

Mapping the Evolution Classroom to Experience: A Global Bibliometric Analysis of Experiential Learning in Physics Education

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Article Info	Abstract
Article history: Received: March 4, 2026 Accepted: April 20, 2026 Published: July 26, 2026 Keywords: Bibliometric analysis Classroom engagement Experiential learning Physics education Science education This article is licensed under a Creative Commons Attribution-Share Alike 4.0 International license © 2026 Jurnal ilmiah Pendidikan Fisika	The integration of traditional classroom instruction and hands-on experience through experiential learning in physics education requires systematic mapping to understand its research development. This study aims to: (1) analyze publication trends and geographic distribution; (2) identify influential journals, authors, and collaboration networks; (3) determine dominant research themes through keyword analysis; and (4) propose future research directions. Data were retrieved from the Scopus database (2020–2025), comprising 30 sources and 54 documents. A quantitative bibliometric method was employed using RStudio with the Bibliometrix package to examine publication trends, collaboration patterns, and thematic structures. The findings show a significant increase in publications in 2024 (15 documents), with the United States contributing the largest share (64.4%). Collaboration networks remain fragmented across 14 clusters. Thematic analysis identifies “educational innovation” as a motor theme, while “physics education” appears as a basic yet relatively isolated theme. Overall, experiential learning research in physics education is growing rapidly and shows strong potential for technology integration. These findings imply that researchers, educators, and curriculum developers need to promote stronger international collaboration, develop more context-specific experiential learning models, and integrate emerging technologies to enhance the relevance and effectiveness of physics education. However, broader international collaboration and more contextualized approaches are needed to strengthen future research development.
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INTRODUCTION

Experiential Learning (EL) is a critical paradigm in responding to the challenges of 21st-century education, emphasizing the development of skills. Complex skills such as critical thinking, creativity, collaboration, and problem-solving ([González-Pérez & Ramírez-Montoya, 2022](#)). As an active learning method, EL places students at the center of the learning process through a concrete cycle of experience, reflection, conceptualization, and experimentation ([Grabinger & Dunlap, 2011](#)). This approach fundamentally shifts the passive model, where students receive information, toward one where they actively construct their own understanding. In the context of physics education, which is often perceived as an abstract and formulaic subject, the application of EL becomes highly relevant. EL bridges the gap between classroom theory and real-world phenomena, transforming seemingly tedious physics concepts into tangible, observable, and meaningful experiences for students ([Yao, 2023](#); [Zhang et al., 2024](#)).

Specifically, in physics education, EL is realized through activities such as laboratory experiments, engineering projects, interactive simulations, and environmental observations ([Etkina et al., 2019](#)). Through these hands-on experiences, students not only memorize Newton's laws or thermodynamic principles, but they also experience and understand the cause-and-effect relationships associated with these principles ([Bowen et al., 2014](#)). This process not only deepens conceptual understanding but also fosters scientific attitudes, curiosity, and the ability to connect science to everyday life. However, despite its widely advocated benefits, the implementation and research of EL in Physics are scattered across various journals and geographic contexts, creating a knowledge landscape that has not been systematically mapped ([Hallinger & Nguyen, 2020](#)). In the context of the rapid development of educational technology, bibliometric approaches are becoming increasingly crucial for mapping complex and multidisciplinary research trends, as reflected in the study of the integration of AI and augmented reality for the scientific literacy ([Wibowo et al., 2025](#); [Yao, 2023](#); [Zhang et al., 2024](#)). Therefore, this study conducted a bibliometric analysis to map the evolution, global trends, and intellectual structure of EL research in physics education in order to provide a comprehensive roadmap for the future development of this increasingly vital field ([Zhan et al., 2022](#)). The bibliometric analysis enables the quantitative identification of collaboration patterns, geographic distribution, and the evolution of research themes, thereby revealing knowledge gaps and opportunities for EL development in physics that align with current educational innovations.

In recent decades, the global field of education has witnessed a significant surge in publications related to experiential learning (EL) ([Lewis & Williams, 1994](#)). This surge in research interest has been driven by growing empirical evidence regarding the model's effectiveness in increasing student engagement, deepening conceptual understanding, and developing critical and creative thinking skills essential for facing future challenges ([Zhang et al., 2024](#)). EL theory, popularized by David A. Kolb, emphasizes a learning cycle through concrete experiences, reflection, abstract concept formation, and active experimentation ([Kolb & Kolb, 2011](#)). Its successful implementation across various disciplines and educational levels further strengthens its position as an active learning paradigm relevant, thereby encouraging increasing academic exploration ([Connor et al., 2015](#)).

Despite this rapid development, a comprehensive literature map specifically addressing EL in the context of physics education remains minimal ([Bao & Koenig, 2019](#); [Yao, 2023](#); [Zhang et al., 2024](#)). Most existing systematic reviews and bibliometric analyses tend to discuss EL broadly across education or social sciences without delving deeply into the dynamics, trends, and intellectual networks unique to the physics domain ([Hidaayatullaah et al., 2021](#)). A bibliometric analysis of STEM approaches to physics learning reveals that despite significant growth in publications, research remains dominated by general approaches with limited exploration of specific aspects such as Higher Order Thinking Skills (HOTS) and physics problem-solving abilities ([Wibowo, Prahani, et al., 2024](#); [Yao, 2023](#); [Zhang, 2024](#)). This gap hinders our understanding of the evolution of specific research themes, the most influential contributors, and the international collaborations driving the field of physics education ([Traxler et al., 2016](#)). Thus, the main research gap in this study lies in the absence of a focused bibliometric mapping of experiential learning research specifically in physics education. Therefore, a systematic mapping using bibliometric analysis is urgently needed to identify research gaps, formulate a future study agenda, and provide a clear roadmap for academics and practitioners in this field.

Although the implementation of EL in physics education has shown promising progress, the existing literature remains fragmented and requires systematic consolidation

([Tembrevilla et al., 2024](#)). Evidence of this progress, for example, is reflected in the proliferation of intervention studies that utilize virtual simulations to create hands-on learning experiences for abstract physics concepts, as demonstrated by the effectiveness of the Dry Cell Microscopic Simulation (DCMS) in improving students' conceptual understanding of batteries ([Wibowo et al., 2017](#)). Departing from this gap, this article aims to explicitly map the evolution, trends, and global landscape of EL research in physics education through a bibliometric analysis approach ([Bittermann et al., 2023](#)). This quantitative method was chosen for its ability to comprehensively analyze a large body of literature, uncover patterns that may not be visible in traditional narrative studies, and map the intellectual relationships that shape the development of a field. The novelty of this study lies in its specific focus on experiential learning in physics education, rather than on experiential learning in general educational contexts, and in its use of bibliometric analysis to provide a more systematic picture of publication trends, collaboration networks, and thematic developments in this field.

This bibliometric mapping is designed to uncover three fundamental aspects. First, to track the temporal evolution of the field by analyzing publication trends, growth, and shifts in research focus over time ([Yan & Zhiping, 2023](#); [Yao, 2023](#); [Zhang et al., 2024](#)). Second, to identify global trends and patterns, including geographic distribution, international collaboration networks, and the most influential institutions and journals ([Leydesdorff et al., 2013](#); [Yao, 2023](#); [Zhang et al., 2024](#)). Third, to describe the intellectual landscape through keyword and citation analysis, this study identifies dominant research themes, emerging areas, and the theoretical foundations underlying the development of EL in the context of physics ([Bozkurt & Zawacki-Richter, 2021](#)). Thus, this study is expected to provide a comprehensive visual and narrative map to guide future researchers in identifying opportunities and directing more focused academic inquiry.

This study was designed to achieve comprehensive mapping by answering a series of key questions formulated based on the principles of bibliometric analysis ([Gan et al., 2022](#)). These questions aim not only to describe the current state of EL research in physics education but also to analyze the dynamics and relationships that shape the development of this field ([Docktor & Mestre, 2014](#)). For example, one dominant research trajectory is the use of virtual simulation technology to create hands-on learning experiences that are difficult to access in conventional laboratories, such as the visualization of microscopic processes in heat transfer ([Wibowo et al., 2016](#)). By examining publication trends, the most influential contributors, and dominant research tracks, this study attempts to unravel the knowledge structures established over the past few decades and identify the key driving forces guiding the field's evolution.

These research questions were specifically formulated to address previously identified gaps in the literature. Although several bibliometric and review studies have examined experiential learning in general education contexts (e.g., [Hidaayatullaah et al., 2021](#); [Bozkurt & Zawacki-Richter, 2021](#)), they tend to provide a broad overview without focusing specifically on the dynamics of experiential learning within physics education. In addition, previous studies in physics education have largely emphasized instructional approaches such as STEM or problem-solving ([Prahani, et al., 2024](#)), with limited attention to systematically mapping experiential learning as a distinct research domain.

Therefore, this study offers a more focused and updated bibliometric analysis by specifically examining experiential learning in physics education using recent Scopus-indexed publications (2020–2025). By exploring geographic distribution and institutional affiliations, this study uncovers global collaboration patterns and research productivity concentrations in the field. Meanwhile, an analysis of emerging keyword networks and themes provides a deeper understanding of the field's conceptual evolution and identifies

underexplored research areas. Accordingly, the objectives of this study are to analyze publication trends and geographic distribution, identify influential journals, authors, and collaboration networks, determine dominant research themes through keyword analysis, and propose future research directions. Ultimately, this study contributes to the literature by providing a more specific, up-to-date, and discipline-focused bibliometric mapping, which serves as an empirical basis for formulating a strategic future research agenda in experiential learning within physics education.

Based on the identified research gaps and the need for a more systematic understanding of experiential learning in physics education, this study is guided by the following research questions:

- 1) How have global publication trends and patterns in experiential learning research within physics education evolved over time?
- 2) Who are the most influential authors, journals, and countries contributing to this field, and how are collaboration networks structured?
- 3) What are the dominant and emerging research themes in experiential learning within physics education based on keyword and thematic analysis?
- 4) What are the main challenges and future research opportunities in integrating experiential learning into physics education?

These research questions aim to provide a comprehensive bibliometric mapping that not only describes the current state of the field but also identifies its intellectual structure, development trajectory, and potential directions for future research.

METHODS

This study is exploratory, descriptive, and quantitative in its methodological approach. This exploratory study aims to map the underexplored knowledge landscape of experiential learning in physics education, identifying patterns and relationships that may have been overlooked in previous studies. The descriptive nature of this study allows for a comprehensive overview of the current state of the field, including publication distribution, collaboration networks, and the development of research themes over time. The quantitative approach used ensures that the analysis is based on measurable, structured empirical data, resulting in objective, verifiable findings.

Methodologically, this study adopted bibliometric analysis techniques to examine the collected literature. Bibliometric analysis allows for tracking developments in a scientific field through quantitative metrics such as citation patterns, collaboration networks, and keyword analysis ([Kumar, 2025](#)). This approach has proven effective in uncovering research trends and developments in specific scientific fields, as demonstrated in a bibliometric study on creative thinking in physics education that successfully mapped the evolution of research themes over several decades ([Darman, et al., 2024](#)). This study utilized the Bibliometrix package in RStudio to conduct a comprehensive analysis that included descriptive statistics, collaborative analysis, and thematic mapping ([Aria & Cuccurullo, 2017](#)). RStudio was chosen for its ability to process large amounts of bibliometric data and produce accurate visualizations for various relational analyses ([Guleria & Kaur, 2021](#); [Yao, 2023](#); [Zhang et al., 2024](#)). Through this approach, this study not only presents descriptive statistics on knowledge production in this field but also reveals the intellectual structures and developmental patterns underlying the field of experiential learning research in physics education.

This study used the Scopus database as the sole source for bibliometric data collection. Several fundamental considerations justify this selection. First, Scopus is widely recognized as one of the leading and most trusted citation indexes for bibliometric research, providing extensive, curated coverage of the scientific literature ([Birkle et al., 2020](#)).

Second, Scopus's claim to be the world's largest peer-reviewed abstract and citation database promises comprehensive publication coverage, including over 30,000 actively published titles from various international publishers, making it highly suitable for global trend analysis. Third, a rigorous journal selection process by Scopus's independent Content Selection and Advisory Board (CSAB) ensures that indexed literature meets high-quality standards in terms of editorial policies, publication regularity, and relevance to the broader scientific community and international audience.

Despite these advantages, several methodological considerations should be acknowledged. In terms of coverage, relying solely on the Scopus database may limit the inclusion of relevant publications indexed in other databases such as Web of Science or Google Scholar, potentially leading to incomplete representation of the research landscape. However, Scopus was selected due to its broad multidisciplinary coverage and consistent indexing standards, which are essential for ensuring data reliability in bibliometric analysis.

In terms of data quality, Scopus provides curated and peer-reviewed sources, which enhances the credibility and consistency of the dataset. Nevertheless, variations in indexing practices, author affiliations, and keyword standardization may affect the accuracy of bibliometric mapping.

Furthermore, this study is limited by the selected time frame (2020–2025) and the use of specific search keywords, which may exclude earlier foundational studies or relevant publications that use different terminologies. Therefore, the findings of this study should be interpreted within these methodological constraints, and future research is recommended to incorporate multiple databases and extended time spans to obtain a more comprehensive understanding of experiential learning research in physics education.

Explicit and systematic inclusion and exclusion criteria were applied to ensure that the analyzed data were relevant and consistent with the research objectives. This process followed the main steps of bibliometric analysis to obtain an accurate and reliable dataset. The main inclusion criteria included the following: (1) Documents must address the topic of experiential learning in the context of physics education; (2) the publication period was limited from 2020 to 2025; (3) only peer-reviewed documents, such as journal articles and conference proceedings, were included. Meanwhile, the exclusion criteria applied were (1) ignoring books, dissertations, and materials that were not peer reviewed to maintain the focus on core scientific communication; (2) excluding documents for which full access was not available; and (3) excluding documents whose titles and abstracts were not in English, considering Scopus's recommendation that indexed content be readable by an international audience. This screening process is carried out in stages to ensure a high-quality final dataset.

The data collection process was conducted on September 17, 2025, through the Scopus platform using a pre-developed search string. The search query was constructed to capture publications related to experiential learning within the context of physics education. The query was applied to the title, abstract, and keywords fields to ensure comprehensive retrieval of relevant studies, as shown below:

TITLE-ABS-KEY ("experiential learning" AND "physics education") AND PUBYEAR > 2019 AND PUBYEAR < 2026.

The search query was iteratively refined to balance sensitivity and specificity, ensuring that relevant studies were captured while minimizing irrelevant results. This query was designed to ensure the retrieval of literature published between 2020 and 2025. The initial search yielded 54 documents that met the basic search parameters. This data was then exported in CSV format, including complete metadata such as title, abstract, authors, affiliations, publication year, publication source, keywords, and citation information. The data export was carried out in stages to ensure the completeness and accuracy of the dataset.

obtained. All collected data were then subjected to a systematic filtering process based on pre-established inclusion and exclusion criteria.

The screening process was conducted in stages following the PRISMA flow framework to ensure transparency and reproducibility. The initial search using the predefined query resulted in 54 records retrieved from the Scopus database. In the first stage, records were screened based on document type, where only journal articles and conference proceedings were retained, and other document types such as books, editorials, and book chapters were excluded. However, all retrieved documents ($n = 54$) already met the document type criteria.

In the second stage, a relevance screening was conducted through title and abstract evaluation to ensure alignment with the research focus on experiential learning in physics education. No records were excluded at this stage, as all documents were found to be relevant to the study objectives. Therefore, the final dataset consisted of 54 documents, which were included in the bibliometric analysis. The detailed screening process is illustrated in the PRISMA flow diagram (Figure 1).

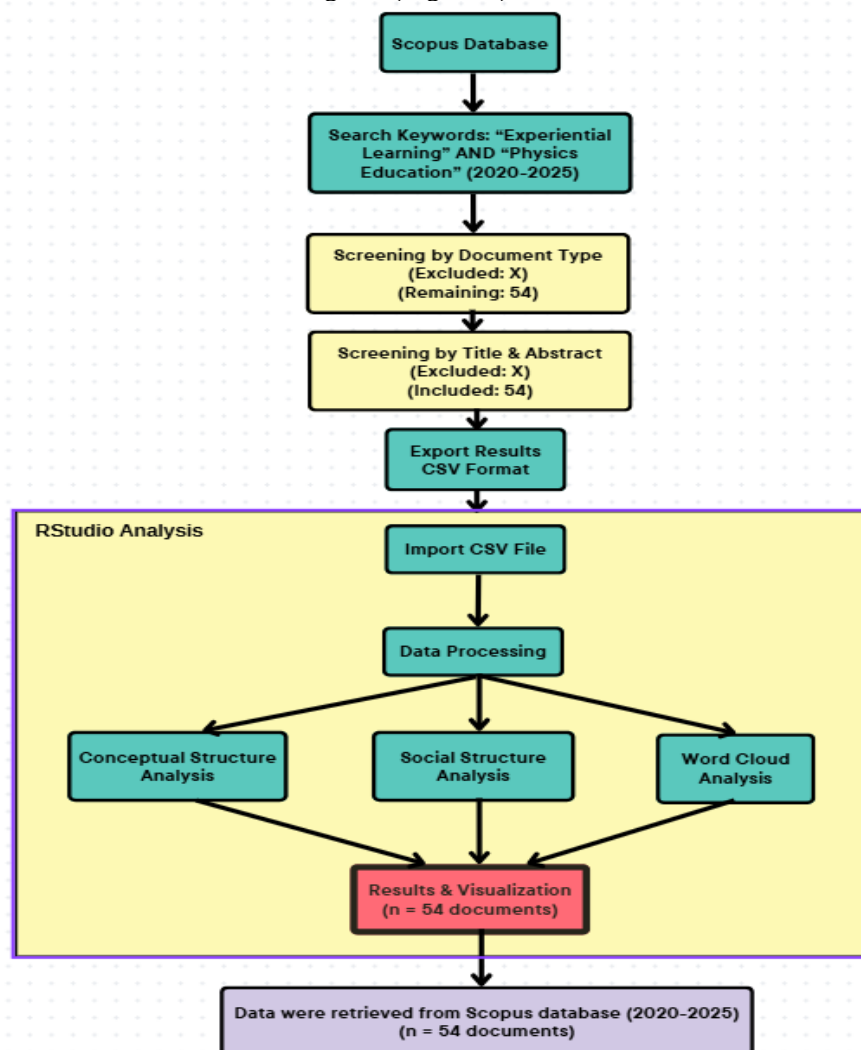


Figure 1 Bibliometric analysis workflow for mapping the evolution of experiential learning in physics education using Scopus-indexed publications

This study employed RStudio with the bibliometrix package to conduct a comprehensive bibliometric analysis, as the package was specifically developed for scientific bibliometric research. The bibliometrix package in RStudio includes the built-in Biblioshiny utility, which provides a graphical interface for non-programmers and produces comprehensive analyses with customized plot representations ([Guleria & Kaur, 2021](#)). This package enables a variety of essential bibliometric network analyses, including co-authorship analysis to map collaborations between authors and institutions, keyword co-occurrence analysis to identify dominant research themes, and citation analysis to understand the intellectual structure of experiential learning research in physics education. Bibliometrix combines bibliometric techniques such as co-word analysis, co-citation network analysis, collaboration network generation, and Sankey plots to analyze the evolution of a research field ([Guleria & Kaur, 2021](#)). RStudio was chosen for its flexibility in processing large amounts of bibliometric data and its ability to produce accurate and informative network visualizations. This tool allows for the analysis and visualization of relationships between authors, countries, journals, co-citations, and terms, and assists in examining maps and deriving themes from them ([Guleria & Kaur, 2021](#)).

Prior to in-depth analysis using R in the studio, the collected data was analyzed using the “Analyze Search Results” feature available within the Scopus platform. This feature was used to obtain an overview and initial descriptive statistics of the document collection, including the distribution of publications by year, institutional affiliation, country, and publication source. This initial analysis helped clarify the basic characteristics of the document corpus before conducting a more in-depth exploration with bibliometric software. The combination of an initial analysis using Scopus and an in-depth analysis using RStudio ensured that this study had a comprehensive methodological foundation to answer the research questions.

RESULTS AND DISCUSSION

What are the global publication trends and patterns related to integrating Evolution Classroom to Experience and experiential learning in physics education based on bibliometric data from the Scopus database?

Annual publication trends in experiential learning physics education (2020-2025) are shown in Table 1.

Table 1 Annual publication trends in experiential learning physics education (2020-2025)

Year	Amount Publication	Annual Growth	Presentation Growth
2020	8	-	-
2021	7	-1	-12.5%
2022	9	+2	+28.6%
2023	9	0	0%
2024	15	+6	+66.7%
2025	6	-9	-60.0%

An analysis of global publication trends in the field of experiential learning reveals a dynamic growth pattern during the period 2020-2025. The data shows fluctuations with a nadir in 2021 (7 publications) and a peak in 2024 (15 publications). A significant 66.7% growth in 2024 indicates increasing research interest and recognition of the importance of experiential learning approaches in physics education. An average annual publication of 9 articles with a compound annual growth rate (CAGR) of 17.0% from 2020 to 2024 reinforces the finding that this research field is experiencing rapid global development. However, it is important to note that the data for 2025 may represent partial-year publications at the time of data collection. Therefore, the apparent decline in 2025 should

be interpreted with caution, as it may not fully reflect the total annual research output for that year. Annual scientific output on experiential learning in physics education based on Scopus-indexed publications is shown in Figure 2.

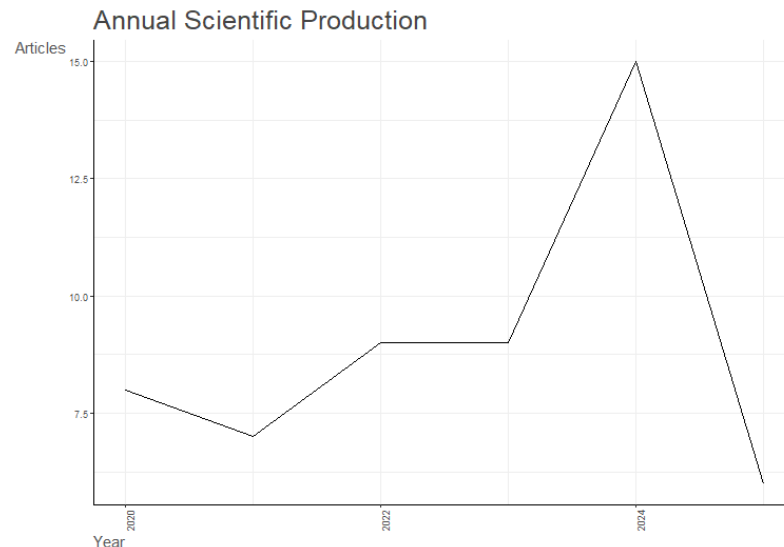


Figure 1 Annual scientific production on experiential learning in physics education based on Scopus-indexed publications

The graphical visualization of publication trends explicitly confirms the exponential growth observed in this research field. Figure 2 shows a relatively flat curve during the 2020-2023 period, followed by a dramatic spike in 2024, resulting in the highest peak of the entire observation period. The 66.7% increase from 2023 to 2024 is reflected in the sharp slope of the line, indicating a significant acceleration in research interest. Although the 2025 data shows a decline, it is still above the average annual publication rate (9 articles) during the 2020-2023 period, indicating that research productivity remains higher than in the early years of the study period. The overall pattern points to optimism for the continued development of experiential learning in physics education, with 2024 being a turning point in global research productivity.

From a theoretical perspective, this trend aligns with the increasing adoption of EL principles, particularly Kolb's learning cycle, which emphasizes the transformation of experience into knowledge through reflection and experimentation. In the context of Physics Education Research (PER), this growth reflects a broader shift from traditional transmission-based instruction toward active learning approaches that promote conceptual understanding and student engagement.

Analysis of publication sources reveals a significant concentration of research in conference proceedings compared to traditional ones. The ASEE Journal Annual Conference and Exposition dominates the publication landscape with nine articles (16.7% of the total), indicating that the engineering education community is a significant hub for the development of experiential learning research in physics. This pattern is reinforced by the presence of several other prominent engineering conferences, such as IEEE EDUCON and the Frontiers in Education Conference, in the top rankings. Interestingly, the Journal of Physics: Conference Series and Physics Education represent physics-specific outlets, albeit with lower contributions, indicating a dialogue between engineering and pure physics approaches in the development of this field.

This dominance of engineering-oriented publication venues suggests that experiential learning in physics is increasingly influenced by applied and design-based approaches, consistent with previous research emphasizing the role of real-world problem-solving and the integration of conceptual and practical knowledge in physics education. The most relevant sources publishing research on experiential learning in physics education based on Scopus-indexed publications are listed in Figure 3.

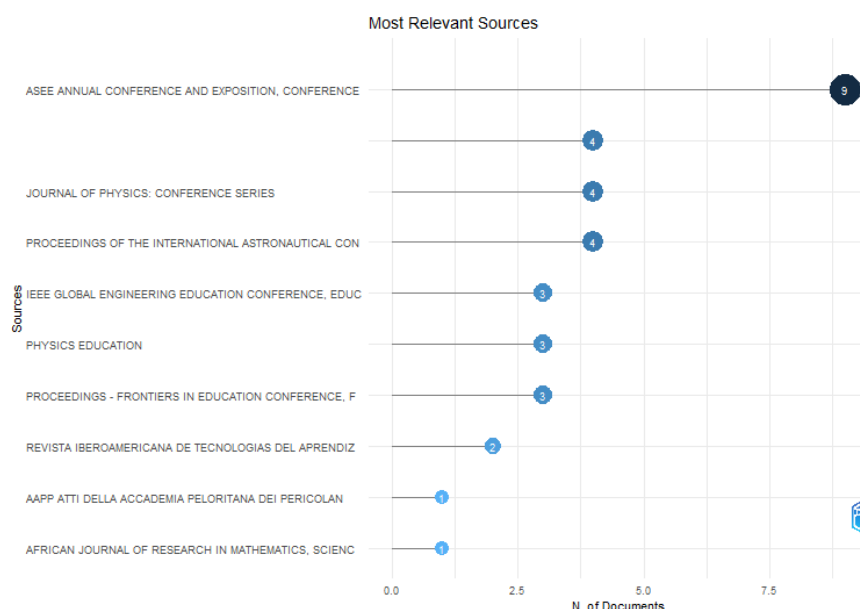


Figure 2 Most relevant sources publishing research on experiential learning in physics education based on Scopus-indexed publications

Analysis of the geographic distribution of research reveals a significant dominance of the United States with 87 publications, representing approximately 64.4% of the total global research output in the field of experiential learning in physics education. Indonesia ranks second with 13 publications (9.6%), followed by Mexico (12 publications, 8.9%) and Italy (11 publications, 8.1%). This distribution pattern indicates an intense concentration of research in North America, with notable contributions from Southeast Asia and Europe. Interestingly, despite the United States' quantitative dominance, there is balanced representation from developing countries such as India, Brazil, and Malaysia, indicating that interest in experiential learning approaches in physics education has spread globally.

From a PER perspective, this uneven distribution highlights disparities in research capacity and access to innovation in physics education, which may influence how experiential learning is implemented across different educational contexts.

The global distribution of scientific production on experiential learning in physics education based on Scopus-indexed publications is shown in Figure 4.

Analysis of the evolution of research topics reveals interesting temporal developments in the field of experiential learning in physics education. The topic of 'students' emerged as the most dominant concept with a frequency of 31 occurrences, indicating a continued focus on aspects of learning from the learner's perspective. Significantly, 'experiential learning' itself recorded 22 occurrences, with a median of 2023, indicating its consolidation as a core research area. Temporal patterns reveal that fundamental topics such as 'education' and 'experiential learning' have been of interest since 2020, while more specific topics such as 'teaching' (median 2024) and 'educational innovation' (median

2024) have emerged as more recent trends, reflecting the field's evolution towards more focused pedagogical innovation.

Country Scientific Production

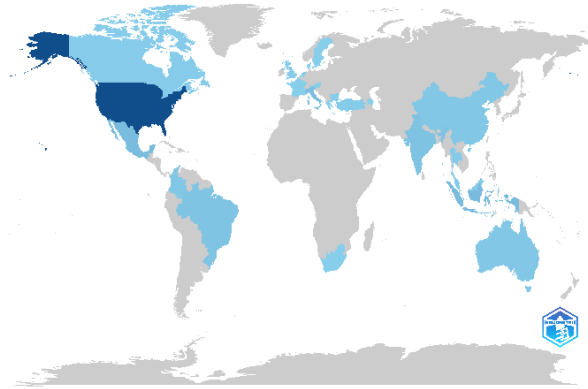


Figure 3 Global distribution of scientific production on experiential learning in physics education based on Scopus-indexed publications

The prominence of “students” as a central theme reflects a strong alignment with experiential learning theory, which positions learners as active agents in constructing knowledge. In PER, this focus is consistent with the emphasis on student-centered learning environments that support conceptual change and active engagement. Trending research topics in experiential learning in the field of physics education based on publications indexed in Scopus are shown in Figure 5.

Trend Topics

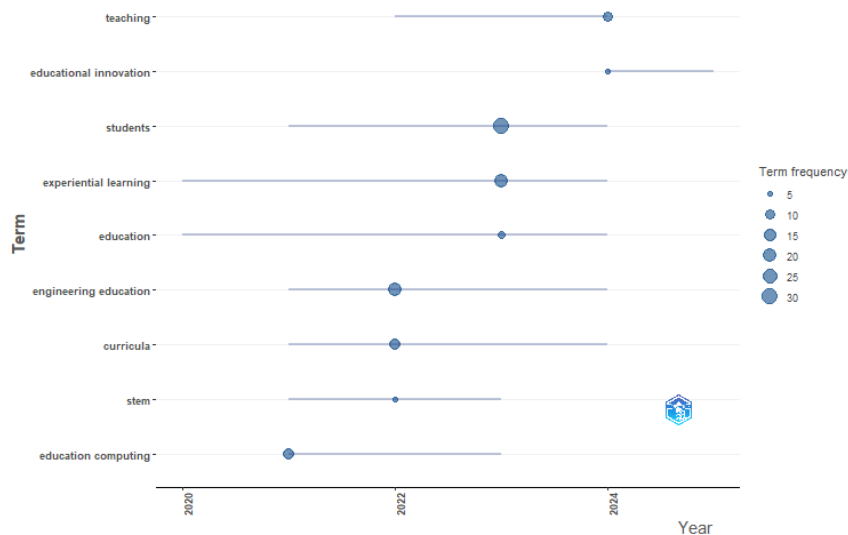


Figure 4 Trending research topics in experiential learning within physics education based on Scopus-indexed publications

A network analysis of research collaborations reveals fragmented patterns in the field of experiential learning in physics education. Fourteen distinct collaboration clusters were identified, with the largest group consisting of nine researchers (Cluster 2) led by Bering, Edgar A. and involves researchers such as Gamblin, Rachel B., Greer, Michael L., and Khan, Shuhab Danishwar. This collaboration pattern indicates a concentration of research

activity in isolated groups, with few cross-cluster connections. Interestingly, Nieto-Jalil, José M., emerges as an important node with the highest betweenness (value 1), indicating a role as a bridge in the collaboration network.

Such fragmentation may limit the development of cohesive theoretical and methodological frameworks within PER, where collaborative research is essential for validating instructional innovations across diverse educational settings. Bibliometric mapping of the author collaboration network in experiential learning research in physics education, depicting the main research groups and influential contributors is shown in Figure 6.

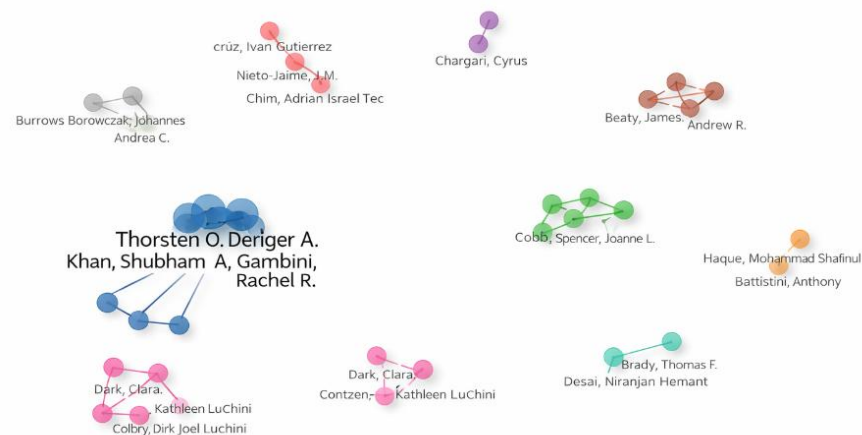


Figure 5 Bibliometric mapping of author collaboration networks in experiential learning research in physics education, illustrating major research clusters and influential contributors

What are the prospects and opportunities for developing Evolution Classroom to Experience to improve experiential learning in physics education?

Thematic map analysis identified 'educational innovation' as the primary motor theme with high density (265.44) and medium centrality (1.41), indicating up-and-coming development prospects for the Evolution Classroom to Experience in Physics Education. This cluster includes emerging concepts such as 'challenge-based learning,' 'mobile technology,' 'sensor technologies,' and 'smartphones,' which offer significant opportunities for integrating mobile technology into experiential physics learning. Its position in the motor themes quadrant indicates that educational innovation has become a key driver of the field's development, with a substantial impact and a mature level of development.

These findings are consistent with experiential learning theory, which emphasizes authentic and context-rich learning environments, and with PER approaches that advocate the integration of technology to support inquiry-based and experiential physics learning.

Topic trend analysis identifies 'educational innovation' as the most promising research frontier, with a median peak in 2024-2025, signaling significant opportunities for the development of the Evolution Classroom to Experience in physics education. This trend is supported by the strong emergence of 'teaching' as a topic, with a median peak in 2024, reflecting a shift in focus towards pedagogical innovation and more effective teaching methodologies. The combination of educational innovation and experiential learning, which has reached a mature phase (median year 2023), provides an ideal foundation for developing a more transformative physics learning model.

The word cloud analysis reveals a rich conceptual landscape for the development of the Evolution Classroom to Experience, with 'students' as the center of attention (frequency

31), followed significantly by ‘engineering education’ and ‘experiential learning’ (frequency 22 each). The dominance of these three concepts forms a fundamental triad for future development, emphasizing the importance of a student-centered approach integrated with engineering education methodologies through an experiential learning framework. The strong presence of the concepts of ‘educational innovation’ (frequency 5) and ‘e-learning’ (frequency 4) in the cloud identifies clear opportunities for digital innovation to transform the physics learning experience. A visualization of keyword frequencies depicting the thematic landscape and evolution of experiential learning research in physics education is shown in Figure 7.

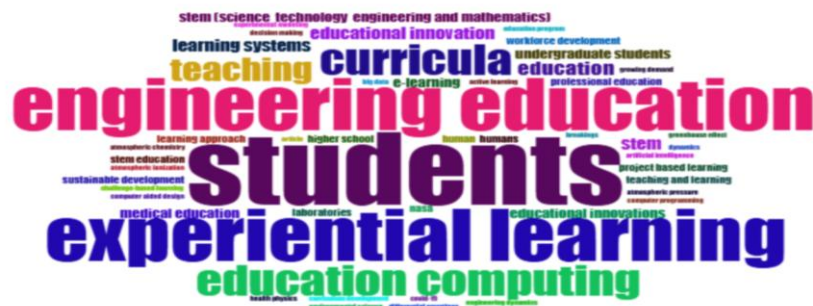


Figure 6 Keyword frequency visualization illustrating the thematic landscape and evolution of experiential learning research in physics education

Co-emergence network analysis revealed three main conceptual clusters that offer prospects for the development of the Evolution Classroom to Experience. Cluster 1, centered on students (betweenness 490.66), shows opportunities to deepen the student-centered learning approach through integration with engineering education and experiential learning. Cluster 2, with its focus on educational innovation (betweenness 0.2), identifies significant opportunity gaps in connecting educational innovation with emerging technologies such as e-learning and mobile technology, which currently remain relatively isolated in the network. Thematic mapping of experience-based learning research in physics education based on keyword co-occurrence analysis, showing the main groups and their interrelationships is shown in Figure 8.

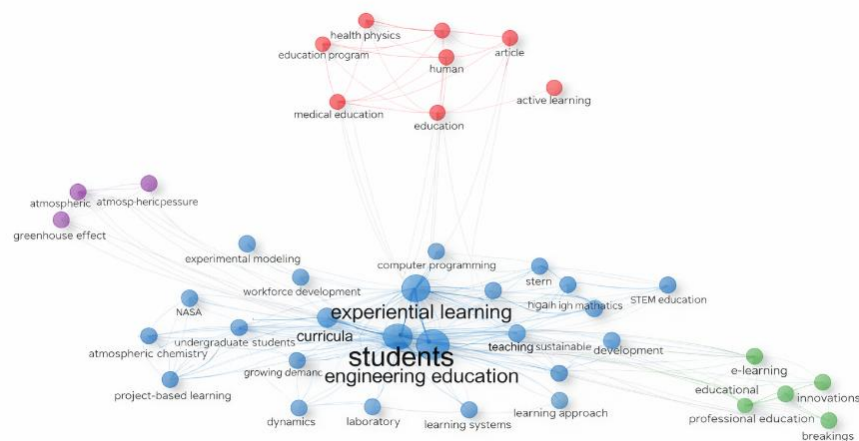


Figure 7 Thematic mapping of experiential learning research in physics education based on keyword co-occurrence analysis, showing major clusters and their interconnections

What are the main technical and pedagogical challenges in integrating Evolution Classroom to Experience and Experiential Learning in Physics Education?

Thematic map analysis identified significant technical and pedagogical challenges in integrating Evolution Classroom into Experience, with 'physics education' emerging as an isolated basic theme in the bottom left quadrant (density 50, centrality 0). This marginal position reveals the fundamental challenges in developing experiential learning approaches explicitly designed for physics education contexts, compared to the more dominant general education approach. The highly developed 'students' cluster (centrality 10.35) further demonstrates the imbalance between a focus on students versus developing physics content adequate for experiential approaches.

This challenge reflects a critical gap between experiential learning theory and its implementation in physics education, as PER emphasizes the importance of aligning pedagogical strategies with the specific epistemological characteristics of physics.

Co-emergence network analysis reveals significant structural challenges in integrating Evolution Classroom into Experience, as evidenced by an apparent conceptual fragmentation across the three main clusters. The highly centralized 'students' cluster (betweenness 490.66) actually displays an imbalance with the 'educational innovation' cluster, which has a very low betweenness (0.2), indicating pedagogical challenges in aligning technological innovation with the real needs of learners. This conceptual disconnect is exacerbated by the position of 'physics education,' which does not emerge as a central node, reflecting the technical difficulties in developing an experiential approach specifically designed for the physics discipline.

An analysis of the most cited documents reveals recurring technical and pedagogical challenges in implementing experiential learning in physics education. The most influential document by [Czaplinski & Fielding \(2020\)](#), with 22 citations, identifies challenges in developing a practical 'contextualized blended learning framework,' highlighting technical difficulties in integrating experiential approaches with existing digital platforms. Similarly, [Chinaka's \(2021\)](#) study, which compared PhET simulations with phenomenon-based experiential learning and received 10 citations, identified pedagogical challenges in balancing digital simulations with authentic learning experiences, particularly in the context of learning complex physics concepts such as parabolic motion. The citation impact of key publications that shaped the development of experiential learning research in physics education is shown in Figure 9.

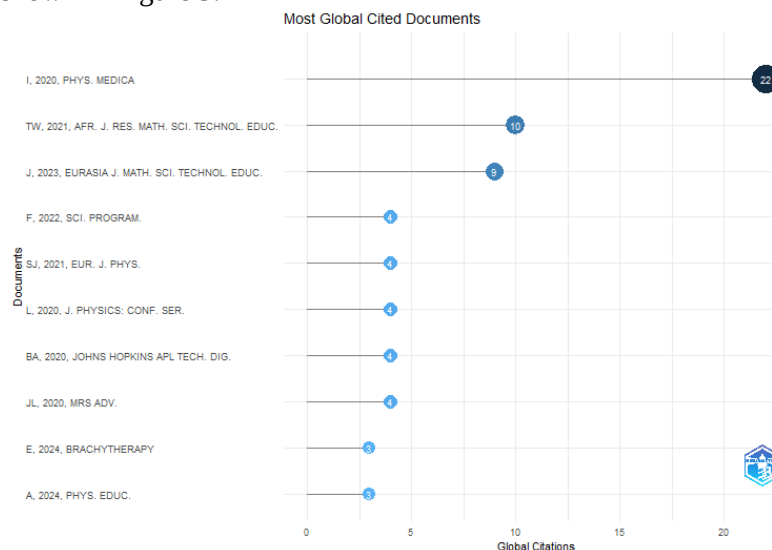


Figure 8 Citation impact of key publications shaping the development of experiential learning research in physics education

Topic trend analysis identifies a fundamental pedagogical challenge through a marked imbalance between the focus on ‘students’ (frequency 31) and a lower attention to ‘teaching’ (frequency 10), indicating challenges in developing practical teaching approaches to facilitate experiential learning. The temporal gap between the emergence of fundamental topics such as ‘experiential learning’ (since 2020) and the implementation of topics such as ‘educational innovation’ (emerging in 2024) reveals the challenge of translating theoretical concepts into scalable, sustainable, and innovative practices.

Based on the publication trends presented in Table 1 and Figure 2, the observed increase in research output in recent years indicates an accelerated phase of global interest in experiential learning within physics education. This trend suggests that the field is entering a stage of rapid expansion, in line with previous studies highlighting the growing importance of active and student-centered learning approaches in physics education, where the demand for innovative pedagogical strategies is becoming increasingly urgent. Rather than reflecting a temporary fluctuation, this pattern may represent a structural shift in how physics education responds to contemporary challenges, particularly those related to digital transformation and post-pandemic learning environments.

Referring to the geographic distribution shown in Figure 4, the dominance of contributions from developed countries highlights their central role in shaping the research agenda and advancing experiential learning practices. At the same time, the growing participation of developing countries indicates a widening global engagement and the increasing relevance of contextualized physics education. However, the fragmented collaboration patterns shown in Figure 6 suggest that research efforts are still relatively isolated, pointing to the need for stronger international collaboration to enhance knowledge exchange and integration.

Based on the analysis of publication sources in Figure 3, the prominence of conference proceedings reflects the dynamic and practice-oriented nature of this research field. This pattern indicates that experiential learning in physics education is closely linked to applied innovation and rapid dissemination of ideas. However, it also implies a potential limitation in the depth of theoretical development, suggesting the need for more rigorous and sustained contributions in high-impact academic journals ([Carpenter & Cone, 2014](#); [Crompton, 2025](#); [Stallings et al., 2013](#)).

As indicated by the topic trend analysis in Figure 5, the shift from general discussions of experiential learning toward more specific themes such as teaching practices and educational innovation reflects the maturation of the field. This transition suggests that experiential learning is no longer confined to conceptual discourse but is increasingly being translated into structured instructional strategies ([Jordi, 2011](#); [Kolb, 2014](#)). Nevertheless, challenges remain in ensuring that these innovations are scalable, systematically implemented, and adaptable across diverse educational contexts.

According to the thematic map presented in Figure 8, educational innovation emerges as a central driving force in the development of experiential learning in physics education. This indicates that the integration of emerging technologies and innovative pedagogical models plays a crucial role in transforming learning experiences. The growing emphasis on technology-enhanced learning environments suggests opportunities to bridge theoretical understanding with real-world applications, thereby making physics learning more meaningful and accessible.

The topic trend analysis further highlights the emergence of educational innovation as a key research frontier, indicating a shift toward deeper pedagogical engagement. This suggests that the field is moving beyond adoption toward refinement and optimization of experiential learning approaches. Such developments open opportunities for designing

hybrid learning models that combine experiential, inquiry-based, and technology-supported strategies to create more adaptive and personalized learning experiences.

Based on the keyword frequency visualization in Figure 7, the strong emphasis on student-centered concepts highlights the importance of positioning learners at the core of the educational process. This pattern suggests that experiential learning in physics is increasingly aligned with interdisciplinary approaches, particularly those connected to engineering and real-world problem-solving. As a result, there is significant potential to design learning environments that foster active engagement, creativity, and practical application of physics concepts.

The co-emergence network analysis presented in Figure 8 reveals that certain conceptual clusters, particularly those related to educational innovation, remain relatively disconnected from other key themes. This indicates a gap between technological development and pedagogical implementation, suggesting the need for more integrative frameworks that align innovation with meaningful learning processes. The advancement of technologies such as artificial intelligence and learning analytics offers promising pathways to address this gap by enabling more responsive and personalized experiential learning environments.

At the same time, the thematic map suggests that physics education remains comparatively underdeveloped within the broader experiential learning discourse. This pattern is consistent with calls for discipline-based research that operationalizes physics-specific learning goals rather than merely transferring generic pedagogical frameworks across educational domains ([Bao & Koenig, 2019](#); [Kaya et al., 2025](#)). Physics learning involves not only participation in concrete experiences but also the coordination of observations, mathematical representations, scientific models, conceptual structures, and epistemic beliefs about knowledge and evidence ([Brewer, 2008](#); [Watson & Thomas, 2024](#)). Therefore, experiential learning models should be adapted to the distinctive conceptual and epistemological practices of physics. Existing evidence further indicates that instructional approaches explicitly emphasizing inquiry, model building, reflection, and conceptual reconstruction can improve conceptual understanding and support more expert-like beliefs about learning physics ([Madsen et al., 2015](#); [Pesman et al., 2025](#)). Accordingly, future research should develop and empirically test domain-specific experiential learning models that connect concrete experience and reflective observation with mathematical modeling, conceptual abstraction, evidence-based reasoning, and active experimentation in physics.

The collaboration patterns shown in Figure 6 further reinforce this issue, as the observed fragmentation suggests limited interaction between research groups and thematic areas. This lack of integration reflects both technical and pedagogical challenges in aligning learner-centered approaches with technological innovation, indicating that future research should focus on building more cohesive and interdisciplinary research networks.

Based on the citation analysis presented in Figure 9, existing studies reveal that implementing experiential learning in physics education involves complex technical and pedagogical considerations. These include challenges in integrating digital tools with authentic learning experiences and in balancing efficiency with conceptual depth. Such challenges become more pronounced when dealing with abstract physics concepts, which require carefully designed experiential strategies to support meaningful understanding.

Finally, the temporal patterns identified in Figure 5 suggest a gap between theoretical development and practical implementation, indicating that while experiential learning has gained conceptual traction, its translation into effective teaching practices remains limited. This highlights the need for future research to focus on developing comprehensive instructional frameworks that not only enhance student experiences but also support educators in designing and facilitating effective experiential learning in physics education.

CONCLUSION

This study provides a comprehensive bibliometric mapping of experiential learning in physics education, revealing that the field is undergoing rapid development and increasing global attention. The findings indicate a growing shift toward educational innovation and more structured pedagogical approaches, reflecting the maturation of experiential learning from a conceptual framework into practical implementation within physics education. However, the field remains characterized by imbalances in global research contributions and fragmented collaboration networks, which may limit the integration and advancement of knowledge. The study highlights the importance of strengthening international collaboration, particularly through cross-country research partnerships and collaborative networks, developing context-specific experiential learning models, and integrating emerging technologies to enhance the effectiveness and relevance of physics education. At the same time, several challenges persist, particularly in aligning technological innovation with the specific needs of physics learning and in supporting educators to effectively implement experiential approaches. This study is limited by its reliance on a single database, a restricted publication timeframe, and a focus on bibliometric analysis without direct examination of classroom practices. Therefore, future research should incorporate multiple data sources, extend the temporal scope, and integrate empirical or systematic review approaches to provide a more comprehensive understanding of experiential learning in physics education.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, TEDP; methodology, TEDP; formal analysis, TEDP; investigation, TEDP; data curation, TEDP; writing—original draft preparation, TEDP; writing—review and editing, IMA and TBP; supervision, IMA and TBP; academic guidance and manuscript review, FCW and IS. All authors have read and agreed to the published version of the manuscript.

AI DISCLOSURE STATEMENT

The authors declare that artificial intelligence (AI) tools were used only to assist with language improvement and manuscript editing. The authors remained fully responsible for the conceptualization of the study, methodology, data analysis, interpretation of findings, and the final content of the manuscript.

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