



Detecting and visualizing research trends of blended learning: A bibliometric analysis of studies from 2013-2022

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Abstract

Blended learning (BL), an innovative, technology-supported pedagogical approach, has been extensively adopted in schools and universities. The learning effectiveness of BL has been investigated in multiple domains of education, computer science, nursing, engineering, and psychology. To uncover the major trends of BL research, this study embarked on a bibliometric analysis of a total of 719 studies published in the recent 10 years (2013-2022) and indexed in the Web of Science core collection. Adopting a quantitative approach and the visual analytical tool of CiteSpace, the review study identified the development trends, the influential researchers and research institutions, and pivotal studies and topics of the field and informed its future progression. The findings revealed a growing trend in BL research in the past decade as reflected in the exponential growth in the number of publications and citations. Charles R. Graham, Chang Zhu, Robert A. Ellis, and Feifei Han were the most prolific, influential researchers in the field, and the Griffith University, the University of Hong Kong, the Vrije Universiteit Brussel, the Monash University, and the National Taiwan Normal University were the prominent research institutions, which engaged in frequent collaborations with others. The United States, China, and Australia were the top-3 contributors to BL research measured by the number of publications, and the studies conducted and reported by researchers in the USA, Turkey, Taiwan, and Spain were cited the most often. Document co-citation analysis unveiled the pivotal studies and topics of the research field, including blended course designs, institutional adoption, achievement, higher education, active BL, flipped classroom, and communication skills.

Keywords: blended learning, trend study, bibliometric analysis, data visualization

INTRODUCTION

The development and advancement of information and communications technologies (ICT) provide strong technological support for improving and innovating pedagogical approaches (Basilotta-Gómez-Pablos et al., 2022; Haleem et al., 2022). Compared with traditional face-to-face instruction and e-learning, blended learning (BL) is considered more effective as it allows learning at anytime and anywhere and affords improved learning outcomes with the integration of online and offline teaching and learning (Baeppler et al., 2014; Siripongdee et al., 2020; Yang et al., 2021). BL in the form of flipped

classroom could enhance student self-efficacy and intrinsic motivation for learning (Thai et al., 2017; van Alten et al., 2020), academic performance (Bazelais & Doleck, 2018; Hamadneh et al., 2022; Lu et al., 2018), and the development and application of self-regulated learning strategies (Broadbent, 2017; Eggers et al., 2021).

However, researchers have also pointed out that BL is not a panacea. Issues concerning technological support (Kumar et al., 2021; Padilla-Melendez et al., 2013), student characteristics (e.g., attitude and self-regulation skills) (Kintu et al., 2017), learning style (G. Cheng & Chau, 2016; Shamsuddin & Kaur, 2020), admission rate, learning motivation (Law et al., 2019),

Contribution to the literature

- By utilizing CiteSpace's data visualization technology, the study enables scholars to comprehend the evolutions, connections and significance of the research topics in blended learning.
- The identification of pivotal literature, scholars and research institutions within the realm of blended learning research offers valuable references and insights to researchers who intend to engage in extensive collaborative efforts.
- The discovery of temporal aspect and citation relationships of literature equips scholars with insights into forthcoming research directions in the field.

and institutional reform and leadership (Anthony, 2021; Carbonell et al., 2013; Garrison & Vaughan, 2013) may also compromise its application and effectiveness. The adoption issues of BL in higher education are related to the students, the academic staff, and the management, such as management attitudes toward BL are “positively determined by the strategy, structure, and support factors”; student learning effectiveness in BL programs is “positively predicated by achievement, engagement, involvement, retention, and cognitive outcome”; and for academic staff, the effectiveness of BL implementation is “significantly influenced by delivery, performance, evaluation, and motivation” (Anthony et al., 2019).

To address these problems, published research highlights the need to guide and facilitate the teachers to develop and implement interventions of BL (Heilporn et al., 2021; Zacharis, 2015), instructional strategies (Boelens et al., 2018; Megahed & Hassan, 2022), and curriculum for BL programs (Alammery et al., 2014; Stahl, 2021). Institutions of higher education are expected to enhance BL adoption following a three-stage framework of awareness/exploration, adoption/early implementation, and mature implementation/growth, with each stage focusing on distinctive strategies, structures, and supports (Porter et al., 2014). To amplify the scale and effect of BL, coordinated efforts from the institution, the instructor, and the technological domain are required. BL should be conceived and enacted as social, dynamic processes (Bokolo et al., 2020; Taylor & Newton, 2013) in which the creative potentials of the faculty are leveraged (Anthony, 2021) and the affordances of mobile technologies for collaboration, coordination, and communication are integrated to augment student experiences (Alshehri & Cumming, 2020; Lai et al., 2013).

So far, there have been abundant investigations of theoretical frameworks (Garrison & Vaughan, 2008; Picciano et al., 2021, p. 3), influencing factors (Apandi & Raman, 2020), and implementation strategies of BL, but explorations and visualizations of research trends of BL are still in need. This study aimed to contribute to this area by providing a systematic review of BL research published in the past decade with a focus on temporal and structural visualization enabled by the analytical tool of CiteSpace. The findings will inform future developments of theories and practices of BL.

LITERATURE REVIEW

Theoretical Foundations of Blended Learning

The COVID-19 pandemic that broke out in the spring of 2020 forced schools to conduct more activities at home, including studying and working. This has also prompted policy makers and educators to actively seek effective solutions for teaching and learning. BL is emerging as an educational innovation and solution during the COVID-19 pandemic (Karma et al., 2021). For example, massive open online courses have been applied in BL courses (de Moura et al., 2021), and related researchers explored the use of BL in engineering higher education during the COVID-19 lockdown (Ożadowicz, 2020).

With technological support, BL combines and coordinates diverse approaches, technologies, and activities both online and offline (Khalil et al., 2018). It connects meaningful experiences of online and face-to-face classroom learning (Garrison & Kanuka, 2004), and its conception has evolved to “encompass a much richer set of learning strategies or ‘dimensions’” (Singh, 2021). BL is not only a combination of technology, pedagogy and tasks (Azizi et al., 2020), it is also an effective combination of relevant learning environments and instructional strategies (Chaeruman et al., 2020). The main components of an effective BL include interaction, class length, and online resources (Li et al., 2021). BL helps to build knowledge and build learning communities through activities such as class presentations, discussions, peer feedback, and paper analysis (Zhu et al., 2021). Platforms such as Blackboard, WebCT, and Moodle provide virtual learning environments to facilitate student interaction with BL content (Le et al., 2022).

Cronje (2020) argues that the definition of BL should be structured around learning theory. Learning theories of behaviorism, cognitivism, and social constructionism inform the instructional designs, pedagogical approaches, and assessment strategies of BL (Ertmer & Newby, 2013; Picciano, 2021). Social constructive theories of learning play a particularly important role in theory development of BL (Woltering et al., 2009). From the social constructive perspective, Norberg et al. (2011) proposed the time-based blended learning model and

Derntl and Motschnig-Pitrik (2005) proposed the blended learning systems structure (BLESS), both being useful frameworks for curriculum and course design. However, the role of teachers in a blended program of learning is somewhat neglected in BLESS. The concept of community of inquiry (CoI) articulated in Garrison and Vaughan (2008), which encompasses three core elements of cognition, society, and instruction and highlights their interrelations and interactions, has been extensively applied in online and BL research and practice. For example, using CoI framework to explore students' learning experiences in blended courses (Zhang, 2020), and investigating the effectiveness of BL pedagogy in clinical skills through a framework of inquiry community framework (Siah et al., 2021).

Review Studies of Blended Learning

A survey of BL literature renders several review studies. A recent systematic review of Eggers et al. (2021) identified four important types of self-regulation strategies in BL environments, including the cognitive, metacognitive, motivational, and management. To enhance student self-regulation, more attention should be paid to strategies of the cognitive, motivation, and management domains. The review study reported in Anthonysamy et al. (2020) confirmed the positive correlation between self-regulation strategies and many non-academic outcomes such as learning motivation, student participation, and learning attitude in BL programs in higher education. Other reviews focus on the use of BL to augment entrepreneurship education. Viebig (2022) captured and categorized four archetypes of BL in this discipline, including the traditional blend, the for-action blend, the in-action blend, and the experiential blend, and analyzed their respective advantages and challenges.

BL has been applied to teach various subject areas according to the related studies. For example, research in the field of education focuses on the model (structure and factors) of BL adopted in higher education and its research theory, and the influencing factors affecting the adoption and implementation of BL by students, lecturers and administrators (Anthony et al., 2022). There was the application of BL in English language teaching (Hashemi & Si Na, 2020), the impact of BL and project-based learning on preservice teachers' creative thinking in learning biology (Yustina et al., 2020). And the application of BL in the field of computing science to improve the learning process by using BL (Chytas et al., 2022).

Several literature reviews have summarized and advised on the application of BL in medical education (Leidl et al., 2020). Khalil et al. (2018) contended the integration of different learning approaches, technologies, and activities of BL could improve the teaching and learning of anatomical sciences following a framework that can help analyze, plan, integrate, design,

develop, implement, and assess instructional activities and materials. A combination of the flipped classroom, a popular BL model, and team-based learning could enhance student knowledge level, problem-solving skills, and learning satisfaction in courses of public health (Kang & Kim, 2021). The positive effect of this mixed approach for improving student academic performance was also confirmed in Nishigawa et al. (2017) that focused on the learning of clinical dentistry and in Anas et al. (2022) and Haley et al. (2020).

The findings could inform the adoption of different types of BL in accordance with the context and circumstances. The strengths of both online and face-to-face modes of learning are maximized and more e-learning contents are provided and leveraged in a blended program (Al-Rahmi et al., 2018). Review studies on the application of BL to the teaching and learning of a specific discipline are very informative. However, more review studies are needed to the development of BL theories and practices (Halverson et al., 2014). Methodologically, quantitative, visual analyses in the research field are challenging and very limited.

RESEARCH QUESTIONS

This study aimed to investigate and answer the following four research questions:

1. What was the general status and trend of BL research, as reflected in the yearly distribution of studies and citations in the past decade?
2. What were the main research areas in BL was investigated?
3. Which researchers, research institutions, and countries/regions were prolific and influential in BL research?
4. Which studies and topics were pivotal and important in BL research?

RESEARCH METHODS

Publication Selection

The publications included in this review were listed in the social sciences citation index (SSCI) archived in the database of Web of Science core collection last updated on January 29, 2023. Using the title keyword of "blended learning", the author conducted a precise search of documents published in the past decade (2013-2022). The first round of search rendered a total of 796 documents, including 677 articles, 37 early access articles, 38 review articles, 13 meeting abstracts, 11 editorial materials, 10 book reviews, five proceeding papers, four corrections, and one letter. Only the 719 original articles (i.e., 677 articles, 37 early access articles, and five proceeding papers) were selected for analysis. The total citations of these selected publications were 14,409, with 20.04 citations per publication. Excluding

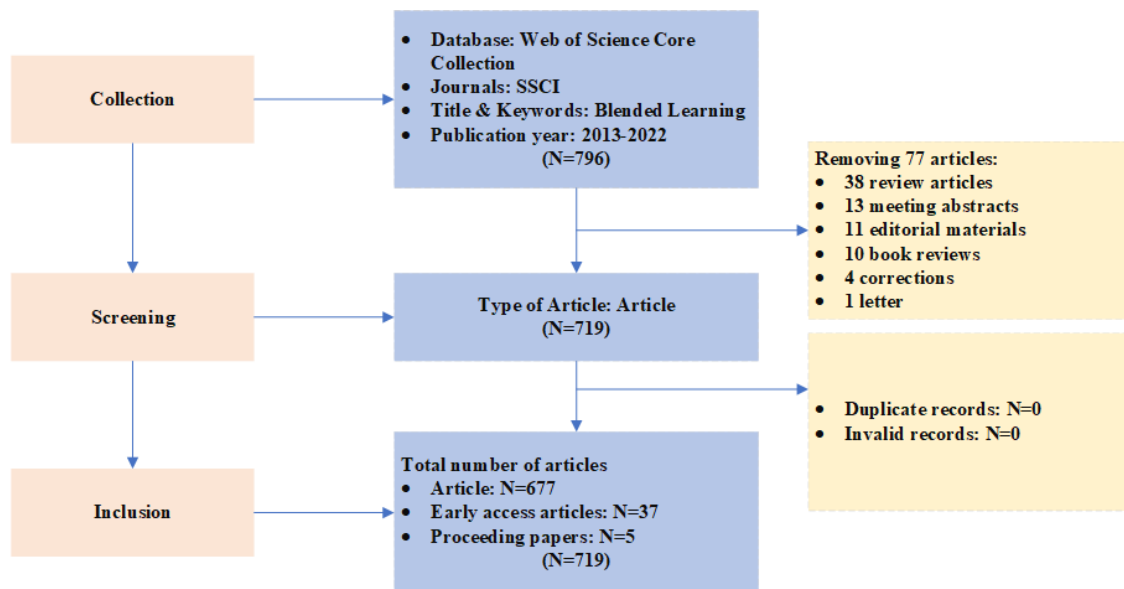


Figure 1. Blended learning articles selection process (Source: Authors' own elaboration)

self-citations, the total number of citations was 12,878. The aggregated number of documents that had cited these publications was 9,595 and reduced to 9,176 when self-citing was excluded. The h-index of the selected publications was 54. For the complete process of publication selection, please refer to **Figure 1**.

Coding Methods and Data Analysis

The study was conducted using bibliometric analysis. Bibliometric analysis is a method used to analyze large amounts of scientific data. It can allow us to understand the evolution of a particular field as well as emerging fields (Donthu et al., 2021). Commonly used bibliometric analysis tools include RStudio Bibliometrix, VOSviewer, and CiteSpace (Ding & Yang, 2022; Kemec & Altınay, 2023; Moral-Muñoz et al., 2020). Among them, CiteSpace is a powerful and popular tool (Rawat & Sood, 2021). CiteSpace is a tool for visualizing and analyzing trends and patterns of a knowledge field or domain. It can help identify the research front, the progression of knowledge, and the evolution of collaboration networks and citation networks (Chen, 2004).

In this study, CiteSpace 6.1. R6 was used to uncover the trends and connections of the collected BL publications. It has been adopted by many review studies in the area of educational technology (Liu et al., 2022; Rashid et al., 2021). In practice, the collected publications were coded based on its year of publication and citation using a Microsoft Excel spreadsheet. The yearly distribution of articles and their citations, which could reflect the overall development trend of the research field, was calculated and visualized via a line chart with a trendline. To identify the prolific, influential researchers, research institutions, and countries/regions in BL research, collaboration networks and co-citation networks of the publications were generated using CiteSpace (Chen, 2014; Huang et al., 2020). Diagrams

illustrating the author, institution, and country/region of the publications were developed, displaying the patterns and strength of research collaboration in the field. The cited reference diagram constructed revealed co-citations of documents. Meanwhile, the critical, pivotal publications, which reflected the important topics of the research field, were identified. Based on the time-zone view in CiteSpace II, a temporal analysis that could unearth the research fronts of the field (i.e., the emergent and transient grouping of concepts and underlying research issues) and its intellectual bases (i.e., citation and co-citation footprint in literature) was also conducted (Chen, 2006).

FINDINGS AND DISCUSSION

Yearly Distribution of Publications and Citations of Blended Learning Research

Figure 2 displays the yearly distribution of articles and citations of BL research in the past decade. The year of 2015 was considered a turning point. Before that year, BL research was still at the exploratory stage, with an average of 45 publications per year and a slight annual decline since 2013. After the year of 2015, the research field developed rapidly. Within the seven years of 2016-2022, 584 publications were achieved, accounting for 81% of the total sample, with an average of 83 per year. With regard to the number of citations, there was an increase every year throughout the period of analysis. Similarly, the increase was more evident after the year of 2015.

Based on the fitness between the yearly distribution of publication and citation of BL research and the exponential function of $y = e^x$, a growing trend of the research field was identified ($R^2=0.7723$ and citation $R^2=0.9075$). The past decade witnessed a growing

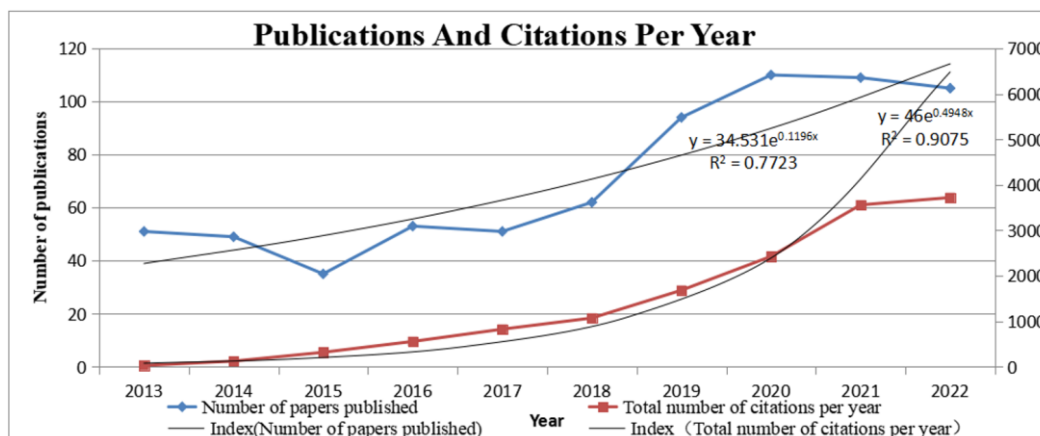


Figure 2. Publications & citations of blended learning research in 2013-2022 (Source: Authors’ own elaboration, using Microsoft Excel software)



Figure 3. Collaboration networks of blended learning researchers (Source: Authors’ own elaboration, using CiteSpace 6.1.R6 software)

momentum in BL research, and the momentum is expected to continue.

Major Research Areas

BL has been investigated by researchers from diverse domains and perspectives. According to the classification of research areas in the Web of Science, BL has been studied in a good number of areas including but not limited to educational research, computer science, nursing, engineering, psychology, public environmental occupation health. Investigations of BL in educational research were the most frequent, accounting for 67.45% (485) of the total publications, followed by computer science (10.57%) and nursing (8.20%). The technologies fueled the development of BL in educational research and computer science. With deepened understanding and improved practice, BL has been applied to the teaching and learning of a wide spectrum of disciplines. Recently, it attracted much attention in areas of environmental sciences ecology, health care sciences, linguistics, science technology, and social sciences (Bosch et al., 2022; Chen, 2022; Hamadneh et al., 2022).

Prominent Contributors of Blended Learning Research

Based on collaboration network analysis of BL research at the micro-level, meso-level, and macro-level respectively, the prolific, influential researchers, research institutions, and countries/regions of the research field were uncovered.

Prolific researchers

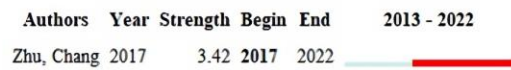
The number of years selected for “time slicing” in CiteSpace (i.e., slice length) would influence the construction of collaboration networks of researchers and the identification of prominent researchers in the field. To provide a more comprehensive view, two “slice length” values, one being one and the other being 10, were used in this study. The diagrams showing the collaboration networks of researchers, using the two “slice length” values, were displayed in Figure 3, respectively, with the node in red indicating the prominent researchers (i.e., researchers who had frequent collaborations with others).

Top 3 Authors with the Strongest Citation Bursts



A. Slice length=1

Top 1 Authors with the Strongest Citation Bursts



B. Slice length=10

Figure 4. Most cited researchers of blended learning (Source: Authors’ own elaboration, using CiteSpace 6.1.R6 software)

As shown in the first diagram in **Figure 3** (slice length=1), Chang Zhu from the Vrije Universiteit Brussel, Feifei Han from the Australian Catholic University, and Charles R. Graham from the Brigham Young University, compared with their counterparts, were more prominent and established in BL research. In the second diagram in **Figure 3** (slice length=10), Chang Zhu was the most prominent. Other popular, productive researchers of BL in the past decade included Robert A. Ellis, Bram Pynoo, Jo Tondeur, and Katrien Struyven. The collaborations between Feifei Han and Robert A. Ellis, among Merrick Zwarenstein, Salla Atkins, Senia Rosales-Klintz, and Weirong Yan, and among Javed Iqbal, Muhammad Naseem Afzaal, and Muhammad Zaheer Asghar were also frequent.

In CiteSpace, researchers with the strongest citation bursts and the time period of such bursts could also be illustrated. As shown in **Figure 4**, during the years of 2013 and 2017, Charles R. Graham was the most influential in BL research. In the two years that followed (2017-2019), the works of Chang Zhu gained more attention and citation. More recently (2020-2022), it was Feifei Han whose research was cited often. When the “slice length” value was set at 10, Chang Zhu was identified as the most influential researcher in the field, whose research has been extensively and frequently referenced since the year of 2017.

Price law ($M=0.749\sqrt{NMAX}$) (Price, 1963) was used to measure the productivity of researchers of BL (Iglič et al., 2017). In the equation, $NMAX$ is the largest number of publications made by a single researcher in the field, and M is the threshold for determining a core, productive researcher of the field. For publications collected for this review study, M was 2.48. Hence, a researcher who published three or more studies between 2013 and 2022 was recognized as a prolific and influential researcher of BL. For the list of researchers who achieved more than three publications, please refer to **Table 1**.

Research institutions

Collaboration networks of research institutions using two “slice length” values, one being one and the other being 10, were generated and presented in **Figure 5**. The overall density of the two networks was 0.0115 and 0.0142, respectively, both below 0.1, indicating that institutional collaboration in BL research was infrequent overall. As shown in the first diagram in **Figure 5** (slice

Table 1. Prolific & influential researchers of BL in 2013-2022

Rank	Author	No. of publications
1	Graham, Charles R.	11
2	Zhu, Chang	11
3	Ellis, Robert A.	10
4	Han, Feifei	10
5	Pynoo, Bram	7
6	Tondeur, Jo	6
7	Struyven, Katrien	6
8	Hwang, Gwo-Jen	5
9	Iqbal, Javed	5
10	Spring, Kristian J.	4
11	Dias, Sofia Balula	4
12	Macaruso, Paul	4
13	Vanslambrouck, S.	4
14	Ramirez-Arellano, Aldo	4
15	Diniz, José Alves	4
16	Chu, Samuel Kai Wah	4
17	Asghar, Muhammad Zaheer	4

length=1), the Griffith University and the University of Hong Kong were the prominent institutions, engaging in comparatively frequent cooperation with other research institutions. In terms of citations (part A in **Figure 6**), the outputs of the Brigham Young University were cited often during the years of 2013 and 2017, and in the two years followed (2017-2019), publications from the Vrije Universiteit Brussel gained more attention and were cited frequently.

In the second diagram of **Figure 5** (slice length=10), the Vrije Universiteit Brussel, the Monash University, and the National Taiwan University collaborated with other institutions actively in BL research. In terms of citations (part B in **Figure 6**), it was the works of Vrije Universiteit Brussel, the Brigham Young University, and the Monash university that were referenced often. The foci of investigations included the interrelations among student characteristics/background, BL design features, and learning outcomes (Kintu et al., 2017) and the impact of BL on student academic performances in higher education (Vo et al., 2017). Similar to the Brigham Yong University, the Universidad de Granada was also relatively productive in BL research, but its research was conducted independently.

Contributing countries and regions

Based on the number of publications and the centrality in the collaboration network (with “country”



A. Slice length=1

B. Slice length=10

Figure 5. Collaboration networks of blended learning research institutions (Source: Authors' own elaboration, using CiteSpace 6.1.R6 software)

Top 2 Institutions with the Strongest Citation Bursts

Institutions	Year	Strength	Begin	End	2013 - 2022
Brigham Young Univ	2013	3.65	2013	2017	
Vrije Univ Brussel	2017	3.73	2017	2019	

A. Slice length=1

Top 3 Institutions with the Strongest Citation Bursts

Institutions	Year	Strength	Begin	End	2013 - 2022
Vrije Univ Brussel	2017	3.51	2017	2022	
Brigham Young Univ	2013	2.57	2013	2022	
Monash Univ	2013	2.54	2013	2022	

B. Slice length=10

Figure 6. Prolific & influential research institutions of blended learning in 2013-2022 (Source: Authors' own elaboration, using CiteSpace 6.1.R6 software)

Table 2. Prolific & influential countries & regions in BL research

Rank	Country/region/city	n	Centrality
1	USA	126	0.31
2	China	120	0.44
3	Australia	75	0.16
4	Taiwan	52	0.11
5	Spain	48	0.21
6	England	42	0.14
7	Canada	27	0.02
8	Turkey	23	0.00
9	Belgium	22	0.00
10	Malaysia	20	0.00
11	Germany	20	0.20

Note. n: Number of publications

as the node type and 1 as the “slice length” value), the United States, Peoples Republic of China, and Australia were identified as the most prolific and prominent countries in BL research, producing a total of 126, 120, and 75 publications, respectively in the past decade. Other influential regions and countries (i.e., with a>0.1 centrality in the collaboration network) included Taiwan, Spain, and England (Table 2).

Countries and regions with the strongest citations were displayed in Figure 7. During the years of 2015 and 2017, published research on BL from the United States was cited frequently; during the years of 2013 and 2018, research from Turkey was referenced often; during the years of 2014 and 2016, research from Taiwan gained much attention; and during the years of 2013 and 2014,

it was Spain that output highly recognized research on BL.

Document co-citation clusters decomposed from document co-citation networks could help identify the pivotal studies in the research field and the key topics for investigation. The clusters derived in this review study (with timespan: 2013-2022, slice length: 1, and selection criteria: Top 50 per slice) was presented in Figure 8.

Modularity (Q=0.683>0.3) and Silhouette (S=0.8553>0.7) of the clustering confirmed its validity. Labels selected by the log-likelihood ratio test method were used to refer the clusters and were displayed at the right side of Figure 8. A total of seven major clusters were identified, each representing a key topic in BL research. The pivotal studies in a cluster were marked out along the timeline, and the major findings were summarized and discussed in the following.

The first cluster was **blended course designs (#0)**. Pivotal publications in this cluster have summarized and articulated the major challenges that different stakeholders of a BL program often encounter and provided insights for future endeavors on BL design. In developing BL programs, how to incorporate flexibility, stimulate interactions, facilitate student learning processes, and foster an affective learning climate are the four major challenges (Boelens et al., 2017). Technologies play a key role in enabling and empowering interactions. And the outcomes, implications, and future directions of BL designs in higher education should be analyzed and discussed from the perspective of interaction supported

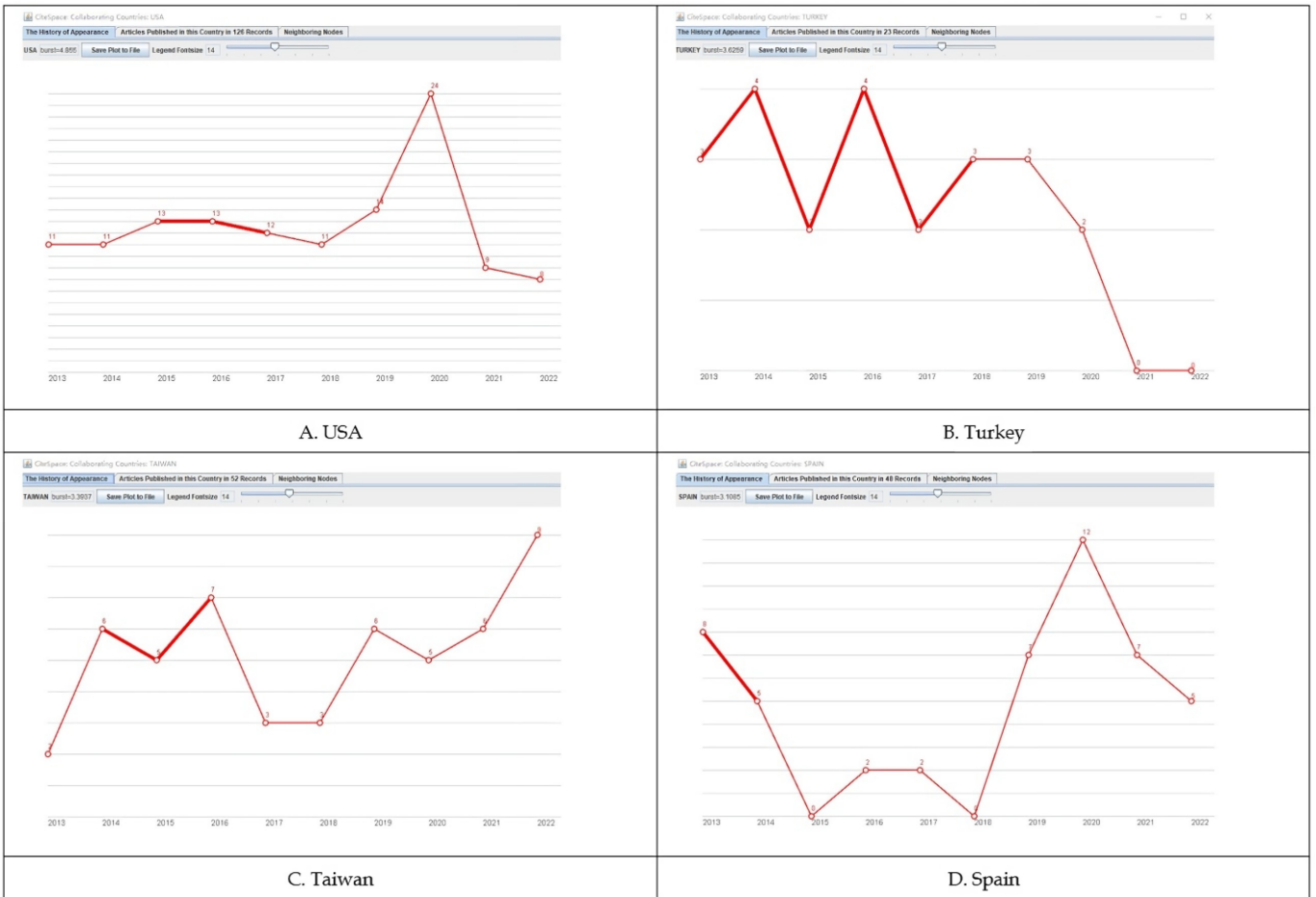


Figure 7. Countries/regions/cities with the strongest citations (Source: Authors’ own elaboration, using CiteSpace 6.1.R6 software)

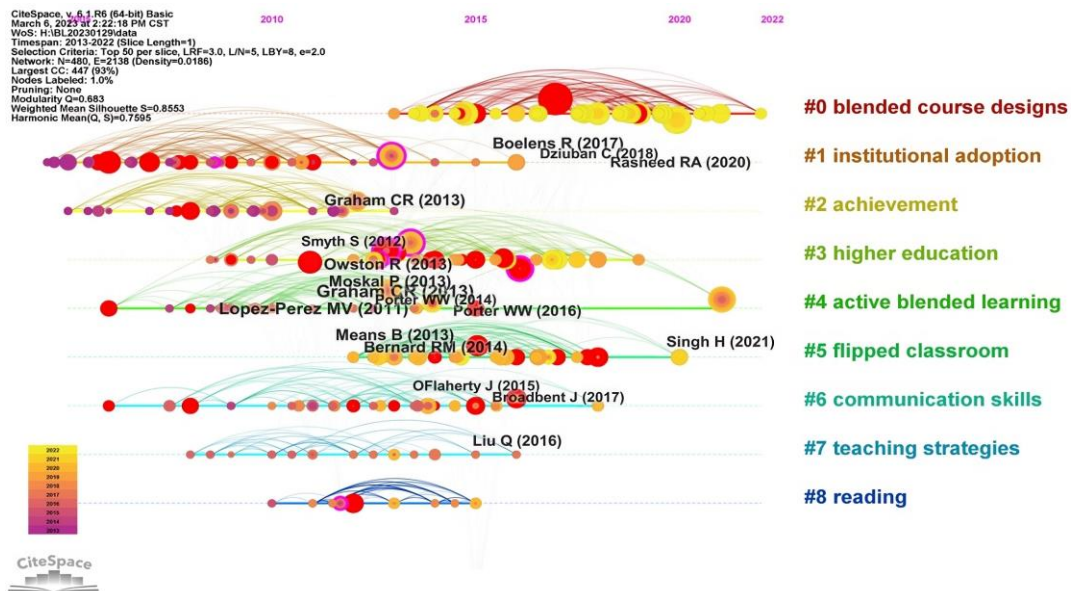


Figure 8. Clusters of document co-citation networks of blended learning research in 2013 and 2022 (Source: Authors’ own elaboration, using CiteSpace 6.1.R6 software)

by ICTs (Dziuban et al., 2018). For students, the major challenges in BL programs usually lie in self-regulation and the use of technologies to support learning; for teachers, in the integration of technologies to augment teaching; and for educational institutions, in the

provision of appropriate technologies for instruction and effective training and professional development for teachers (Rasheed et al., 2020).

Despite the challenges, BL programs have achieved many positive educational impacts and the critical

factors that influence the effectiveness of BL adoption have been further investigated (Vaughan, 2007).

Under the cluster of **institutional adoption (#1)**, there are several influential studies that focused on improving student satisfaction in BL. The interrelations among student perception of collaborative learning, social presence, and overall satisfaction in BL environment were explored (So & Brush, 2008). Based on the theory of social cognition, the factors that determine student satisfaction in the blended e-learning system environment were identified (Wu et al., 2010). How to improve student learning experience was another important question for investigation.

Under the cluster of **achievement (#2)**, relevant research elaborates the theoretical framework and practical guidelines for BL design, focuses on learners and learning, and proposes techniques and tools to engage students (Garrison & Vaughan, 2008), supports students in using asynchronous tools such as forums, wikis, and blogs (Macdonald, 2008) and encourages higher education to provide opportunities for students to obtain a better learning experience through flexible and effective interactive modes (De George-Walker & Keffe, 2010). Smyth et al. (2012) analyzed and described student experiences in BL postgraduate programs for nursing and midwifery, and the findings could inform future efforts to unlock potentials of the blended approach for improving nursing education.

BL also proven effective in enhancing student academic performance and lowering the rate of drop-out. Under the cluster of **higher education (#3)**, López-Pérez et al. (2011) investigated the adoption and implementation of BL in higher educational institutions and confirmed its significant, positive impacts on enhancing student performance and persistence in learning. This seminal study was frequently referenced, providing guidance for studies on the relationship between BL adoption and student learning performance and school drop-out rate that followed. Graham et al. (2013) provided a stage-based framework for higher educational institutions to strategically adopt and implement BL programs. Institutional strategies, structures, and supports required at the distinctive stage of awareness/exploration, adoption/early implementation, and mature implementation/exploration were delineated and deliberated. Theoretically, the study was significant by contributing a systematic approach for guiding and evaluating the design and implementation of BL. Effective implementations of BL require the coordination and alignment of the institutional, faculty, and student goals, reliable and robust infrastructure, as well as policy supports (Moskal et al., 2013). In the same cluster, Owston et al. (2013) examined student perception and preference of BL from four areas of overall learning satisfaction, convenience afforded, sense of engagement, and views on learning outcomes.

Porter et al. (2014), based on the framework proposed in Graham et al. (2013), analyzed the adoption of BL in 11 higher educational institutions in USA and articulated the issues to accommodate. The team further discussed the institutional drivers and barriers for faculty adoption of BL, including the availability of infrastructure, technological support, pedagogical support, the provision of evaluation data, and the institutional purpose for adoption (Porter & Graham, 2016).

Pivotal studies identified in the cluster of **active blended learning (#4)** indicated the need and investigated the method to tackle challenges in BL from the perspectives of curriculum design, technological support, instructional strategies, and student participation. Additional learning time, instructional resources, and course elements should be involved to encourage learner interactions (Means et al., 2013). Diverse forms of technological support (e.g., cognitive support, content/presentational support, interaction support) should be engaged to enhance student achievement (Bernard et al., 2014). And emerging technologies and innovative learning models such as artificial intelligence could be harnessed to augment blended programs of learning (Singh, 2021). Student participation and action are also important factors that regulate the effectiveness of a BL program.

In the cluster of **flipped classroom (#5)**, related research has explored the use of active learning and constructivist learning methods in flipped classrooms (Jensen et al., 2015). It was found that aspects of students' online collaborative learning should be considered in a BL environment (Ellis et al., 2016). Students' motivation was examined for engaging them in flipped learning (Vanslambrouck et al., 2018); Further studies have shown that BL approaches have a positive impact on learning transfer (Demirer & Sahin, 2013). O'Flaherty and Phillips (2015) provided a comprehensive overview of this particular model of BL and systematically analyzed the links between pedagogy and educational outcomes. Focusing on the student, Broadbent (2017) found the application of self-regulated learning strategies was more frequent in online learning in the context of flipped classroom.

In the cluster of **communication skills (#6)**, the effectiveness of BL versus face-to-face learning for teaching clinical skills was explored (McCutcheon et al., 2015). Adopting BL in engineering (architecture) and design, the learning outcomes were positive (Francis & Shannon, 2013). The combination of face-to-face and online delivery methods was beneficial to enhance the students learning experience (Poon, 2013).

In the cluster of **teaching strategies (#7)**, the related studies focused on: exploring teachers' experiences of teaching nursing undergraduates in a BL environment (Jokinen & Mikkonen, 2013); improving teaching strategies for learner-content interaction in BL (Kuo et

Table 4. Publications with the strongest burst of citations

Burst	Publication	Cluster #
6.93	So, H. J. (2008), <i>Computers & Education</i> , V51, P318	1
6.32	Boelens, R. (2017), <i>Educational Research Review</i> , V22, P1	1
6.21	Moskal, P. (2013), <i>The Internet and Higher Education</i> , V18, P15	3
5.43	Porter, W. W. (2016), <i>The Internet and Higher Education</i> , V28, P17	3
5.40	Wu, J. H. (2010), <i>Computers & Education</i> , V55, P155	1
5.04	Vaughan, N. (2007), <i>International Journal on E-Learning</i> , V6, P81	1

al., 2014); exploring factors that affected learners' learning satisfaction (Eagleton, 2015). The workload and time investment faced by teachers in implementing BL, teaching skills, and BL integration methods were also emphasized (Ma'arop & Embi, 2016).

In the cluster of **reading (#8)**, research explored the ways to integrated BL into reading tasks with aims of improving students' reading skills in grades 1-2 (Schechter et al., 2015), and the practice of K-12 BL in reading (Powell et al., 2015), meanwhile, the relationship among BL Teaching, administration, and professional development (Hilliard, 2015).

In the time-zone view of the clusters of document co-citation networks, a purple ring circles the nodes, which represent publications whose betweenness centrality equals or is over 0.1; the thicker the ring, the more pivotal the publication is and nodes in the red color indicate that there were bursts of citations of the publications within the period of analysis, presenting the fronts and key topics of the research field. As illustrated in **Figure 8**, the pivotal publications of BL research were mainly in the clusters of **institutional adoption (#1)** and **higher education (#3)**. The strength and time duration of citation burst of a publication are important indicators for its significance in the field. Based on these two indicators, the most influential publications of BL in 2013-2022 were listed in **Table 3**.

The betweenness centrality of a publication in a co-citation network is another key indicator for the significance of the publication in the research field. Publications with a betweenness centrality higher than 0.1 were listed in **Table 4**. Following the theory of knowledge, such "central" publications are often the literature in which important theories and/or innovative concepts are proposed and may lead to the emergence of new fronts and topics in a research field. They are structurally important in a knowledge network, taking a central position with multiple connections with other publications. Therefore, the seven publications listed in **Table 4** were recognized as the milestone research on BL in 2013-2022.

Cluster-wise, the milestone publications were mainly in the cluster of **institutional adoption (#1)** and **higher education (#3)**. The first four publications were introduced in previous paragraphs. The 5th publication, Arbaugh et al. (2009), reviewed research of online and BL in business disciplines. The findings provide guidance and directions for future integration and

improvement of BL programs in these disciplines. Drysdale et al. (2013) summarized the trends of growth, context, and methodologies of BL research and outlined the important research topics for future study. Picciano et al. (2012) examined the scope and significance of online learning in American K-12 education and expounded the advantages, issues, and costs of sustaining and scaling online and BL at the K-12 Level.

CONCLUSIONS

This review study adopted the visual analytical tool of CiteSpace to provide a systematic, structured overview of the knowledge domain of BL and its progression. Harnessing the power and potentials of knowledge visualization, it analyzed BL research published in the recent 10 years following the quantitative approach. It identified the prominent, prolific, and influential researchers, research institutions, and countries/regions in the field and uncovered the development trends and pivotal publications and topics. The findings can inform future developments and directions of BL research. Our study suggested that in the past 10 years, the research of BL has basically been in an overall steady upward trend. From the distribution of published papers and citations every year, it can be seen that the number of citations increases exponentially with the increase in the number of published papers. We found that BL has a wide range of applications in various disciplines, covering educational research (67.455%), computer science (10.570%), nursing (8.206%), engineering (5.424%), psychology (4.729%), public environmental occupational health (3.894%), environmental sciences ecology (3.199%), health care sciences services (3.199%), linguistics (3.060%), and science technology (3.060%). The most published papers are in the area of education. The research of BL in geography, music, architecture, and chemistry is still very weak.

From the data analysis, the number of publications in countries such as USA (126 articles), China (120 articles), and Australia (76 articles) was more than other places. Griffith University, Vrije University Brussel, Brigham Young University, Deakin University, Monash University, National Taiwan Normal University, University of Hong Kong and University of Sydney, etc. have published more papers. Graham, Charles R., Zhu, Chang, Ellis, Robert A., Han, Feifei, and other researchers have made many achievements in BL

research and have the most far-reaching influence, forming a group of researchers based on Griffith University, University Hong Kong, Vrije University Brussel, Monash A multilateral cooperation network represented by universities and scientific research institutions such as University and National Taiwan Normal University.

Through the cluster structure analysis of the literature co-citation network, we found the development and evolution dynamics of the BL discipline, and the formed clusters were #0 blended course designs, #1 institutional adoption, #2 achievement, #3 higher education, #4 active blended learning, #5 flipped classroom, #6 communication skills, etc. The research results show that BL research is getting more and more attention from various countries and educational institutions, and the application advantages of BL in different disciplines and fields are highlighted.

The comparative advantages of BL in relation to the traditional face-to-face instruction are obvious (Means et al., 2013). When adopted and implemented appropriately, BL will significantly improve student academic results, learning motivation, attitude, and satisfaction (McCutcheon et al., 2018; Woltering et al., 2009). Meanwhile, it also provides better flexibility in teaching and learning (Jun & Ling, 2011). BL can promote learners to learn more flexibly, and other aspects are basically consistent with the conclusions of several other studies (Li et al., 2022; McKenzie et al., 2022; Müller & Mildenerger, 2021) Given the challenges, measures are to be designed and enacted to augment designs and implementations of BL to optimize learner experience (Bliuc et al., 2007) and to strengthen ICT skills and infrastructure for institutional adoption (Ashraf et al., 2021). Therefore, this study encourages higher education institutions to provide students with greater flexibility in terms of BL and to provide a wider range of choices for the students.

Study Limitations and Future Direction of Blended Learning research

The findings of this review study are not conclusive considering the fact that the selection of different parameters in the tool of CiteSpace (e.g., slice length) may generate different networks and clusters and support alternative conclusions. It is believed that two areas will continue to be the foci of investigations in BL research. One is the design elements (e.g., models, learning analytics, environment, and system) and support structures (e.g., technology, institutions, and the faculty) of BL. For example, leveraging BL to maximize the use of the limited physical environment (Baepler et al., 2014) and to improve teaching effectiveness and attitudes of pre-service teachers (Atmacasoy & Aksu, 2018), and sustaining BL programs with critical strategies, structures and supports at the higher education level (Graham et al., 2013). The other focal area

is student experience and performance in online learning (e.g., participation, satisfaction, motivation, and outcomes). For example, exploring the relations between student self-efficacy and satisfaction (Al-Rahmi et al., 2018), examining student engagement in BL programs (Manwaring et al., 2017), and inspecting the impact of technological and human factors on student activity and outcomes in BL (Bower et al., 2015).

BL has been integrated into the teaching and learning in the contexts of educational research, computer Science, nursing, engineering and psychology and other disciplines, although various results have been generated in cluster or blended course designs, the factors including curriculum elements, learner characteristics, teaching strategies and teaching methods should be suggested to delivery more effective BL courses for the students. The current research still lacks a comprehensive research perspective, and more research of BL can be conducted from an interdisciplinary perspective. For example, a mix of physical and virtual experiments can be achieved by designing educational games combined with physical experiments (Cheng et al., 2022). A study was conducted for exploring the relationship between emotional intelligence and learning habits in a BL environment (Iqbal et al., 2022). Research can be done on interactive learning through BL approaches (Barbosa, 2022; Tsou & Tsai, 2022). Accurately assessing learning effects is an important issue in BL. Currently, there are many studies on the design and development of BL teaching and learning materials and activities, student learning experience, and assessment strategies, but it is difficult to accurately assess the learning outcomes. Both the design and evaluation of BL are inseparable from the support of teachers and institutions. BL requires teachers to flexibly use different teaching strategies and technical tools in different scenarios. However, teachers currently have relatively little professional skills, practical experience, and technical support in the field of BL. Therefore, future research can expand and extend aspects of BL design, evaluation methods, teacher training, and institutional support that represent a comprehensive research perspective.

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