

A Visualization Analysis of Problem-Based Learning in Colleges Using VOSviewer

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Abstract: In order to gain insight into the current research status and development trend of problem-based learning (PBL) in colleges and universities, this study employs the bibliometric method to conduct statistical and analytical studies based on the examination of journal papers and review papers within the Web of Science (WOS) database. The objective is to provide a reference point for research in related fields. The findings indicate a sustained expansion in PBL research output at universities, with the United States accounting for most documents in the field, while European research institutions such as Aalborg University and Maastricht University are at the forefront. Nevertheless, the density of collaborative networks between authors is relatively low, and cross-institutional and interdisciplinary collaboration still requires further strengthening. The majority of research results are published in academic journals such as Academic Medicine and the International Journal of Sustainability in Higher Education. Presently, the focal point of PBL research in colleges and universities is undergoing a transition from a “single-discipline focus” to an “interdisciplinary integration.” This integration is profoundly intertwined with the nascent fields of modern educational technology and education for sustainable development, thereby offering a novel avenue for the advancement of pedagogical approaches and educational equity.

Keywords: Problem-based learning; Web of Science; VOSviewer; Visualization analysis

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1. Introduction

Problem-based learning (PBL) represents an innovative teaching method initially proposed in the 1960s at McMaster University School of Medicine in Canada. The objective of this pedagogical approach is to cultivate students’ capacity to solve complex, real-world problems^[1]. This pedagogical approach is centered on the student, with guidance from the teacher facilitating a process of learning through specific problems. This enables students to enhance their abilities in self-directed learning, innovation, and teamwork through active exploration.

In recent years, there has been a growing recognition of the value of new teaching methods, with an

increasing application of PBL pedagogy in university education. This has extended to a range of disciplines, including physics, language, medicine, and beyond^[2,3]. In comparison with traditional pedagogical approaches, PBL has been demonstrated to facilitate the enhancement of students' motivation, interest, and problem-solving abilities, as well as their comprehension and practical application of problems^[4].

Nevertheless, despite the growing body of research on PBL, there is a paucity of comprehensive and systematic analyses of the current status and development of PBL in the field of university education. In order to address this gap in the literature, this study employs a bibliometric approach, utilizing the published research literature as a basis for analysis. The VOSviewer tool is employed for the visualization and analysis of research on PBL pedagogy.

The main purpose of the study is to reveal the research publication trend of PBL in higher education, analyze the distribution characteristics of authors, institutions, journals, and countries, sort out the current research status, and explore the future development trend through keyword co-occurrence analysis and other methods. It aims to provide a scientific basis for subsequent related research and promote the in-depth development and widespread application of PBL pedagogy in higher education.

2. Methodology

2.1. Research tools

In recent years, knowledge mapping has emerged as a novel research method within the field of infometrics. It employs a visual representation of the interrelationships and development processes of knowledge, utilizing citation analysis, co-occurrence analysis, and visualization analysis. This paper employs the VOSviewer bibliometric tool for knowledge mapping. In comparison with other similar software, the software guarantees the scientific rigor of the knowledge map to the greatest extent, rather than compromising the accuracy of the co-occurrence of the relationship between the nodes at the expense of ensuring the clarity of the representation^[5]. The software is capable of presenting a variety of network views, including clustering, labelling, and density, which are effective tools for researchers to view knowledge evolution, analyze hotspots in a field, and mine thematic clusters. Concurrently, the acquired data are subjected to comprehensive analysis on the Web of Science platform's own online analytical functions. The data were summarized and visualized in terms of the number of publications, authors, institutions, countries, co-occurrence networks, and so forth. An overall analysis of research on problem-based learning pedagogy in universities was then carried out.

2.2. Data sources

The Web of Science (WOS) core collection database from Corevision was selected as the literature source, and the following search conditions were set: the database was selected as the Web of Science core collection, the citation index was set as Science Citation Index Expanded (SCI-EXPANDED)--1975-present and Social Sciences Citation Index (SSCI)--1975-present, an advanced search was used with TS=(((“Problem- based learning”)AND(“college*” or “university*”)))^[6,7] as the search formula, with a search period of 2004–2024 and the type of literature restricted to articles and reviews for a precise search. A total of 1,051 documents matching the topics were retrieved. The time of the search is December 1, 2024, and the specific selection process is shown in **Figure 1**.

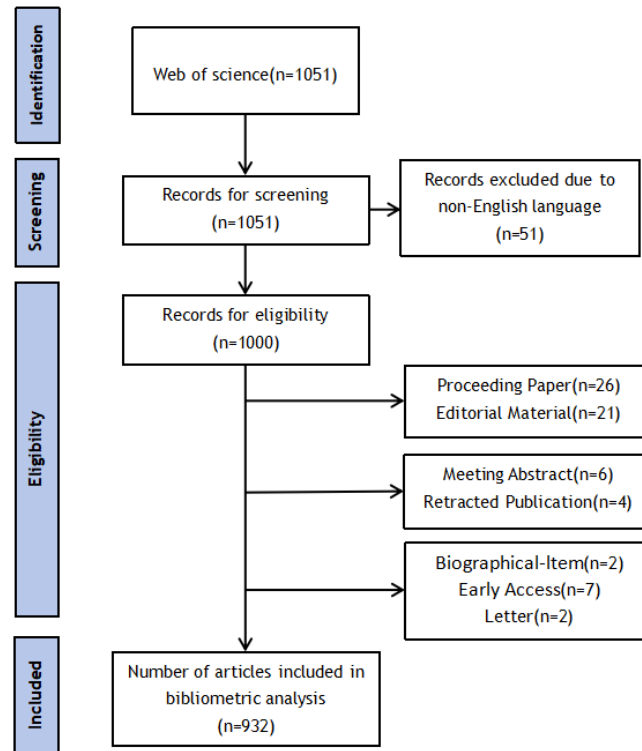


Figure 1. PRISMA flow diagram

3. Results and discussion

3.1. Research status on problem-based learning in college

3.1.1. Statistical analysis of the annual number of publications

A total of 932 publications on problem-based learning in colleges and universities have been produced between 2004 and 2024. The earliest known literature on this topic was published in 1991 in the journal *MEDICAL TEACHER* [8]. The number of annual publications serves as a benchmark for gauging the advancement of research in the field. It provides insight into the research trajectory of scholars in the field while reflecting the trend of relevant research in the field [9]. The entire university's problem-based learning initiative can be divided into two distinct phases: the initial and stabilizing period and the subsequent rapid growth period. The initial and stabilizing period, spanning from 2004 to 2015, is characterized by considerable fluctuations in the annual publication volume, with an overall trend that remains between 40 and 50 articles. The initial value was relatively low in 2004 (31 articles), before gradually increasing to reach a high point in 2009 (52 articles). This reflects the initial development stage of PBL research in colleges and universities. The overall trend is more stable, although there is a decline in some years (e.g., 34 articles in 2012). This suggests that the concept of PBL is gradually gaining attention in teaching and learning in higher education, although its research scope and application remain in the exploratory phase. Following 2016, the number of publications increased steadily, rising from 51 in 2016 to a high of 72 in 2021, but declining to 46 in 2023 (Figure 2). This phase demonstrates a notable surge in research activity, particularly between 2020 and 2022. This may be attributed to the rising popularity of online learning, which has fostered a renewed interest in PBL. Despite the decline in 2023, the overall level remains higher than at the outset, indicating that the diversification of teaching and learning modes has contributed to an increase in the number of publications.

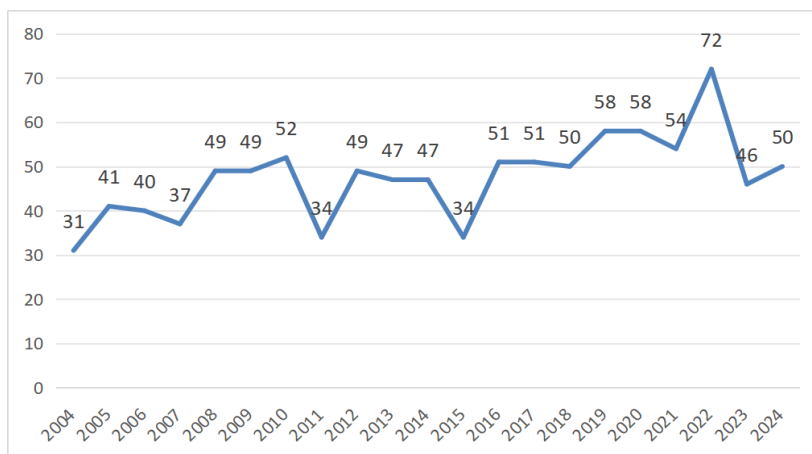


Figure 2. Annual distribution of publications on problem-based learning in colleges and universities (2004–2024)

3.1.2. Author co-occurrence analysis

Author co-occurrence analysis provides a visual representation of the highly productive authors and their collaborations in the field, which is useful for grasping the key forces in the research field^[10]. Over the past two decades, 932 core documents on problem-based learning in universities have involved 3,261 authors, and 28 core authors have been identified through the application of Price’s law, which establishes a minimum threshold of three publications per author. The size of the dots indicates the number of publications by each author, with larger dots representing a greater number of publications and, consequently, a more prominent role in the field. The lines between the dots represent the existence of mutual cooperation among the authors, as illustrated in **Figure 3**. With du, xiangyun, guerra, aida as the center, poulton, terry, ellaway, rachel h. as the center, schmidt, henk g. as the center, and schmidt, henk g. as the core author, the core author is the author who has published the most works. Wijnia, Lisette, and others demonstrate a more pronounced collaborative network with an increased number of collaborators. Nevertheless, the overall impression is that there is a relatively low level of collaboration between authors, with the majority of scholars working independently. The analysis demonstrates that the level of collaboration among the principal researchers in the field of problem-based learning in higher education is relatively low, and the interconnectivity is not particularly robust, even among high-output authors from the same institution. It is recommended that the leading role of the core authors be assumed with a view

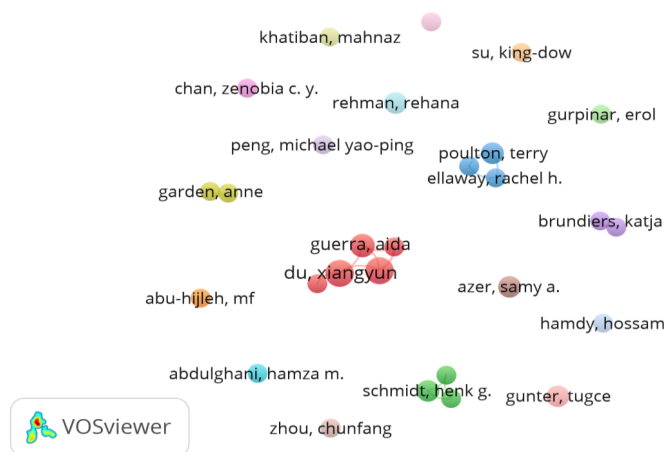


Figure 3. Visual map of author cooperation

to further strengthening the cooperative inquiry among researchers from the same institution, cross-institutional researchers, and researchers from different disciplines. This will facilitate the formation of a research synergy and promote the in-depth development of research in the field.

3.1.3. Analysis of institutional collaboration networks

The analysis of the issuing institutions can reflect the distribution and reserve of research power in the field of problem-based learning research in universities ^[11]. A total of 137 papers, representing approximately 14.7% of the total number of papers on the topic of problem-based learning in higher education, were published by the top 10 issuing institutions. This evidence suggests that these institutions are the primary contributors to research in this field. As illustrated in **Figure 4**, Aalborg University, Maastricht University, and the University of Hong Kong are situated at the core of the collaborative network, characterized by large nodes and frequent connections. This suggests their prominent role in academic leadership with regard to PBL research and dissemination. Similarly, Erasmus University and Rotterdam also occupy important nodes. Erasmus University Rotterdam also plays an important role in this context, demonstrating its influence in international PBL cooperation. With regard to the regional distribution of these institutions, Aalborg University and Maastricht University exemplify the intensive collaboration and compact network structure observed among European universities, thereby underscoring Europe’s leading role in the promotion and application of problem-based learning. Furthermore, institutions such as Aalborg University and Erasmus University Rotterdam not only form close networks with regional higher education institutions (HEIs) but also establish cross-regional links with those in North America and Asia. Middle Eastern universities, such as King Saud University and Arabian Gulf University, are emerging as centers of cooperation in the region, including through collaboration with Europe. Asian universities, such as Hong Kong Polytechnic University and China Medical University, play a role in the network, but their involvement is relatively limited in comparison to the core universities in Europe and the United States. There is also room for improvement in terms of the frequency of cooperation.

In general, a limited number of institutions (e.g., Aalborg University, Maastricht University, etc.) occupy a central position and promote extensive multi-regional collaboration. Concurrently, some regions (e.g., the University of Sharjah, Gifu University, etc.) are emerging and demonstrating active involvement. In the future, it will be important for global PBL research to focus on strengthening the participation of disadvantaged regions and promoting interdisciplinary cooperation.

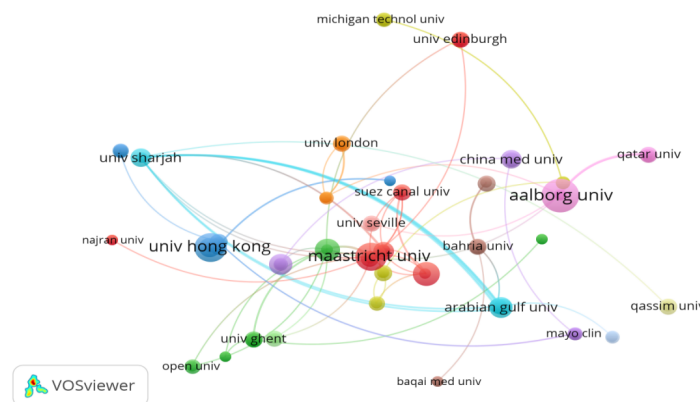


Figure 4. Visualization map of institutional cooperation (univ = university)

3.1.4. Analysis of literature citations

The citation count of a document serves as a direct indicator of its influence and contribution within its respective field. **Table 1** presents the top six most-cited articles in the field of problem-based learning (PBL) research in higher education. As shown in **Table 1**, the most frequently cited article is “The Flipped Classroom: A Course Redesign to Foster Learning and Engagement in a Health Professions School” by Jacqueline E. McLaughlin, published in 2014. During this period, research on PBL in higher education was entering a phase of steady development. In this study, McLaughlin effectively integrated the flipped classroom model with PBL, significantly enhancing students’ motivation and engagement, while fostering their critical thinking and problem-solving skills ^[12]. This innovative teaching approach provided a novel application context for PBL, enriching instructional practices and establishing an important research paradigm in medical education.

Furthermore, Katja Brundiers and Malathi Srinivasan are the most frequently cited authors, with Brundiers’ article having been cited 324 times and Srinivasan’s article having been cited 300 times. These high citations indicate that problem-based learning, as a student-centered instructional strategy, is receiving increasing attention from academics and educational practitioners. Furthermore, its theoretical and practical value has been widely recognized. The cited literature is primarily drawn from academic journals such as *Academic Medicine*, *International Journal of Sustainability in Higher Education*, and *Surgical and Radiological Anatomy*, which are the principal outlets for publishing research findings on problem-based learning in colleges and universities.

Table 1. Top six most cited papers in the Web of Science Core Collection Database

Title	Author	Journal	Citations	Average per year
The Flipped Classroom: A Course Redesign to Foster Learning and Engagement in a Health Professions School	Jacqueline E. McLaughlin	Academic Medicine	665	60.45
Real-World Learning Opportunities in Sustainability: From Classroom into the Real World	Katja Brundiers	International Journal of Sustainability in Higher Education	324	21.60
Comparing Problem-Based Learning with Case-Based Learning: Effects of a Major Curricular Shift at Two Institutions	Malathi Srinivasan	Academic Medicine	300	16.67
Do We Need Dissection in an Integrated Problem-Based Learning Medical Course? Perceptions of First- and Second-Year Students	Samy A. Azer	Surgical and Radiological Anatomy	250	13.89
First Year Medical Student Stress and Coping in a Problem-Based Learning Medical Curriculum	KJ Moffat	Medical Education	245	11.67
Problem-Based Learning: Influence on Students’ Learning in an Electrical Engineering Course	Aman Yadav	Journal of Engineering Education	236	16.86

3.1.5. Analysis of collaborative networks in major countries/regions

The data from the papers were imported into the VOSviewer (1.6.20) software for processing. In analyzing the cooperation network, the size of the circle is indicative of the corresponding country or region’s publication status. The connecting lines between the circles indicate the connection between individuals. A larger circle indicates a higher number of publications, while a more intensive connecting line signifies a stronger cooperation relationship. **Figure 6** comprises 50 network nodes, 168 links, and 8 clusters. The network nodes correspond to country names, with node size positively correlated with the number of documents. Links indicate the existence of a cooperative relationship between countries or regions. Furthermore, clusters can be used to

represent the proximity of cooperation between countries or regions. In the network, nodes and links within the same cluster are represented by the same color.

As illustrated in **Figure 5**, the United States of America occupies the largest node in the graph, indicating that it has published the greatest number of papers on problem-based learning research in higher education. Furthermore, the United States of America has more extensive and robust interconnectivity with several countries, including Germany, the People’s Republic of China, Canada, and England. This suggests that these countries engage in frequent and close collaborative endeavors. Furthermore, China, England, Saudi Arabia, and Spain are also prominent nodes, indicating that they have made significant contributions to the field of problem-based learning in higher education. People’s Republic of China has established robust collaborative relationships with Malaysia, Saudi Arabia, and other countries in Asia. This illustrates China’s collaborative network within the Asian region. The United States and the People’s Republic of China are identified as key players in facilitating cross-regional connections, fostering partnerships with numerous countries to bridge different regions. They serve as a conduit in the global network of cooperation, particularly facilitating connections between Europe and America with Asia. Concurrently, England also serves as a cross-European conduit, establishing robust connections with numerous European countries.

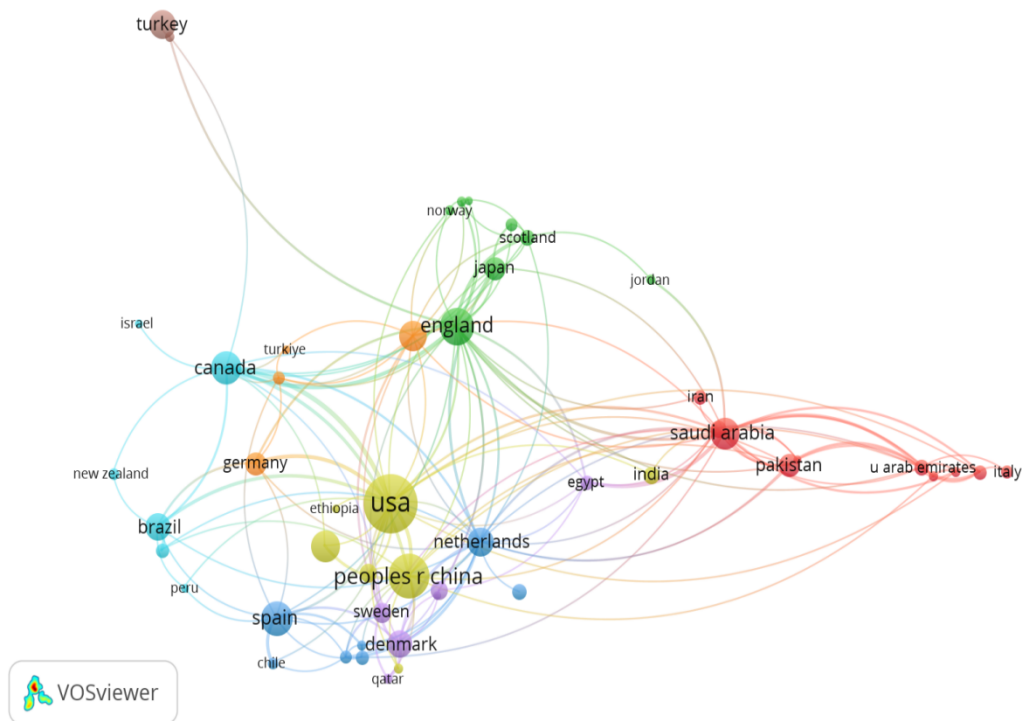


Figure 5. Countries/regions cooperation network

3.2. Trends in problem-based research relevant to college education

3.2.1. Keyword co-occurrence mapping

Keywords are a summary of the main content of the literature, and analyzing the keywords of related literature in a certain field can help to understand the research hotspots in this field^[13]. When selecting keywords, due to individual differences in the expression of some words, the phenomenon of multiple words is common, which may lead to inaccurate keyword co-occurrence mapping. In order to solve this problem, firstly, the

expressions of keywords in all the literatures are unified. For example, “problem based learning,” “problem-based learning (pbl),” “pbl,” “problem-based learning, methods,” can be harmonized as “problem-based learning”; “student perceptions” can be harmonized as “perceptions,” “academic-achievement” can be harmonized as “achievement,” and so on. To obtain the graph displayed in **Figure 6**, the relevant settings are run. Each node represents a keyword, with the size of the keyword indicating the frequency of that keyword. The keywords are ordered according to frequency, from the highest to the lowest. The keywords with the highest frequency are problem-based learning (525 times), education (204 times), university (124 times), medical education (118 times), student (170 times), performance (61 times), curriculum (125 times), and knowledge (56 times). In conjunction with the mapping, it becomes evident that the primary focus of PBL-related research in higher education is on pedagogical innovation, curriculum design and implementation strategies, student learning experience, and effectiveness assessment in higher education, with a particular emphasis on the application in medical and science education. This reflects the significant value of PBL in enhancing knowledge, skills, and critical thinking.

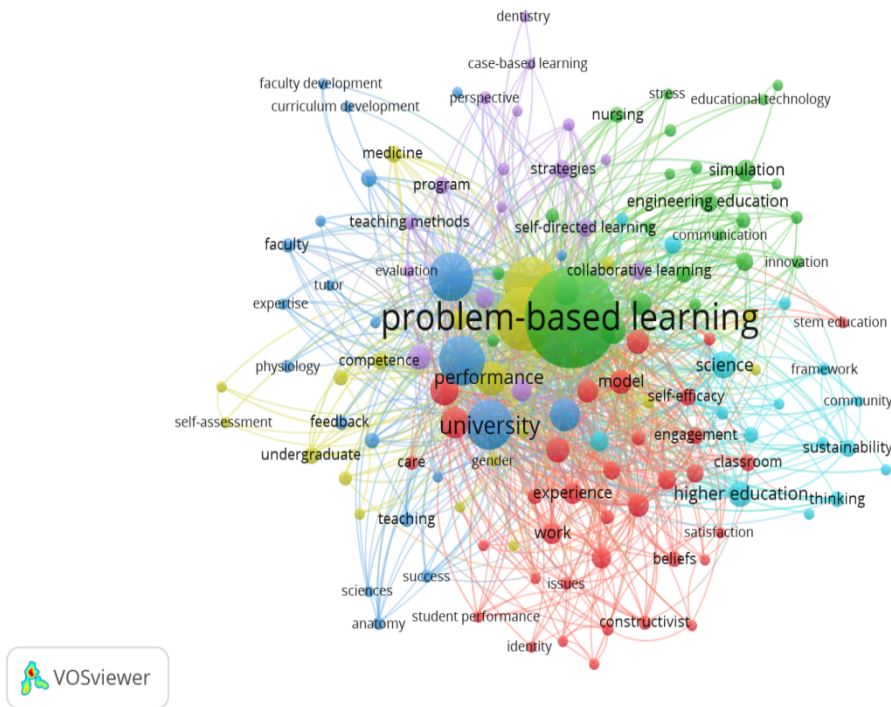


Figure 6. Keyword co-occurrence mapping

3.2.2. Keyword co-occurrence timeline analysis

The visualization maps were selected based on the frequency of occurrence of the keywords, with a minimum frequency of three occurrences and obtained along the time axis. The size of the node representing a keyword is indicative of the frequency of occurrence. The color of each node represents the research area that is the subject of the greatest interest at a given point in time. The direction of the lines connecting the nodes indicates the direction of knowledge flow, with the color transitioning from purple to yellow in accordance with the temporal sequence. In **Figure 7**, the purple nodes represent the period preceding 2005, and the yellow nodes represent the period subsequent to 2020. The greater the number of nodes associated with a given keyword that are colored

an important area of research. Tiwari *et al.* ^[15] conducted a comparative analysis between PBL and case-based learning (CBL), concluding that CBL is more responsive to the needs of both students and faculty in medical education, particularly in terms of fostering lifelong learning, open-ended inquiry, and teamwork. Additionally, it offers an alternative to traditional PBL group instruction. Furthermore, a study conducted by Srinivasan *et al.* ^[16] demonstrated that PBL offers substantial benefits over the conventional lecture format (lecturing) in fostering critical thinking skills in nursing students.

Furthermore, group discussion, as a crucial element of PBL instruction, has demonstrated substantial impacts on fostering students' collaborative abilities, critical thinking, and problem-solving competencies. The integration of ICT technologies, such as computer-supported PBL (CSPBL) and distributed PBL (DPBL), has introduced new avenues for enhancing the adaptability of PBL teaching and distance learning. Nevertheless, research in this phase is primarily concerned with comparative analyses of different teaching methods, and the comprehensive integration of PBL in actual teaching and learning remains in the initial stages of investigation.

In short, the research conducted during the initial phase has established a theoretical foundation and practical experience that inform the implementation of PBL in medical and nursing education. Through the comparative analysis of teaching methods and techniques, it has yielded valuable insights that will inform the subsequent advancement of research and interdisciplinary applications of PBL.

The second phase is the deepening and innovation phase of PBL research in higher education (2011–2024). During this period, the research field is undergoing constant expansion and integration with a variety of educational theories and technological tools. Additionally, a significant number of new themes and keywords have emerged, including “Engineering Education,” “Curriculum Change,” and “Education for Sustainable Development.” There is application of game-based learning, hypermedia systems, multimedia, foreign language education, applications and education for sustainable development in the classroom. The field of foreign language education has also seen applications in the field of chemistry. The focus of our research has shifted gradually from single-discipline teaching practices to interdisciplinary and cross-field educational innovations.

Yadav *et al.* ^[17] investigated the potential of problem-based learning in an undergraduate electrical engineering program. Their findings indicated that this approach facilitated students' comprehension of concepts within the specialized curriculum, enhanced their problem-solving abilities, and was an effective strategy for improving academic performance. Kerr and Yan ^[18] implemented a problem-based learning approach in a chemistry laboratory course by posing and solving authentic research problems. This approach stimulated students' interest and motivation to learn, and improved students' problem-solving skills and overall retention. Furthermore, PBL combined with augmented reality (AR) mobile games and game-based learning significantly improved the interactivity of the learning environment and student engagement. For example, Guerra ^[19] investigated the effectiveness of gamified learning and PBL theory in language teaching, exploring the potential of AR technology as a complement to traditional media (e.g., print materials) in this context. Furthermore, Wiek *et al.* ^[20] integrated problem-based and project-based learning approaches in higher education, highlighting the enhancement of diverse student competencies in the process of formulating and resolving intricate problems, which plays a pivotal role in Education for Sustainable Development (ESD). Meanwhile, Tejedor *et al.* ^[21] asserted that the integration of ESD has become a central topic in engineering education. The study demonstrated that, despite the fact that PBL and ESD share principles such as interdisciplinary collaboration and learning, they continue to encounter challenges in practice, which constrains the comprehensive integration of sustainable development.

Secondly, the advent of online education has also stimulated innovation in the application of PBL.

Aslan ^[22] investigated the role of problem-based learning in an online real-time classroom, and the results demonstrated that PBL was efficacious in enhancing students' academic achievement, problem-solving abilities, and interaction levels. Furthermore, Lee ^[23] investigated the utilization of computer-supported problem-based learning (CPBL) in medical education and discovered that, despite CPBL exerting a constrained overall influence on pedagogical approaches, it engendered certain alterations in students' expectations and perceptions of the tutor's role in group activities, which were closely associated with students' familiarity with the technology. In summary, this phase of PBL research has furnished invaluable support for enhancing educational efficacy, advancing curriculum reform, and attaining the Sustainable Development Goals (SDGs) through technology integration, innovative online educational models, and cross-disciplinary integration. Furthermore, it has established a foundation for future practical advancement in optimizing educational models and applying theory.

4. Conclusion

The development of PBL research in higher education serves to confirm the far-reaching impact of the trend of "student-centered" change in education. The core concept of this trend goes beyond the traditional mode of knowledge transfer, focusing instead on the cultivation of students' comprehensive abilities, innovative thinking, and sustainable development. This shift has facilitated the innovation of teaching modes in higher education and provided a crucial framework for advancing educational equity and quality improvement. At the present time, PBL research has progressed from the initial phase of investigation, which was characterized by a single-discipline focus, to a period of rapid development, during which there has been a shift towards multidisciplinary integration. Additionally, the focus of research has expanded from a comparative analysis of teaching modes and the construction of theoretical frameworks to encompass the practice of interdisciplinary application, technological integration, and innovative pedagogies. The theoretical and practical value of PBL is widely acknowledged by the international academic community. However, there is still scope for improvement in cross-institutional and cross-disciplinary collaboration, particularly in the promotion and application of PBL in the fields of social sciences, humanities, and vocational education, which require further exploration.

It is recommended that in the future, PBL research in colleges and universities should be closely integrated with emerging technologies such as artificial intelligence, big data, and virtual reality. This integration should be undertaken in order to achieve the optimization of teaching methods and the personalization of educational experience. This can be achieved by constructing a more adaptive, creative, and inclusive learning model. Meanwhile, PBL, as an open and flexible teaching strategy, merits further investigation for its potential in addressing real-world complex problems and fostering innovative thinking. Driven by globalization and technological innovation, research into PBL in colleges and universities will continue to deepen and promote the transformation of the teaching mode from a focus on a single discipline to interdisciplinary integration. This will open up new paths for the future development of education and play a greater role in the transformation of human society into a knowledge-based economy. As a result of the ongoing transition of human society towards a knowledge-based economy, it will assume a more prominent position.

Disclosure statement

The authors declare no conflict of interest.

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