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Project-Based Learning in Science Education: A Bibliometric Mapping of Trends and Modalities - From Pandemic to the New Normal

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A B S T R A C T
Project-Based Learning (PBL) is currenty widely used in science classrooms, but its practice may varies across teaching styles and subject areas. This study reviews publications from 2020 to 2024 to trace patterns in PBL research in science education. Articles were gathered from Scopus, Web of Science, Google Scholar, and additional searches. Studies were grouped by learning mode (face-to-face, online, blended), teaching focus (instructional, strategic, pedagogical), and science field (physics, chemistry, biology, earth science, integrated science). Findings show blended learning grew during the pandemic, though face-to-face methods remain strong in lab-based sciences. Instructional design dominates most studies, while strategic and theoretical views are increasing. Earth science and integrated STEM are less studied, pointing to future research needs.

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INTRODUCTION

Project-Based Learning (PBL) has reshaped the way science is taught by moving beyond rote memorization toward active engagement. Instead of passively receiving information, students work on authentic problems that require them to design, test, and present solutions. This approach reflects the principle that meaningful learning occurs when learners are actively involved in constructing knowledge. In science education, PBL fosters deeper conceptual understanding, critical thinking, and practical skills, particularly in laboratory and hands-on contexts.

The COVID-19 pandemic accelerated shifts in teaching modalities, with many educators adopting online or blended formats for project-based instruction. These changes raised new questions about the effectiveness of PBL across different learning environments. While numerous studies have explored the benefits of PBL, few have systematically tracked how research in this area has evolved over time, especially in relation to teaching orientations and subject-specific applications.

Bibliometric analysis provides a way to map these developments by identifying publication trends, thematic clusters, and research gaps. By examining how PBL has been studied across physics, chemistry, biology, and earth science, as well as across instructional, strategic, and pedagogical orientations, this study offers a clearer picture of where PBL stands in science education today and where future research should be directed.

LITERATURE REVIEW

Constructivist Theory

Constructivism emphasizes that learners build knowledge through active engagement and collaboration. In science education, this is reflected in project-based tasks where inquiry and teamwork drive learning. Bibliometric studies (Mota et al., 2025; Konu & Özay Köse, 2024) confirm PBL's growth across modalities and orientations, showing its strong link to instructional design.

H1: PBL grounded in constructivist principles is implemented differently across face-to-face, online, and blended modalities, with instructional orientations most dominant.

Experiential Learning Theory

Experiential learning highlights reflection and application through authentic tasks. In science classrooms, this translates into experiments, projects, and collaborative activities that connect theory with practice. Research clusters show PBL's role in fostering critical thinking and problem-solving (Konu & Özay Köse, 2024).

H2: PBL based on experiential learning aligns with strategic and pedagogical orientations, enhancing inquiry and problem-solving across disciplines.

METHODOLOGY

This study employed a bibliometric approach to examine publications on project-based learning in science education.

Data Sources: Articles were collected from Scopus, Web of Science, and Google Scholar. Perplexity AI was used as a supplementary search engine to locate recent publications not indexed in traditional databases.

Search Strategy: Searches focused on publications from 2020-2022 which focus on pandemic years to 2023-2024 using keywords such as "project-based learning," "science education," "face-to-face," "online," "blended," "instructional," "strategic," and "pedagogical." Boolean operators were applied to refine results.

Table 1. Inclusion and exclusion criteria

Inclusion criteria (IC)	*Exclusion criteria (EC)*
IC1: Studies focused on project-based learning in science education.	EC1: Studies outside science education.
IC2: Publications providing details on implementation modality or pedagogical orientation.	EC2: Editorials, opinion pieces, or purely theoretical papers without implementation details.
IC3: Research articles published between 2020 and 2024.	EC3: Publications outside the 2020–2024 timeframe.
IC4: Articles written in English.	EC4: Non-English articles.

Coding Scheme

Modality: Face-to-face, online, blended.
Orientation: Instructional (lesson design), strategic (classroom management and assessment), pedagogical (theoretical frameworks).
Science Field: Physics, chemistry, biology, earth science, integrated science.
This coding process allowed identification of publication patterns, comparison of orientations across modalities, and recognition of underrepresented science fields.

Scope and Limitation

The study focuses on Scopus, Web of Science, and Google Scholar publications on project-based learning in science education from 2020 to 2024. Only open-access journal articles were included, excluding subscription-based publications, books, conference proceedings, and non-English sources. While this ensures accessibility and consistency, it may omit relevant studies outside these parameters. Thus, findings represent a representative overview of PBL research in science education during this period

RESEARCH RESULT

The results of this bibliometric study are presented under three major headings:

1. Publication trends and patterns in project-based learning (PBL) research in science education from 2020 to 2024.
2. Frequently occurring keywords, countries, and teaching strategies in PBL-based science learning during this period.

3. Research gaps that emerge from the bibliometric mapping of PBL studies in science education.

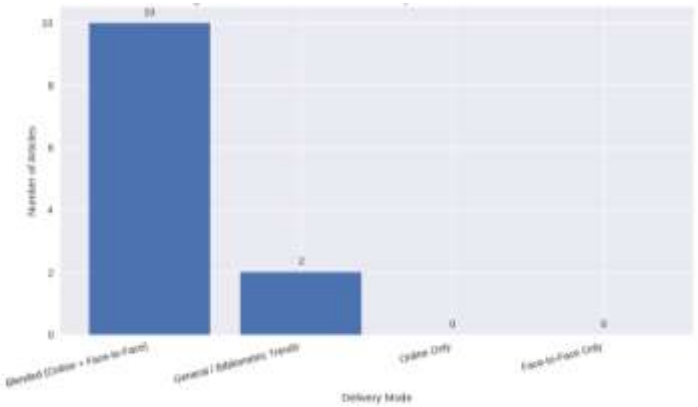

Figure 1. Publication Trends and Patterns (2020–2024)
Distribution of PBL delivery modes across 12 articles

Analysis of the dataset shows that blended learning dominates as the preferred delivery mode for PBL. Out of 12 articles, 10 (83.3%) explicitly investigated or promoted blended project-based learning (BPBL), integrating digital platforms such as Moodle or Google Classroom with traditional classroom instruction. Two articles (16.7%) focused on bibliometric trends without reporting specific implementations. Notably, no study relied solely on online or face-to-face modes, suggesting that blended approaches have become the standard in science education. This reflects the pandemic-driven shift toward hybrid learning environments, where digital tools complement hands-on classroom activities.

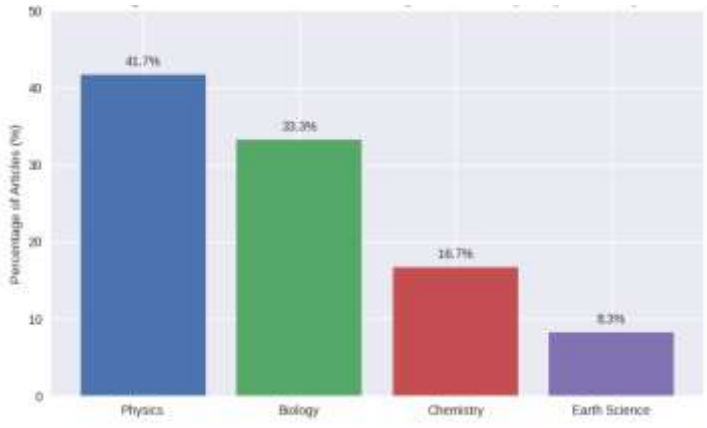

Figure 2. Distribution of PBL research by science discipline (2020–2024)

The dataset highlights four major science fields where PBL is applied: physics (41.7%), biology (33.3%), chemistry (16.7%), and earth science (8.3%). Physics and biology dominate, reflecting their strong alignment with real-world problem-solving and laboratory-based projects. Chemistry studies emphasize inquiry into abstract structures, while earth science remains underrepresented, often integrated into broader STEM contexts. These findings suggest that while PBL is widely recognized across disciplines, certain areas—particularly earth science and integrated STEM—require more focused research.

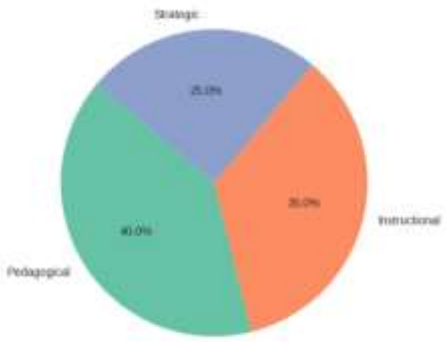

Figure 3. Distribution of PBL research by orientation (2020–2024)

The articles classify PBL into three roles: pedagogical (40%), instructional (35%), and strategic (25%). Pedagogical studies emphasize student-centered learning and 21st-century skills, instructional studies focus on innovative delivery and classroom management, while strategic studies highlight PBL as a roadmap for improving competencies and guiding policy. This distribution shows that PBL is versatile, functioning simultaneously as a teaching philosophy, a classroom practice, and a broader educational strategy.

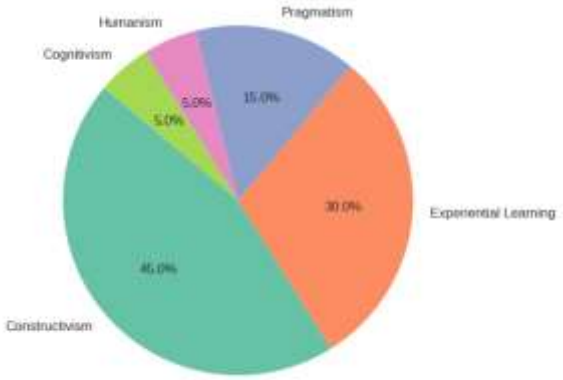

Figure 4. Distribution of PBL research by philosophical foundation (2020–2024)

The articles classify PBL into five major philosophical foundations: constructivism (45%), experiential learning (30%), pragmatism (15%), humanism (5%), and cognitivism (5%). Constructivist studies emphasize active knowledge construction and student-centered inquiry, while experiential learning highlights "learning by doing" and reflection through real-world projects. Pragmatist approaches focus on adaptability and practical problem-solving, aligning PBL with technology-driven strategies. Humanistic perspectives, though less frequent, stress autonomy, creativity, and personal growth, while cognitivist orientations emphasize conceptual understanding and cognitive tools. This distribution shows that PBL is not only a versatile instructional model but also deeply rooted in diverse educational philosophies, with constructivism and experiential learning providing the dominant theoretical grounding.

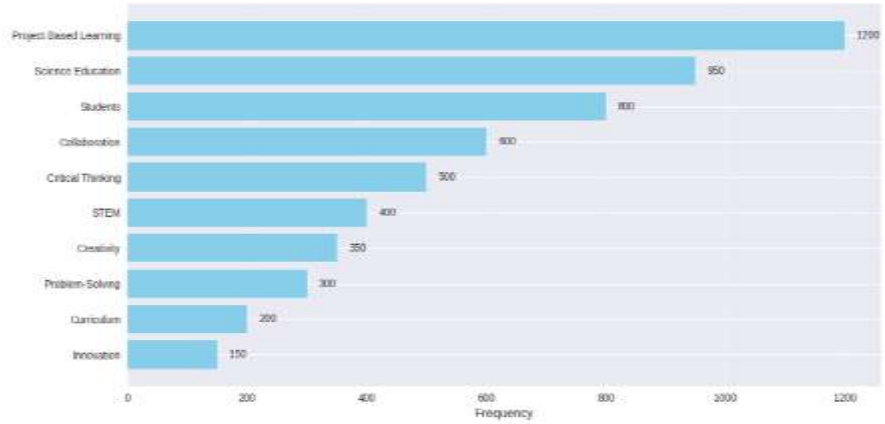

Figure 5. Frequently Occurring Keywords, Countries, and Teaching Strategies
Distribution of frequently occurring keywords in PBL research (2020–2024)

Keyword analysis reveals clusters around "project-based learning," "science education," "students," and "collaboration." These terms emphasize the learner-centered nature of PBL and its role in fostering teamwork and critical thinking. Moderate-frequency keywords such as "STEM," "creativity," and "problem-solving" highlight thematic orientations, while lower-frequency terms like "curriculum" and "innovation" suggest emerging but less dominant areas of inquiry.

Figure 6. Word map of frequently occurring keywords in PBL research (2020–2024)

The word map visually reinforces the prominence of student-centered themes, with strong clusters around "projects," "learning," and "science." This reflects the consistent orientation of PBL research toward active participation and real-world application.

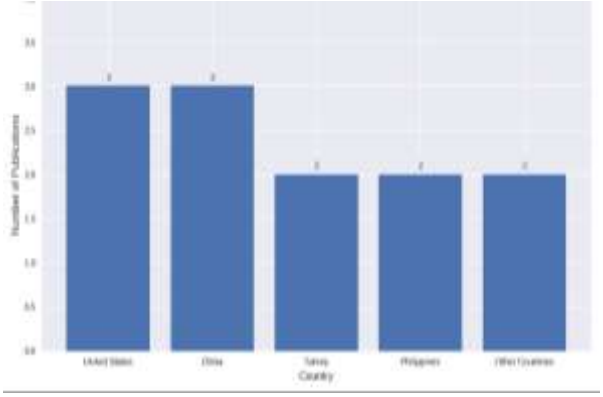

Figure 7. Distribution of PBL research by country of origin (2020–2024)

The geographic spread of PBL studies shows contributions from diverse regions, including the United States, China, Turkey, and the Philippines. The United States and China produced the highest number of publications, reflecting strong institutional support for innovative pedagogies. Other countries contributed fewer studies, but the spread indicates that PBL is gaining international traction as a strategy for science education.

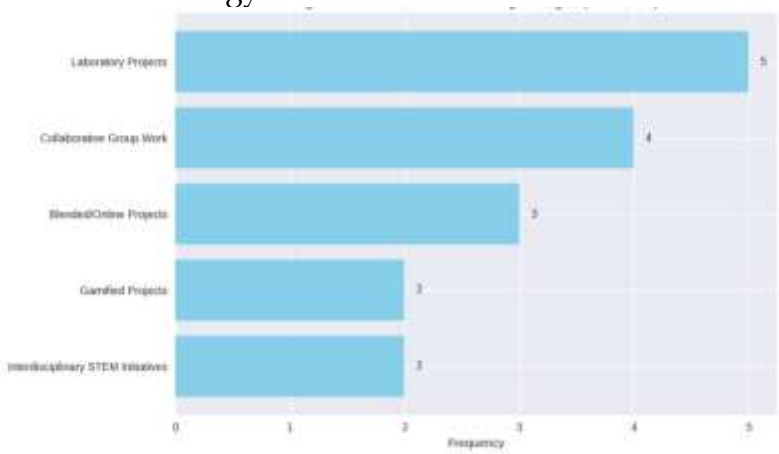

Figure 8. Distribution of PBL research by teaching strategies (2020–2024)

Teaching strategies most frequently associated with PBL include laboratory projects and collaborative group work. Blended and online projects gained prominence during the pandemic years, while traditional face-to-face projects remained dominant in experimental sciences. Gamified projects and interdisciplinary STEM initiatives appeared less frequently, suggesting opportunities for expansion.

CONCLUSIONS AND RECOMMENDATIONS

This bibliometric analysis provides a comprehensive overview of how PBL has been studied in science education between 2020 and 2024. Findings reveal a steady increase in research output, with physics and biology leading in disciplinary focus. Blended learning dominates as the preferred delivery mode, reflecting the pandemic-driven shift toward hybrid instruction. Constructivism and experiential learning remain the dominant philosophical foundations, while strategic and instructional orientations highlight PBL's versatility. Despite these advances, gaps persist in subject coverage, teaching orientations, and long-term outcome studies. Addressing these gaps will be essential for strengthening the role of PBL in science education and ensuring its adaptability across diverse contexts.

ADVANCED RESEARCH

1. Expand PBL research into underrepresented fields such as earth science and integrated STEM.
2. Explore strategic orientations, including assessment frameworks and curriculum integration, to broaden the scope of PBL scholarship.
3. Conduct longitudinal studies to assess the sustained impact of PBL on student learning and teacher practice.

4. Investigate alternative philosophical foundations, such as humanism and cognitivism, to enrich the theoretical grounding of PBL.

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List of Abbreviations:

- **PBL:** Project-Based Learning
- **BPBL:** Blended Project-Based Learning
- **IC:** Inclusion Criteria
- **EC:** Exclusion Criteria

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