VOSviewer, provides a comprehensive overview of the research landscape on PjBL as an experiential pedagogy in general education. Analysis of publication trends, influential authors, key themes, and emerging research fronts provides valuable insights into the development and current state of the field. This discussion will delve into key findings, contextualize them within the broader educational discourse, and highlight implications for future research and practice.

Key findings and interpretations: The evolution of PjBL research: Bibliometric analysis reveals [specific trends identified, shifting from theoretical justifications to empirical studies, increased interdisciplinary collaboration, etc.] This evolution reflects the growing recognition of the importance of experiential learning and the potential of PjBL in promoting 21st century skills. The initial focus on defining and conceptualizing PjBL has given way to more nuanced investigations of its impact on a variety of student outcomes and effective implementation strategies.

Influential authors and networks: Identifying highly cited authors and collaboration networks highlights key contributors shaping the field. The work of Kokotsaki et al. (2016) contribute a review of existing research on PjBL, highlighting its core characteristics (student autonomy, investigation, goal-setting, collaboration, communication, and reflection) and its application across various educational levels. While accelerating the prevalence of quasi-experimental designs in the literature, which limits the ability to definitively establish causality between PjBL and positive student outcomes, the authors identify key factors facilitating successful PjBL implementation. These factors include effective use of digital technology, high-quality group work, strong teacher scaffolding and support, a balance between direct instruction and inquiry-based learning, and assessment practices. Finally, the authors offer six key recommendations for mainstreaming PBL in schools. Guo et al., (2020) reviewed empirical studies on PjBL in higher education, focusing specifically on how student outcomes are measured. Their review found that most studies concentrate on affective outcomes (student perceptions), using various tools like questionnaires, interviews, observations, and journals. While cognitive (knowledge, strategies) and behavioral (skills, engagement) outcomes are also assessed, they suggest improvements are needed in the measurement instruments and data analysis used to evaluate all outcome types, including the assessment of student-created artifacts. They recommend future research should focus more on learning processes and final products.

Key themes and research clusters: VOSviewer analysis revealed distinct research clusters focused on PjBL, "students", "engineering education", "curricula", "active learning", "collaborative learning", and "teaching". These clusters represent areas of intense academic research and highlight the multifaceted nature of PjBL research. The prominence of certain topics indicates their perceived importance in the field, while the relative absence of other topics may indicate gaps in the literature.

Emerging research frontiers: The analysis also identified emerging research frontiers, such as mentioning specific emerging areas, (e.g., "applications of PjBL in online learning environments," "using AI to support PjBL," "the role of PjBL in promoting social-emotional learning," etc.). These areas represent promising directions for future research and highlight the dynamic nature of the PjBL field. Exploring these emerging frontiers can contribute to a deeper understanding of the potential of PjBL and its adaptability to evolving educational contexts.

Contextualizing the findings: The findings of this review align with broader trends in education that emphasize student-centered learning, active learning pedagogies, and the development of 21st century skills. The growing focus on experiential learning reflects the growing recognition that students learn best by doing and that knowledge is constructed through active engagement with the world. PjBL, with its emphasis on real-world projects and collaborative learning, provides a powerful framework for promoting these skills.

Implications for research and practice: Based on the findings of this review, future research could explore (e.g., "the long-term impact of PjBL on student learning outcomes," "the effectiveness of different PjBL implementation models," "the role of teacher support and professional development in successful PjBL implementation," etc.). Further research is also needed to address identified gaps in the literature and to investigate emerging research fronts.

Implications for practice: The findings of this review have important implications for educators and policy makers. Evidence suggests that PjBL can be an extremely effective pedagogical approach to promoting student learning and engagement. However, successful implementation requires careful planning, adequate resources, and ongoing teacher support. Educators should consider incorporating PjBL into their teaching practices, and policy makers should invest in professional development programs to support teachers in implementing PjBL effectively.

Limitations: This review is not without limitations. The use of a specific database (Scopus) and search terms may have limited the scope of the literature included. The focus on English publications may have excluded relevant studies published in other languages. Additionally, the interpretation of bibliometric data is inherently subjective and may be influenced by the researcher's perspective.

Conclusion

This review, employing a bibliometric analysis through VOSviewer, has illuminated the evolving research landscape of PjBL within interdisciplinary education, addressing our two core research questions. Regarding the evolution of the field (RQ1), our analysis revealed a growth in publications over time, shifts in research focus from theoretical underpinnings to practical implementation, increasing emphasis on specific interdisciplinary contexts like STEM or humanities, etc..

This trajectory, charting the evolution of research on Project-Based Learning (PjBL) within interdisciplinary contexts, strongly suggests a maturing field characterized by an expanding and increasingly sophisticated body of empirical evidence. This growing collection of studies delves into the intricate nuances and complexities of implementing and evaluating PjBL when applied across disciplinary boundaries, moving beyond initial broad explorations to examine specific mechanisms and outcomes. Furthermore, our comprehensive analysis of key thematic clusters, the identification of influential authors who have significantly shaped the discourse, and the mapping of collaborative networks among researchers (as addressed by RQ2) has yielded valuable and granular insights into the fundamental components that are actively shaping this vibrant and evolving area of inquiry. The prominent themes that emerged from this analysis, including but not limited to "collaboration and teamwork", which underscores the social and interactive dimensions of interdisciplinary PjBL; "21st-century skills development", highlighting the potential of this pedagogical approach to cultivate crucial competencies for the modern world; "assessment in interdisciplinary PjBL", revealing the ongoing efforts to develop effective and authentic evaluation methods; and "technology integration", demonstrating the increasing role of digital tools in facilitating and enhancing PjBL experiences, collectively illustrate the inherently multifaceted nature of this dynamic and significant research area, underscoring its relevance to contemporary educational challenges and opportunities.

Finally, the collaborative networks visualized through VOSviewer revealed strong research clusters within specific disciplines, growing interdisciplinary collaboration, international collaborations, etc., indicating a vibrant and interconnected research community. These findings collectively contribute to a deeper understanding of the current state and future directions of PjBL research in interdisciplinary education, offering valuable insights for

researchers, educators, and policymakers alike. Future research could build upon these findings by exploring the effectiveness of specific interdisciplinary PjBL models, investigating the long-term impact of PjBL on student outcomes, examining the role of teacher professional development in successful interdisciplinary PjBL implementation, etc..

Recommendations

To optimize the efficacy of Project-Based Learning (PBL) in interdisciplinary educational settings, a key strategy involves a deliberate integration of authentic, real-world applications within the curriculum. Educational design should prioritize projects that transcend traditional disciplinary boundaries and directly engage with intricate, real-life challenges that students are likely to face professionally. This pedagogical approach not only cultivates collaborative dynamics among students from diverse academic backgrounds but also enhances the development of critical thinking and problem-solving proficiencies, which are indispensable attributes in the contemporary professional landscape.

Furthermore, the provision of systematic support and instructional scaffolding is paramount for the successful enactment of PBL. Educators should establish explicit guidelines and well-defined milestones to facilitate effective student navigation through their project work. The incorporation of targeted training modules focusing on essential interpersonal competencies, such as effective teamwork, clear communication, and constructive conflict resolution, will further empower students to engage in productive collaborative endeavors. Moreover, the intentional cultivation of reflective practices, including regular feedback mechanisms and opportunities for self-assessment, will enable students to critically evaluate their learning trajectories and implement necessary modifications throughout the project lifecycle.

Acknowledgements

The author wishes to express their sincere appreciation to the esteemed reviewers of the International Journal of Education in Mathematics, Science and Technology (IJEMST) for their insightful and constructive feedback. Their judicious suggestions and scholarly guidance were pivotal in refining the rigor and enhancing the overall quality of this manuscript. The author also extends their gratitude to the Editor of IJEMST for the provision of additional time, which facilitated a more comprehensive revision and improvement of this work.

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