Educational Administration: Theory and Practice
2024, 30(5), 9877-9892
ISSN: 2148-2403
https://kuey.net/

Research Article

A Systematic Literature Review Of The Effective Of Problem-Based Learning In Blended Learning Environment

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Citation: Li Wang, Jirarat Sitthiworachart, (2024), A Systematic Literature Review Of The Effective Of Problem-Based Learning In Blended Learning Environment, *Educational Administration: Theory and Practice*, *30*(5), 9877-9892, Doi: 10.53555/kuey.v30i5.1183

ARTICLE INFO

ABSTRACT

Blended problem-based learning (BPBL) combines problem-based learning (PBL)'s active engagement with blended learning (BL)'s flexible delivery, creating a powerful learning experience. This paper contributes by conducting a systematic literature review using the PRISMA method, based on selection criteria, covering 24 articles published between 2009 and 2023. The analysis explores the trends, technological integration, and design elements of BPBL. BPBL research has shown a steady growth trend in large samples and multi-disciplinary applications and has a significant effect on students' performance and higher-order thinking abilities in recent years; online course learning platforms and computer software (Google+ Hangout Video Conference, Zoom Application, Google Classroom Application, mobile applications, blogs, and mobile social networks AutoPlay studio; Video recording etc.) are the most widely technology used in BPBL, when integrating technology, we need to consider the benefits and challenges of technology. After analyzing the articles, we proposed that elements such as needs analysis, propose problem, technology integration, teaching activity and resource design, interaction, evaluation and feedback should be considered when designing BPBL, among them, interaction in the learning process is a key element. Finally, we hope this article can provide theoretical and practical guidance for educators when designing BPBL teaching.

Keywords: Problem-based learning, Blended learning, Systematic review, Higher-order thinking

Practitioner notes

What you already know about BPBL review:

- BPBL has a positive effect on students in terms of student courses, higher-order thinking skills, and independent learning abilities;
- Design the teaching process and element composition of BPBL;
- BPBL has the potential for continued research in terms of interaction, learning timing, and teacher role changes.

What this literature review adds:

- This paper summarizes the sample number, type and grouping of BPBL experiments, and points out the development trends;
- This paper lists the experimental effects of BPBL and summarizes how to measure the effects;
- This article summarizes the application, classification and precautions of technology in BPBL

1. Introduction

1.1 Background

With the wide popularity of the internet, blended learning environments combining face-to-face teaching with online learning, have become a popular teaching method. This integration offers numerous advantages within the realm of problem-based learning. Puttasem (2022) showed that blended learning environments allow for greater flexibility and accessibility in delivering problem-based learning. Students can engage in problem-

solving activities both in offline classrooms and online platforms, allowing for more diverse perspectives and a wider range of resources (Palioura & Dimoulas, 2022).
A wealth of research data indicated that blended problem-based learning (BPBL for short) enhances learners' higher-order thinking. Khotimah (2018) demonstrated that PBL learning based on blended learning improved higher-order thinking scores. It is proven that implementing BPBL has been proven to enhance and cultivate students' autonomous learning ability and critical thinking skills (Kartini et al., 2023; Tseng et al., 2013; Kuo et al.,2014; Hikmawati & Ningsih, 2020). A large number of studies have also shown that BPBL can improve students' problem-solving abilities (Yeh, 2010; Yen & Lee, 2011; Warren et.al., 2012).
Additionally, Technology plays an important role in BPBL. Incorporating technology into a blended learning setting can optimize the problem-solving journey by granting students access to pertinent information, virtual simulations, and interactive multimedia resources (Verawati et al., 2022; Liu et al., 2022). Dakhi et al. (2020) outlined that technology plays a pivotal role in fostering students' acclimatization to the blended learning environment. It facilitates interactions between students and teachers also among students. Pardo et al. (2019) emphasized the need to prioritize effective teaching methods, including the utilization of new technology, to enhance the learning process.

1.2 Literature Review

1.2.1 Blended learning
Alammary et al. (2014) reported that blended learning, which combines traditional classroom instruction with online resources to meet students' different needs and preferences, is a promising educational method. Cooney et al. (2000) conducted pioneering research on “blended learning” by combining play and work elements in kindergarten. Bonk et al.(2002) investigated the impact of blended learning on students' professional development in a military course. Mortera-Gutiérrez (2006) pointed out that combining BPBL with technology provides a variety of educational possibilities and reflects the richness of pedagogy.

1.2.2 Problem-based learning
Wijnia and Servant-Miklos (2019) stated that the problem-based learning (PBL for short) approach has its roots in medical education, with its inception dating back to the 1950s. The initial application of this approach was undertaken by Barrows in 1976 at McMaster University. Barrows and Tamblyn (1980) showed that this approach emphasizes acquiring skills and knowledge that can be directly applied to address everyday challenges. Problem-based learning (PBL) has the potential to boost students' autonomous learning abilities, consequently leading to an improvement in their academic performance (Sungur, 2006). Furthermore, it inspires students to acquire knowledge and cultivate self-reliant abilities, empowering them to tackle real-life problems and navigate challenges effectively (Karabulut, 2002). Anggraeni et al. (2023) indicated that the Problem-Based Learning (PBL) model has been proven to be the most effective strategy for enhancing learning when students are exposed to real cases and real-world problems in both situations.
Therefore, the research question of this paper focuses on the effectiveness of problem-based learning in a blended learning environment.

The following three questions direct the study:
1.What are the current trends in researching problem-based learning within a blended learning environment?
2.What are the types of technology combined when applying problem-based learning within a blended learning environment?
3.What are the essential elements to design problem-based learning within a blended learning environment?

This research is segmented into four parts:
The initial section comprises the introduction, encompassing the background, literature review, and the formulation of research questions. The methodology section then delineates the research process and outlines the criteria for selecting articles. The findings section unfolds, showcasing the results, categorization, and analysis. The last was discussion, limitations, and conclusion sections delve into a comprehensive exploration of the findings and provide essential recommendations for future research.

2. Methodology

We adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, as outlined by Moher et al., (2015). Our approach involved a flow diagram encompassing the stages of identification, screening, eligibility assessment, and inclusion (Fig.1).

2.1 Database Search

We conducted a literature review using reputable sources such as Web of Science, Science Direct, and Google Scholar, known for their reliability and high-quality publications. The Subject area is social science. Last, The snowballing technique, as described by (Wohlin,2014) was employed to identify articles that were not initially retrieved through the use of search strings.

2.2 Identification of Search Terms

The descriptors entered in meta-search engines were as follows: problem-based learning， problem-solving process (methods or approach), PBL and blended learning, BL, and blended problem-based learning. These words were put randomly and interchangeably in the meta-search engine with persistent use until studies were exhausted.

Boolean operators are commonly employed in online searches to refine and narrow down results. The method for locating relevant articles is as follows: (“problem-based learning” OR" problem-solving methods" OR "problem-solving process" OR "problem-solving approach" OR "PBL") AND (“blended learning” OR “BL”) OR (blended Problem-based learning).

2.3 Criteria for Inclusion and Exclusion

The criteria for inclusion and exclusion are specified in Table 1.

Table1. Criteria for Inclusion and Exclusion

NO	Inclusion Criteria (IC)	Exclusion Criteria (EC)
1	The title or abstract must explicitly mention both problem-based learning and blended learning (or alternative terms).	No PBL and blended learning (or replacement terms) in the title or abstract.
2	The paper should originate from scholarly articles that have undergone peer review.	From the proceedings of conferences, chapters in books, articles in magazines, news sources, and presentations.
3	The article is written in English.	Articles in Chinese, Japanese or other languages (no English.
4	Blended learning, face-to-face (offline), online teaching and learning.	Only online learning, Distance learning, E-learning.
5	Large groups (30+) participated in the study	The samples were less than 30.

2.4 The Screening Process

Figure 1 illustrates the search process flow using the PRISMA search strategy diagram, prepared in accordance with the guidelines provided by (Moher et al., 2009).

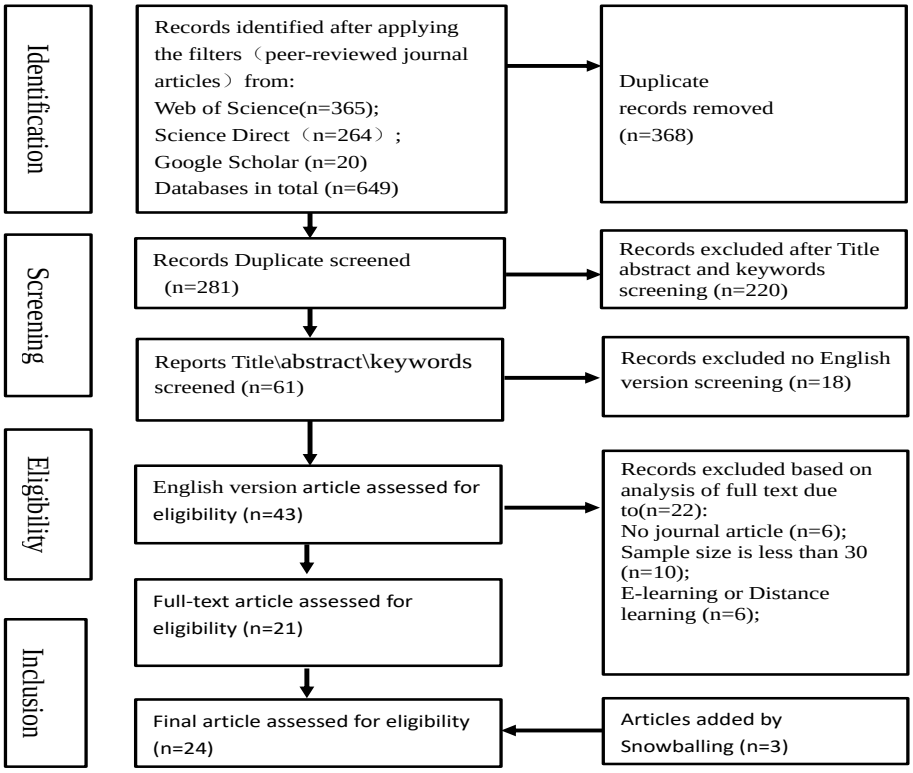

Figure 1. The flow of the PRISMA search strategy diagram

3. Findings

3.1 Data analysis

We utilized a Microsoft Excel spreadsheet to document and systematize the findings from the analysis of 24 articles. Figure 2 illustrates the selected coding categories for this review and their correlation with three research questions. To identify the codes and categories, we thoroughly scrutinized and analyzed the entire

content of the articles incorporated in the systematic reviews.

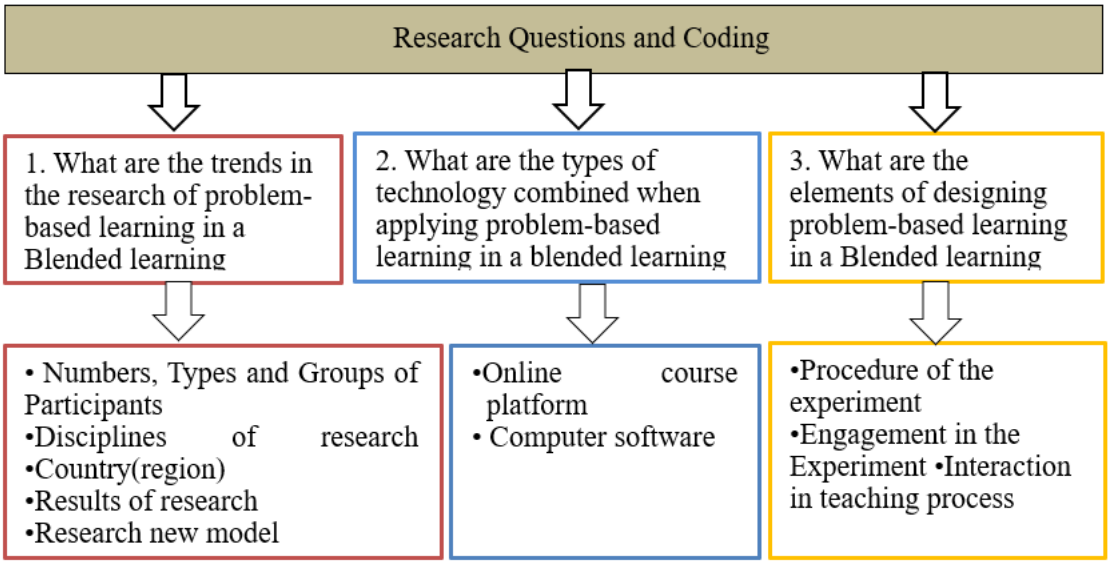

Figure 2. Research Questions and Coding

3.2 RQ1: What are the trends in the research of problem-based learning in a Blended learning environment?

3.2.1 Years of Publication

The distribution of publication years for the 24 articles is shown in Table 2. The article screening deadline was in August 2023. Over the past four years (2020 to 2023), out of the total number of articles, 46% corresponds to a total of 11 articles. The increasing number of eligible articles over the years reflects the growing attention to blended problem-based learning.

Table 2. Details of the articles

Author(s)	Year	Country/rea	Subject	Num	Status	Group Size
Woltering	2009	Germany	Medicine	185	CS	28groups
Hoic-Bozic	2009	Croatia	Computer	30	CS	1group
Yeh	2010	Thailand	Social science	32	MT	6groups
Yen and lee	2011	Taiwan, China	Computer	34	CS	3groups
DELİALİOĞLU	2012	Turkey	Computer	89	MT	1group
Warren	2012	USA	Mathematics	89	CS	2groups
Tseng	2013	Taiwan, China	Engineering	42	CS	3groups
Kuo	2014	Taiwan, China	Computer	80	CS	2groups
EI-Magboub	2016	USA	Medicine	185	CS	24groups
Tsai	2017	Taiwan, China	Biology	41	CS	2groups
Dwiyogo	2018	Indonesia	Physical education	60	GS	1group
Cavicchia	2018	Argentina	Medicine	68	GS	1group
Shimizu	2019	Japan	Medicine	96	CS	2groups
Kardipah	2020	Indonesia	Computer	48	CS	2groups
Hikmawati	2020	Indonesia	Medicine	73	HSS	2groups
Dawilai	2021	Thailand	English	60	CS	2groups
Unal	2021	USA	Computer	94	CS	3groups
Hamzah	2021	Indonesia	Social science	42	CS	2groups
Bukumiric	2022	Europe	Medicine	53	CS	2groups
Servos	2022	Germany	Medicine	317	CS	39groups
Efendi	2022	Indonesia	English	42	MS	3groups
Nurrijal	2023	Indonesia	Education	30	CS	1group
Kartini	2023	Indonesia	Economics	46	CS	2groups
Indriani	2023	Indonesia	Social science	96	CS	2groups

Notes:
CS=College students; GS=Graduate students; HSS=High school students;
MSS= Middle school students; MT=Mature(teachers);

3.2.2 Characteristics of Participants

Participant Count

From Table 2, the number of participants in the studies varies widely, ranging from as low as 30 to as high as 317. Some researchers, such as (Servos et al., 2022) and (El-Magboub et al., 2016), had a significantly large number of participants (317 and 185 respectively). using large samples can improve the comprehensiveness and accuracy of data collection.

The type of Participants

As depicted in Table 2, The participants can be classified into college students (n=18), teachers(n=2), graduate students(n=2), middle school students(n=1) and high school students(n=1). It indicates that there are many types of participants which is beneficial for obtaining a comprehensive view of the topic under study. College students have the largest number of students.

The groups of Participants

Nearly half of the articles (n=11,46%) included two groups (experimental group and control group). To observe the interaction between the groups, some studies are divided into multiple groups, 6 groups (Yeh,2010), 24 groups (El-Magboub et al., 2016), 28 groups(Woltering et al., 2009), 39groups (Servos et al., 2022).

3.2.3 Disciplines of Participants

BPBL has found widespread application across various disciplines. The results indicated a higher frequency of usage in the field of Medicine (n=7), followed by Computer Science (n=6), and Social Sciences (n=3). the use of BPBL in other disciplines is relatively low. Table 2 shows the distribution of BPBL within disciplines.

3.2.4 Country(region) the article located

Table 2 displays the distribution of studies by the countries where they were conducted, Indonesia (n=8), Taiwan, China (n=4) and the United States (n=3). According to the data derived from the analyzed articles, Indonesia has significantly contributed to research in this field, particularly in BPBL.

3.2.5 In terms of research results

Yeung (2015) showed that in the global pursuit of education, fostering higher-order thinking skills (HOTS) has become the primary goal for students in the 21st century. Bloom's Taxonomy encompassed the following levels: Knowledge, Understanding, Application, Analysis, Synthesis, and Evaluation(Bloom,1956). Anderson and Krathwohl (2001) modified Bloom's taxonomy, categorizing cognitive skills into Remembering (C1), Understanding (C2), Applying (C3), Analyzing (C4), Evaluating (C5), and Creating (C6). This adapted taxonomy serves as a reference framework for assessing the depth of thinking skills in learning.

The learning objectives in the Lower-Order Thinking Skill (LOTS) category correspond to the development of C1, C2, and C3, whereas the Higher-Order Thinking Skill (HOTS) encompasses learning that fosters C4 to C6. Purwanto et al.(2020) proposed that students possessing higher-order thinking Skills (HOTS) demonstrate the capacity to analyze, evaluate, and generate innovations when addressing problems. Schraw and Robinson (2011) demonstrated that higher-order thinking skills encompass four key components: reasoning skills, argumentation skills, problem-solving and critical thinking, and metacognition. so taking the above factors together in this review, higher-order thinking ability mainly includes problem-solving ability, critical thinking and creative thinking.

Derived from the analysis of journal articles, the gathered data is represented in Figure 3 below. The research focused on higher-order thinking and other scopes: course achievement (n=14), problem-solving ability (n=9), critical thinking (n=6), and creative thinking (n=5).

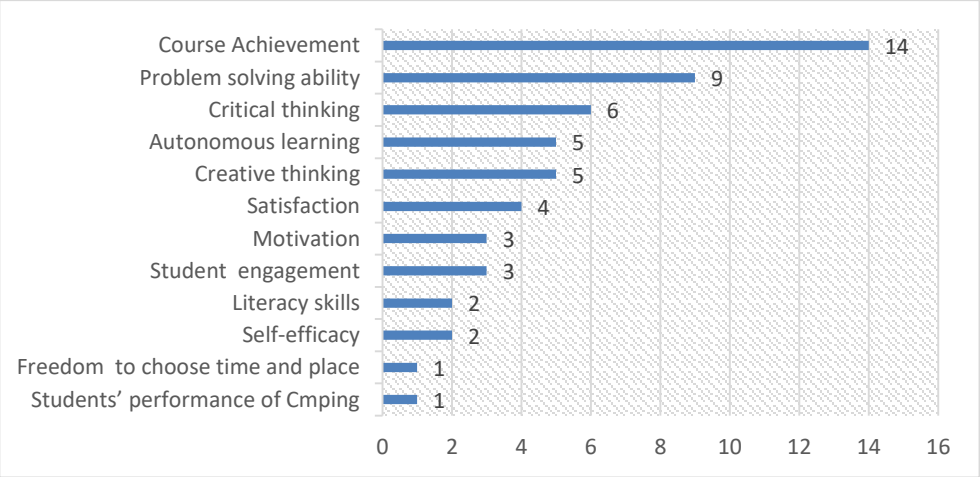

Figure 3 The distribution of the studies in terms of research results

Also, there is an interaction between other results and higher-order thinking skills. Research by (Huang et al., 2022) demonstrated a positive and robust linear relationship between higher-order thinking skills and academic achievement. Students possessing higher-order thinking skills can enhance their performance, increase motivation for learning and mitigate their weaknesses (Widana,2017). We can see higher-order thinking skills and measurement tools in Table 3.

Table 3. Higher-order thinking and Measurement tools

Higher order thinking	Measurement Tools
Problem solving ability	By Completing PBL projects and uploading to the assigned website to measure problem-solving ability(Yeh, 2010); Tsai & Tang（2017) defined the problem-solving scale, which comprises 30 items divided into three sections: problem cognitive-oriented, problem aversion-oriented, and problem confidence-oriented. Respondents rate each item using a 5-point Likert scale; In Dwiyogo's study, data on problem-solving ability was collected through a questionnaire that consisted of two parts: the first part used a 5-point Likert scale; the second part solicited expert opinions (Dwiyogo,2018); Bukumiric et al.(2022) measured problem-solving ability through a test containing 5 questions, totalling25 points. The assessment instrument of problem-solving uses an observation sheet (Efendi & Ariyani, 2022); Kuo et al (2014) adopted a set of web-based assessment criteria proposed by Khachakrit in 2011 to measure problem-solving ability; Prepare a questionnaire to measure problem-solving ability, based on the following indicators: (1) Develop creative solutions; (2) Formulate practical solutions; (3) Actively discover and solve problems; (4) Implement problem-solving strategies; (5) Implement various problem-solving strategies (Indriani et al., 2023); Tseng et al.(2013) employed a semi-structured interview technique, presenting both open-ended and closed-ended questions.16 questions were formulated according to the research objectives and were validated by five experts in the field to establish content validity. Yen and Lee (2011) evaluated problem-solving abilities by conducting content analysis on participants' self-evaluations, instructor records, and system logs. Based on the content analysis, the results were divided into the following six dimensions: Understanding, Planning, Implementation, Evaluation, Conclusion and Report.
Critical thinking skills	Yeh (2010)completed the assessment of critical thinking skills by developing a test; In Nurrijal's study, the assessment of critical thinking skills was conducted through testing papers, categorized into three outcomes: high effective, moderate effective, and low effective (Nurrijal et al., 2023); The students' critical thinking was conducted by the written test (Kartini et al.,2023); Kuo et al (2014) employed the scoring scheme based on critical thinking assessment proposed by Isaksen and Parnes in 1985; Hikmawati and Ningsih (2020) adopted the testing technique developed by Facione in 2011 and applied it to measure students' critical thinking skills, which included 12 questions. By conducting pre-tests and post-tests on students' self-assessments and administering questionnaire assessments to experts, the study was carried out (Tseng et al., 2013).
Creative thinking skills	The author conducted assessments through pre-tests and post-tests, as well as individual and group assignments. The assignments were evaluated by two raters with a minimum of five years of experience in teaching writing(Dawilai et al., 2021); Creative thinking was assessed through an essay test, with the results classified as high, medium or low(Nurrijal et al., 2023); Use performance test rubrics to obtain data on students' creative thinking abilities and analyze the data (Kartini et al., 2023); The creative thinking evaluation scheme proposed by Isaksen and Parnes (1985) was used for evaluation (Kuo et al., 2014); Creative thinking skills were assessed by counting the number of creative ideas generated during group interactive discussions from valid log files, with two coders analyzing and categorizing the content of the interactive conversations (Tseng et al., 2013).

3.3 RQ2: What are the types of technology combined when applying problem-based learning in a blended learning environment?

Of these 24 articles, 3 utilized a blended learning environment and employed problem-based teaching models without specifying the use of any particular technology (Kardipah,2020; Kartini,2023; Indriani,2023). The remaining 21 articles involved technologies like online course platforms and computer software. Table 4 details the technology categories and application environments.

3.3.1 Online Learning Platforms

This category of technological applications involves the utilization of online learning platforms to deliver educational content, assignments, online quizzes, discussion boards, and other teaching resources. These platforms enable students and educators to manage courses and engage in online interactions. As an illustration, Hamzah et al.(2021)formulated a blended learning strategy that utilized a Learning Management System (LMS) incorporating the Web-Centric Course (WCC) model. This approach was specifically designed for Islamic studies to align with curriculum requirements.

3.3.2 Computer Software

This category of technological applications includes the use of multimedia devices and tools such as projectors, zoom applications, electronic whiteboards, and Google Classroom applications to enhance the teaching and learning experience. By delivering and visualizing course content, these technological applications contribute to improving the quality of education, fostering student engagement, and enhancing learning outcomes.

Table 4. The technology used in BPBL

Articles	Technology	Application Environment	Types
Hoic-Bozic et al., 2009	Learning Management System	The problem-based learning method was applied in two settings: a face-to-face classroom and 14 computers connected to the internet, and an online environment utilizing a Learning Management System (LMS).	Online Course Learning Platform
Woltering et al., 2009	Virtual Clinical Order Entry System (VCOE)	The Problem-Based Learning Model was implemented in both a face-to-face setting, equipped with a prepared room containing a conference table, flip chart, and a notebook computer connected to the internet and a web-based learning environment featuring elements like the virtual clinical order entry system and a bulletin board.	
Yeh, 2010	E-learning Platform	The Problem-Based Learning approach was implemented in both online learning through e-learning platforms and traditional teaching environments.	
Delialioğlu, 2012	Course Management System	The course was conducted as a blended learning environment, incorporating weekly face-to-face meetings between students and teachers. Additionally, course materials were delivered online through a course management system to facilitate the implementation of problem-based learning in the course instruction.	
Warren et al., 2012	Courseware Platform	Apply the PBL teaching method in a blended environment (face-to-face classes and online resources supported through the courseware platform, Moodle).	
Tsai and Tang, 2017	Online learning Platform	The PBL method is employed in a blended environment, involving traditional lectures conducted alternately with online courses (a course management system, including online presentation applications).	
Cavicchia et al., 2018	Online Platform	PBL courses were implemented through both traditional face-to-face environments and online learning platforms.	
Unal and Cakir, 2021	Web2.0 technologies	The PBL method was used in online learning platforms and face-to-face environments.	Online Course Learning Platform
Bukumiric et al, 2022	Online learning Platform	PBL courses were delivered through a combination of face-to-face teaching in a computer lab (involving lectures, meetings, internet access, and independent presentations, with all participants possessing basic computer skills and familiarity with the internet but lacking mobile learning experience) and online learning by the Moodle platform.	
Servos et al., 2022	ILIAS Platform	Courses were used in PBL integrated with a face-to-face environment and online learning platform (ILIAS).	
Nurrijal et al., 2023	LMS	Blended learning incorporating PBL courses utilized both face-to-face and online learning modalities, employing synchronous and asynchronous patterns facilitated through the Moodle Learning Management System (LMS)-based e-learning platform.	
Hamzah et al., 2021	LMS	Used the PBL, conducted in face-to-face learning and online learning environments (LMS).	
Kuo et al., 2014	Learning System Platform	Implemented PBL methodologies in both traditional classroom settings and online learning environments through a learning system platform.	

Tseng et al., 2013	Interactive Web Platform	The learning environment is face-to-face courses and interactive online platforms. During the learning process, use concept mapping tools and PBL.	
Shimizu et al, 2019	Course System	Using the PBL method in the course, the learning environment is a face-to-face course and an online-based e-learning environment (LMS).	
Yen and Lee, 2011	Mobile, Web-Based	The PBL method was conducted in mobile, web-based and classroom environments （a computer laboratory）	Computer Software
El-Magboub et al., 2016	Google + Hangout video conference	The PBL method was implemented through both traditional face-to-face classes and online sessions using Google+ Hangout video conference software.	
Efendi and Ariyani, 2022	Zoom Application	The PBL method was conducted and integrated with face-to-face classes and online teaching (Zoom).	
Hikmawati and Ningsih, 2020	Google Classroom Application	PBL methods were used in a blended environment, online learning (such as Google Classroom) and face-to-face classes.	
Dawilai et al., 2021	Mobile Applications	Courses were used in PBL delivered in face-to-face teaching and e-learning environments (online technology such as wikis, mobile applications, blogs, and mobile social networks）	
Dwiyogo, 2018	The AutoPlay studio; Video recording	A new (problem-based learning) PBL model was employed in the blended learning process, encompassing face-to-face courses, online learning and offline learning.	

Table 5.key elements of BPBL

Elements	Definition	Support Material
Analysis	It includes student needs, teacher needs, theoretical basis, etc.	Hoic-Bozic et al. (2009) pointed out that learning systems should consist of elements from behaviorism, cognitivism, and constructivism, as the theoretical foundation; Dwiyogo (2018) demonstrated that the initial stage involves analyzing problem-solving needs, identifying learning sources and problems during the implementation of a blended learning approach, and identifying learner characteristics, the BPBL model is then developed based on this analysis; Delialioğlu (2012) addressed different learner needs in the teaching process; Dawilai et al (2021) highlighted that, in a blended environment, students engaged in PBBL could cultivate creative writing skills by choosing their preferred learning style, time, and location, aligning with their individual learning preferences and requirements; The study by Efendi and Ariyani (2022) highlighted the importance of precise selection of course content with a contemporary foundation that aligns with the requirements of the professional work field; Kartini et al (2023) adopted open-ended questions designed to gather insights into students' needs for learning progress and information.
Learning environment	Create a blended Learning environment	24 articles conducted learning in a blended environment（face-to-face and online learning）,Seen Table 4 for details.
Methodology	Qualitative or quantitative research	Qualitative and Quantitative(n=14); Qualitative(n=2); Quantitative (n=8)
Propose problems	Selecting actual problems	Yeh (2010) emphasized the need for participants to apply problem-based learning (PBL) to real problems; Warren et al (2012) mentioned that tutors need to design authentic tasks to help students master the real-world skills they will need in future jobs. Students need to identify the knowledge, attitudes, and skills they need to master when encountering problems, as well as follow-up actions when new problems arise (Dwiyogo, 2018); In the study of (Cavicchia et al., 2018), tutors prepared questions about health that included contextualized social components representing the main health issues in Argentina; When students solved problems, instructors needed to implement heuristics and provide available methods for students to refer to (Yen & Lee, 2011); Delialioğlu (2012) presented cases with ill-structured problems that were relevant to the content covered during the week and provided explanations; Warren et al (2012) mentioned that the teacher constructed six PBL scenarios, each scenario had a fictional character that needed to be solved, and students played the fictional characters; Dawilai et al (2021) stated that teachers play a guiding role in PBL classrooms, guiding and organizing activities or setting problems for students; Unal and Cakir(2021) presented ill-structured questions to students before learning; Hikmawati and Ningsih (2020) emphasized that teachers can stimulate students' enthusiasm and curiosity by asking questions online.
Elements	**Definition**	**Support Material**
Learning activities design	Develop course plan	Dwiyogo (2018) underscores the importance of choosing the most suitable learning sources while designing learning activities. This ensures the delivery of information or learning materials aligned with the technology available in the specific learning environment. Yeh (2010) developed a 16-week experimental teaching plan based on teaching objectives and learning activities; The lesson plan was divided into nine steps (Implementation process) (Unal & Cakir, 2021); The lesson plan was divided into three stages(Efendi & Ariyani, 2022); Nurrijal et al (2023) provided 16 blended sessions

		(learning resources and learning activities) in the course, providing 120 minutes of independent learning and 120 minutes of collaborative structured work; Yen and Lee (2011) structured a 6-week course that comprised lectures alongside additional projects focused on measuring network transmission speeds in three distinct wireless environments;(Delialioğlu (2012) illustrated that the course convened twice a week, blending the lecture-based approach with online content. The activities included: (i) the instructor presenting the content, (ii) engaging in discussions about the content among the instructor and other students, and (iii) conducting hands-on laboratory activities; Warren et al (2012) pointed out that anchoring all learning activities to a larger task or problem; El-Magboub et al (2016) designed the learning activities to include didactic lectures and three weeks of discussion sessions as well as outdoor activities; Dawilai et al (2021) developed classroom activities encompass virtual classes and discussions; Unal and Cakir (2021) engaged in learning activities, including discussions, collaboration, interaction, and face-to-face communication with groups using Web 2.0 technology or desktop software to address problems and acquire course content; Hikmawati and Ningsih (2020) highlighted that learning activities involve posing questions, forming hypotheses, and gathering pertinent information.
Technology application	Integration of technology in BPBL	The distribution of technological applications in the analyzed articles reveals that three articles explored the implementation of new teaching models within a blended learning environment, six articles concentrated on the incorporation of computer software in BPBL, and fifteen articles highlighted the integration of online teaching platforms with BPBL. Refer to Table 6 for a detailed breakdown.
Interaction	Communication between students and students, students and teachers, online and offline	Interaction is an important element of blended learning design. Hoic-Bozic et al.(2009) advocated for student interaction facilitated by asynchronous communication forums; Yeh(2010) mandates group assignments and participation in online discussions for participants; Kardipah and Wibawa (2020) highlighted the flipped classroom model as fostering interaction among students, lecturers, and classroom learning materials, providing more time for engagement; Dwiyogo (2018) demonstrated the ability of multimedia software to generate interactive user interfaces featuring animations for each appearance/icon; Yeh(2010) emphasized the significance of classroom interaction in the design of blended learning; Delialioğlu (2012) employed a 5-point Likert scale to gauge the level of interaction between students and teachers; El-Magboub et al (2016) depicted the interaction process between tutors and students through the use of sociograms.
Elements	**Definition**	**Support Material**
Learning resources	Preparation of teaching resources in a blended learning environment	Dwiyogo (2018) demonstrated a four-stage process for developing learning resources, including creating storyboards, producing each element of the program, testing and reviewing the program, and implementing media into learning activities.; Hoic-Bozic et al (2009) pointed out that in the process of designing the model, instructors need to design teaching content, interactive elements, resources and tests; (Delialioğlu, 2012) stated that course materials cover a variety of resources, including multimedia, simulation experiments, teaching activities, and game elements, provided through the Internet and live classes.
Evaluation	Assessment of solutions or procedures incorporated during the learning process	In the study of (Woltering et al., 2009), the opinions of both students and tutors were gathered through questionnaires, which included inquiries about student motivation, satisfaction, subjective learning gains, and various aspects of problem-based learning (PBL) characteristics, the questionnaire items covered the quality of the tutor, teamwork, workload, and case design; Yen and Lee (2011) showed that participants were asked to provide self-assessments in which they described the learning task in 30 words, after completing each experiment stage; Hoic-Bozic et al.(2009) conducted a survey with students to assess the effectiveness, quality, and acceptance of AHyCo as a teaching resource; Delialioğlu (2012) conducted a study on student satisfaction with courses, addressing questions related to the quality of teaching and the overall learning environment; Bukumiric et al.(2022) administered an online survey to students anonymously, utilizing a five-point Likert scale to evaluate the satisfaction of students with the PBL modules in the BPBL group; Dwiyogo (2018) indicated that the following activities were completed during the assessment phase: (1) formative assessment, (2) revision, and (3) creation of a prototype for problem-solving learning outcomes based on blended learning; Cavicchia et al (2018) revealed that student assessment was conducted through systematic grading criteria, which students were aware of from the beginning of the course; Hoic-Bozic et al. (2009) assessed the students in the study from two perspectives, First, students' acceptance of a learning model based on the blended learning (BL) model that combines independent learning, online discussions, and problem-based learning was assessed; Second, to assess students' attitudes toward the learning environment provided by AHyCo; Warren et al (2012) assessed satisfaction with the modified course using the university's standard five-item course evaluation and compared it to satisfaction with each component of the existing course; El-Magboub et al.(2016) evaluated classroom and online discussion sessions in a biopharmaceutical problem-based learning course; Dawilai et al.(2021) conducted an evaluation as part of the “learning steps”; Unal and Cakir (2021) prepared a Project evaluation form to evaluate the experimental group's group project; Servos et al.(2022) founded the feasibility of the BPBL approach was assessed with students; Kuo et al.(2014) concluded an evaluation of student interaction and creativity, evaluated and clarified the merits, and shortages.
Elements	**Definition**	**Support Material**
Implementat-ion	Conduct the learning process	Tsai and Tang (2017)examined two groups using pre-tests on the "Learning Attitude Scale" and "Problem-Solving Scale." A post-test on these scales was administered one week after the course, and statistical analysis was performed using SPSS; In the experiment of (Woltering et al., 2009), questionnaires were employed to assess students' motivation,

		satisfaction, subjective learning gains, and PBL characteristics, with analyses conducted using a five-point Likert scale; Kardipah and Wibawa (2020) analyzed achievement tests and interview guides; Unal and Cakir (2021)(2021) collected and analyzed data from personal information forms, achievement tests, and participation scales; Dwiyogo (2018) applied a blended learning approach to problem-solving, involving sixty graduate students majoring in physical education. The implementation took place between 2015 and 2016; Cavicchia et al.(2018) outlined a four-week non-mandatory problem-based learning (PBL) course led by tutors with expertise in medicine and experience in PBL instruction; Yeh (2010) showed that 32 pre-service teachers participated in a 16-week mentoring program; The experimental environment completed by (Tsai & Tang, 2017) included computers and multimedia equipment, PowerPoint and online presentation applications; The course spanned 14 weeks, where participants were tasked with individual creative writing assignments and group projects (Dawilai et al., 2021). Another experiment conducted at Karawang Barat Public Secondary School lasted approximately one month (Efendi & Ariyani, 2022); The study was conducted at SMAN 1 Marga, with 43 students as the research sample (Kartini et al., 2023); The study of (Indriani et al., 2023) was conducted among 96 secondary school Class XI students.
Feedback	Collect opinions on experimental samples	Woltering et al. (2009) demonstrated student preference for a web-based learning environment through student feedback; Similarly, Yeh (2010) used peer assessment at the end of the course to assess group participation in all group assignments. Learning; In a study conducted by(Warren et al., 2012), students were tasked with maintaining a blog to reflect on their experiences in the course, to ensure anonymity, pseudonyms were used instead of students' actual names; Unal and Cakir (2021)employed a project evaluation form to assess group projects within experimental groups, evaluate computer program projects, and evaluate learning processes; Hikmawati and Ningsih (2020) found through feedback that this study had some limitations due to the lack of control over access to information, students were able to share links to references among themselves, and some students were found to be sending similar reference links; Shimizu et al (2019) emphasized the importance of the long-term impact of Blended Problem-Based Learning (BPBL) through feedback; Dwiyogo (2018) reported positive feedback for the development and implementation of a problem-solving approach based on blended learning; Cavicchia et al (2018) required students to fill out an online survey to assess their teachers and their personal performance; Warren et al (2012) asked students to reflect on what they learned and the learning process at the end of the study; Tsai and Tang (2017) demonstrated that students receive immediate feedback when they encounter difficulties, and online platforms allow students to comment on other people's work; Unal and Cakir (2021) showed all groups the feedback provided by each group on a software project; Servos et al (2022) obtained evaluation on the advantages and disadvantages of BPbL or CPbL by setting questions in advance; Efendi and Ariyani (2022) highlighted the integral role of feedback in every learning cycle; Kuo et al. (2014) offered feedback to both teachers and students based on the results of data collection and analysis.

3.4 RQ3: What are the essential elements of designing problem-based learning in a Blended learning environment?

Design elements in Blended Problem-Based Learning (BPBL) involve various components and strategies to create an effective learning experience. By analyzing the articles, some key elements are seen in Table 5.

4. Discussion

4.1 The trends of development in blended problem-based learning

4.1.1 Large sample and groups

Reviewing the research literature, there are 3 studies with student sample sizes exceeding 180 and group sizes exceeding 24. Woltering et al. (2009) conducted a study to assess the impact of Blended Problem-Based Learning (BPBL) on student motivation, cooperation, and satisfaction. The experiment involved 14 groups with a total of 97 students using the new hybrid PBL, while another 14 groups with 88 students utilized the traditional PBL (with a maximum group size of 9 students). In the study of (El-Magboub et al., 2016), there were 185 first-year pharmacy students (24 groups) participated in the experiment. Servos et al. (2022) tested the feasibility and acceptability of blended learning in problem-based learning (BPBL) and traditional PBL teaching, there were 12 groups of BPBL and 27 groups of PBL in the experiment, with a total of 317 students.
Yen and Lee (2011), and Kardipah and Wibawa(2020) both pointed out that the limitation of the study was that a larger sample was needed to confirm the conclusions of the participants. Using a large sample, can enrich the information gathered and reduce the impact caused by students dropping out midway through the experiment. Dividing the large sample into multiple groups for experimentation facilitates active interaction among students within each group and allows for comparisons between different groups.

4.1.2 Diversity of disciplines and participants

Among the articles studied, the experimental courses cover medicine, computer, social science, English, physics, education, engineering, and economics. Participants and number include College students (n=1568), Graduate students (n=128), High school students (n=73), Middle school students (n=42), and Mature(teachers) (n=121). This suggested that the adoption of blended problem-based learning has gained widespread popularity as it incorporates a broader range of courses and samples into its research.

4.2 Benefits and Challenges of technology application in blended problem-based learning

According to a study conducted by Borreson Caruso and Salaway(2007) undergraduate students dedicate an average of 18 hours per week to utilizing technology for coursework. Moreover, more than 80% express a preference for moderate or high use of information technology in their courses. Technology is becoming more and more popular in teaching. Through the articles, we found that technology has both positive benefits and challenges in blended problem-based learning.

4.2.1 Benefits of technology application in blended problem-based Learning

Anggraini et al. (2016) verified that the use of blended learning technology facilitates independent student learning without direct guidance from teachers, enabling access to learning resources without the need for face-to-face meetings. Technology has played a crucial role in supporting blended problem-based learning. Efendi and Ariyani (2022) affirmed that technology enables students to experience ease in learning, providing access to a diverse range of information tailored to their needs. Woltering's investigation, based on student interviews, highlighted the capability of web-based learning environments to utilize multimedia data, simulators, or tools for clinical data and information management, thereby presenting cases more realistically (Woltering et al., 2009). The study by (Tseng et al., 2013) underscored the fusion of Creative Problem Solving (CPS) and concept mapping (CMPING) to evaluate students' learning outcomes. By implementing the strategies outlined in the study, students were provided with the chance to cultivate self-reflection competence with reinforcement. This integrated approach was designed to motivate improved performance. Unal and Cakir (2021) confirmed that employing a collaborative problem-solving approach along with leveraging Web 2.0 technologies can effectively enhance students' knowledge and skills within their respective courses. In addition, Nurrijal et al(2023) reported that online learning resources can present a combination of text, images, videos, and animations, and interactive resources such as quizzes, chats, assignments, and discussion forums can encourage more student participation. Online learning supports students in repeated learning and access anytime and anywhere.

4.2.2 Challenges of technology application in blended problem-based learning

The challenges of technology in blended problem-based learning include resistance from teachers to acquire new teaching technology skills and adapt to new roles, and acceptance of technology among students.

From the perspective of teachers acquiring new teaching skills

For successful implementation of BPBL, teachers must have proficiency in utilizing the relevant technologies. It includes understanding how to navigate online platforms, effectively use digital tools, and integrate them seamlessly into the learning activities. Hence, challenges in blended learning include teachers' technological literacy and proficiency. Numerous studies have highlighted issues confronted by educators related to technology, including problems like technological illiteracy (Brown, 2016), reluctance to adopt new technologies for teaching (Hung & Chou, 2015), and inadequacies in technological competence (Pilgrim et al., 2018). Some tasks that were previously completed in the classroom, such as lectures, seminars, etc., have been replaced by online learning. Students can complete discussions through the learning management system (LMS) or on the forum, and teachers need to master the teaching technology in advance (Hoic-Bozic et al., 2009).

From the perspective of teachers' changing roles

Tseng et al.(2013) confirmed that in the student-centred CPS learning method, teachers are only facilitators of students learning. Woltering et al. (2009) pointed out that in blended PBL learning, teachers are no longer the primary source of initial case information. The changes in the learning environment enable teachers to assist students in self-directed learning and better prepare for offline courses.

In the role of teachers, face the following challenges when organizing the teaching process: Tutors must answer students' questions and evaluate problem-based learning outcomes (Bukumiricet al., 2022); Teachers need to encourage less engaged students to express their ideas, and teachers also need to address plagiarism when students post publications on forums (Cavicchiaet al., 2018); Yen and Lee (2011) reported during the experiment, the teacher instructed students to document their plans and presented problem-solving path maps created by both students and experts which aimed to enhance learners' awareness of the problem-solving process; Hoic-Bozic et al. (2009) showed that in blended learning environments, students are physically and psychologically separated, so teachers need to pay special attention to students who are learning to write online.

From the perspective of students

The prevalence of technology in education necessitates that students acquire skills in computer and information literacy. The results from Cavicchia et al.(2018) emphasized the need for additional support in using the online learning platform. Students expressed difficulties due to a lack of prior experience and knowledge in technological skills, such as accessing the platform or posting in the forums, therefore it is necessary to provide students with training on using the learning platform during the early stages of the project. Novak and Cañas (2007) showed changing the learning behaviour of individuals within a short period is challenging, suggesting that students persist in using their old learning models, which may not positively impact their learning outcomes. Shimizu et al. (2019) demonstrated that the higher the degree of self-directed learning among students, the greater their acceptance of technology in BPBL.

Yen and Lee (2011) pointed out that male students tend to prefer using technological tools, as they are more

confident in utilizing mobile technology for learning tasks. In contrast, female students are more inclined toward engaging with interesting cases and materials in blended learning environments. Research conducted by Yen and Lee (2011) also highlighted the necessity for students to grasp the operational aspects of using various functions of technological tools. They need to comprehend how these tools can aid in the development of problem-solving skills. Nevertheless, students tend to invest excessive time on their mobile devices during the initial stages of problem-solving, neglecting their responsibilities in the project.

Tsai and Tang (2017) highlighted that online learning conducted outside the traditional classroom environment might induce anxiety among students. In the absence of an instructor, students may experience uncertainty about their learning progress and may require additional motivation to complete assignments. Warren et al. (2012) indicated that students expressed to their instructors that they felt anxious about the team structure of course activities and were particularly apprehensive about engaging in second-tier games due to their unfamiliarity with the related technology.

4.3 Interaction in the blended problem-based learning

The quality of interaction in blended problem-based learning can impact the effectiveness of teaching. Savery and Duffy (1995) observed that "knowledge evolves through social negotiation and the viability of individual understandings," highlighting the centrality of interactions between students and peers, as well as between students and instructors, in the learning process. Yen & Lee (2011) reported that while mobile technology and web-based tools offer opportunities for problem-solving learning, learners tend to spend more time on classroom discussions, which can enhance their reflective abilities and course performance. Faculty and observer evaluations, as well as sociograms, suggested that online learning decreased interaction among students and between students and faculty (El-Magboub et al., 2016). El-Magboub et al. (2016) also noted that because of discomfort with online learning, many students perceived the educational value of online discussions to be lower than that of face-to-face interactions. Additionally, approximately one-third of respondents expressed feelings of disconnection in free-form responses to the survey. Consequently, teachers need to encourage and stimulate student participation in interactions in a positive manner. Servos et al. (2022) found that the drawbacks of BPBL approaches include communication limitations in group interviews and the absence of personal contact, raising concerns about potential reductions in learning outcomes. Delialioğlu (2012)evaluated student interaction based on three aspects: Collaborative Learning, Student-Faculty Interaction, and Level of Academic Challenge. Tsai and Tang (2017) argued that engaging in online interaction and discussion enables students to effectively learn through team activities, thereby reducing learning time and costs.

Some factors may affect the effectiveness of your interactions. Kuo et al. (2014) reported that factors such as emotion, gender and age differences may affect learners' interaction with the Internet. Hoic-Bozic et al.(2009) substantiated that the type of assignments has an impact on the mechanisms of discussion. Their findings indicate that, when assignments necessitate more in-depth discourse, all groups participate in discussions both online and in face-to-face settings. El-Magboub et al.(2016) discovered that enhancing interactivity in synchronous online sessions might necessitate counsellors to adapt their teaching styles, including practices like addressing students by name. In a similar vein, Woltering et al.(2009) corroborated that the mode of interaction needs to be tailored to facilitate improved integration between classroom learning and self-instruction.

Ahern and Repman (1994) and Fredericksen et al.(2000) pointed out that interaction is a key factor in students' satisfaction with a course. However, research has also confirmed that excessive interaction can make learners feel overwhelmed, leading to cognitive overload (Hara & Kling, 1999; Mason & Weller, 2000). Therefore, when conducting blended teaching, teachers need to encourage interaction while also designing and guiding student interactions to maximize learning outcomes.

4.4 Researching implications

Notably, the literature examined in this study has provided valuable suggestions for implementing BPBL in the classroom. Theoretical significance and Practical significance can be drawn from the above review.

4.4.1 Theoretical significance

Research on problem-based learning in blended environments holds theoretical significance for instructional model design and teaching effectiveness. The following study proposes a problem-based learning model in a blended environment: Kardipah and Wibawa (2020) developed and designed a problem-based flipped hybrid learning model. Kartini et al. (2023)used the developed Problem-based blended learning model to improve students' critical thinking skills. Indriani et al. (2023) studied the effects of a problem-based blended learning model on problem-solving skills and scientific literacy. Woltering et al. (2009) designed the Seven Steps to PBBL Model based on a network-based learning environment. These models contribute to the theoretical framework for educators to implement problem-based teaching models in blended environments.

4.4.2 Practical significance

Practical implications can be drawn from the article. Analyzing the experimental design, process, and results can guide educators in designing BPBL based on student needs. How to choose the most suitable learning

resources to deliver information or educational materials that align with the technological capabilities in a given learning environment? (Dwiyogo, 2018); How to organize student discussions through virtual classrooms, video conferences, online boards, chats, and group postings? how do stimulate learners' motivation and interest through problem-solving, group assignments, and individual tasks? (Dawilai et al.,2021). Tsai and Tang (2017) confirmed that incorporating real-world scenarios into PBL courses enhances learners' engagement and interest, encouraging them to take a more active stance in problem-solving and peer discussions. However, how to design instructional content based on PBL theory and real-world scenarios is crucial. How can we design curriculum content that aligns with PBL principles and real-world contexts? How do consider gender differences in the application of technology? How to consider the design of interaction in teaching? How to design the different impacts on interaction due to differences in learning styles? etc. Understanding these differences is important for educators to tailor their approaches and create a more inclusive and effective blended learning experience that caters to the diverse learning preferences and styles of students.

4.5 Future research recommendations

Drawing from the findings and insights of this review, we propose the following recommendations for future research：

The relationship between learner gender and acceptance of technology;
The relationship between learning style and participation in interactions;
The influence of various knowledge types (conceptual knowledge, principles knowledge, or critical knowledge) and the nature of learning activities (learner-generated open-ended problems or specific problems assigned by teachers) on the problem-solving processes;
Differences between groups when using large-scale experimental groups.
The impact of different access methods for online courses (PC/laptop or tablet/smartphone) on learning outcomes.
The impact of online discussions and classroom discussions on teaching effectiveness.
Technology and digital literacy for teachers and learners;
Online help-seeking behaviour and procrastination among students in blended learning.
How to design effective interactions?
Teacher practices in blended learning environments and their impact on student engagement in large-scale learning?
How does the integration of blended learning environments affect the daily tasks and teaching methodologies of educators?
What is the proportion of online, offline and traditional teaching modes? etc.

5. limitation

This review study has some limitations. Firstly, we employed strict search and selection criteria, considering only journals deemed to have "high impact". If we had referenced other sources like conference papers, websites, or book chapters, the research results might have varied slightly differently. Secondly, there were some inaccessible studies, such as those with unavailable full texts or not written in English. However, despite these limitations, the results of these studies are sufficient to provide information about the current state of development of blended problem-based learning.

6. Conclusion

While numerous studies have delved into blended problem-based learning and conducted experiments, there is a dearth of review articles specifically addressing blended problem-based learning. This article employs the PRISMA systematic literature review method to investigate 24 articles related to blended problem-based learning, with a particular emphasis on three aspects: development trends, technology applications, and design elements. Although our research foundation is extensive, it is challenging to comprehensively cover all aspects due to restrictions in the selection criteria and the rapid development of technological innovations. Through our research, we observe a growing popularity of the blended problem-based learning model, especially with the integration of technology. When designing teaching methods, it is important to consider the appropriate application of design elements and address challenges related to technology for both teachers and students. Through blended problem-based learning, learners can enhance their course performance and higher-order thinking skills, such as critical thinking and problem-solving. The research directions proposed in this paper provide valuable insights for educators in their future studies.

Based on these reviews, BPBL is extensively employed in education to facilitate student learning. It is not only utilized but also integrated into various disciplines.

Statement on conflicts of interest

We declare that we do not have any conflicts of interest.

Data availability

Data will be provided upon request.

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