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Research trends in blended learning in chemistry: A bibliometric analysis of scopus indexed publications (2012–2022)

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ABSTRACT
Applying bibliometric techniques to blended learning research is still relatively uncommon. This study employs bibliometric analysis, employing data from the Scopus database and VOSviewer to show papers published between 2012 and 2022. The study's sample is made up of publications on blended learning in science that have been indexed by Scopus and were published between 2012–2022, amounting to 194 articles. Through Scopus filters, 85 irrelevant works, including editorials, comments, and book reviews, were excluded. Subsequently, 109 articles relevant to the research objectives were extracted. Citation patterns, publication trends, frequently cited articles, and author keyword analysis were examined, shedding light on the growth of research in blended learning chemistry. As a result, research in blended learning chemistry has grown steadily from year to year in publications in journals with a Scopus index. Analysis and online learning are two terms rarely used concerning blended learning in chemical education. The most often used terms were "e-learning," "online learning," "collaborative learning," and "reverse classroom." Most blended learning research is carried out in the United States and the United Kingdom. For all of the papers examined, bibliometric analysis was utilised to determine goals and key areas of chemical content. The findings contribute to a deeper understanding of the evolution and current state of blended learning in chemistry education, providing insights for future research directions and educational practices.

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Introduction

An educational strategy called blended learning combines in-person and online instruction. Traditional classroom lectures can be combined with online lectures in a setting where technology is used to provide learning materials (Arifiani & Irwanto, 2024). There is plenty of evidence that a blended learning strategy that includes in-person and online learning resources is significantly more successful in raising achievement than employing only in-person education techniques (Ramadhan et al., 2023). However, to be successful, blended learning resources must be created and delivered in a row with sound pedagogical principles (Van, 2016).

Because it integrates conventional classroom methods with online learning models, blended learning is both intriguing and realistic. Learning using a blended learning approach gives students a productive and successful educational experience, expanding their access to the curriculum, improving their learning results, and enabling them to follow teacher instructions (Dziuban et al., 2004). Educators should bear in mind that the adoption of blended learning technology should not aim to replace instructors or professors. As emphasized by Singh and Reed (2001), students' learning does not stem directly from the technology itself, but rather from the effective strategies employed by teachers to communicate using technology. For over a decade, blended learning has been employed in educational settings. However, Chew et al. (2010) suggest that it remains in a developmental phase. The progression has been notably influenced by highly interactive technologies like games and simulations (Dede, 2005; Irwanto et al., 2022). The central topic under debate pertains to whether blended learning proves more effective than alternative learning approaches. Over the past few decades, the educational landscape has witnessed significant transformations propelled by rapid technological advancements (Irwanto et al., 2023a). Traditional education, until recently, stood as the predominant classroom model (Schaber et al., 2010). It typically involves the physical presence of both instructors and students in a classroom setting where teaching and learning activities take place (Nortvig et al., 2018). The emergence of online learning took place in the 1990s (Schaber et al., 2010), presenting a departure from traditional methods. Online learning involves fully virtual courses devoid of physical class meetings, allowing for asynchronous participation of professors and students (Irwanto et al., 2023b; Nortvig et al., 2018). Research has extensively explored the effectiveness of three teaching modes: traditional face-to-face, blended, and online instruction. Dziuban et al. (2004), employing blended learning approaches, found that students utilising blended learning systems outperformed those in fully online environments and, in some cases, even traditional face-to-face instruction. In a recent study, learning was delivered through all three modalities, revealing that an online learning environment outperformed blended and face-to-face methods (Reason et al., 2005). As conventional and online learning paradigms continue to evolve, a third instructional approach has emerged—blended learning—resulting from the integration of traditional and online learning practices. Blended learning serves as a method that harnesses the strengths of various theories, technologies, and applications (Haijian et al., 2011).

With technology, learning may take place anytime, anywhere, without regard to location or time, with the potential for student involvement support. Other learning activities can also boost engagement and assist students in achieving higher achievement (Bliuc et al., 2007). Additionally, students develop their social and academic self-projection skills in online research groups. Importantly, support students in mastering some technologies, and digital learning skills becoming crucial for lifelong learners (Cleveland & Wilton 2018; Sahara et al., 2021; Jebraeily et al., 2020).

Bibliometrics involves the quantitative and descriptive statistical analysis of various types of publications, including journal articles, conference proceedings papers, and book chapters (Ding et al., 2016; Zuccala & Leeuwen, 2011). Bibliographic information can be retrieved by searching databases such as Web of Science (WoS) and Scopus using keywords, authors, journals, and specified time periods. Over the past two decades, the quantitative analysis of publications and citation data has become widely utilised in educational contexts to evaluate top authors and conceptual frameworks (Aria & Cuccurullo, 2017). Two key aspects of bibliometric mapping include the creation of distance-based maps and their visual representation. In bibliometric literature, there is more emphasis on map creation than on graphical representations of these maps (Van Eck & Waltman, 2010). While computer programmes like SPSS and Pajek can generate simple visual depictions of bibliometric literature, they are typically suitable for smaller maps containing fewer than 100 entries (Chen, 2003; Skupin, 2004). Consequently, new software programmes capable of producing larger maps have been developed (Van & Waltman, 2020).

Using bibliometric metrics such as the h-index and impact factor, bibliometrics is frequently used to assess the significance of scientific research. By measuring the number of other publications that reference a specific work, bibliometric indicators can determine the impact of that paper. Many

researchers employed Harzing's Publish or Perish program to determine citation metrics such as the *h*-index and *g*-index (Harzing, 2020). The conceptual framework of this research is that the authors use bibliometric analysis literature, especially for journals published in the last ten years.

Advanced analytical techniques are now readily available to ensure the accuracy of bibliometric analysis and to cover a wide range of publications spanning a significant period of time. Popular databases such as WoS, Google Scholar, and Scopus are commonly utilised (Li et al., 2010). However, as of February 2, 2020, searches using keywords like "blended learning," "achievement," "engagement," "perception," "higher learning," and "bibliometric analysis" yielded no results in the Scopus database. Nonetheless, other articles have explored the relationship between students' perceptions of blended learning courses and their academic performance in higher education (Owston et al., 2013).

Given the persistent disparity between blended learning and perceptions, achievements, and engagement in higher education, the present investigation was undertaken. The research findings identified three factors contributing to educational disparities in Indonesia: limited access to schools, declining school facilities, and inadequate teacher interest and quality. For this study, the authors formulated three research questions: (1) *How have publications on blended learning evolved over the past decade?*, (2) *Which blended learning study in chemistry education has garnered the most citations?*, and (3) *What are the most commonly used search terms for blended learning studies in chemistry education?*

Methodology

The population for this research consisted of chemistry education blended learning articles published up to June 10, 2021, from the Scopus database. From 2012 to 2022, 109 research papers were selected from a total of 194 papers. Data about integrated learning in chemistry education were gathered, processed, and analysed using bibliometric analysis techniques. Data gathering was conducted using VOSviewer data visualization with the Scopus database accessed via www.scopus.com. The search was limited by typing "blended learning" in the search menu, setting the publication date range from "2012" to "2022," selecting the document type "journal," and clicking "search" to retrieve the information. The data from the search results were saved in RIS format for handling using VOSviewer and Microsoft Excel (Irwanto et al., 2023).

The data collected was stored in RIS format. Both descriptive quantitative and qualitative data analysis methods were performed in the present study. Microsoft Excel 2010 was utilised to evaluate data obtained from scientific publications on blended learning in chemistry by year, author, title, and subject. Articles on blended learning in chemistry were analysed using the VOSviewer program. Data processing output took the form of graphs in Excel and network maps based on authors and keywords in VOSviewer. Subsequently, VOSviewer was used to visualize the findings of the analysis, as illustrated in Figure 1 (Moher et al., 2009).

The inclusion and exclusion criteria applied during the study are outlined in Table 1.

Table 1

Inclusion and exclusion criteria

No	Inclusion Criteria	Exclusion Criteria
1.	Limited to documents related to blended learning published in the 2012-2022 period in the Scopus database	1. Documents concerning blended learning that were published outside the timeframe of 2012 to 2022 within the Scopus database
2.	All documents written in English	2. All articles written not in English
3.	All documents in the form of journal articles	3. All documents other than journal articles (e.g., conference papers, books, book chapters, etc.)

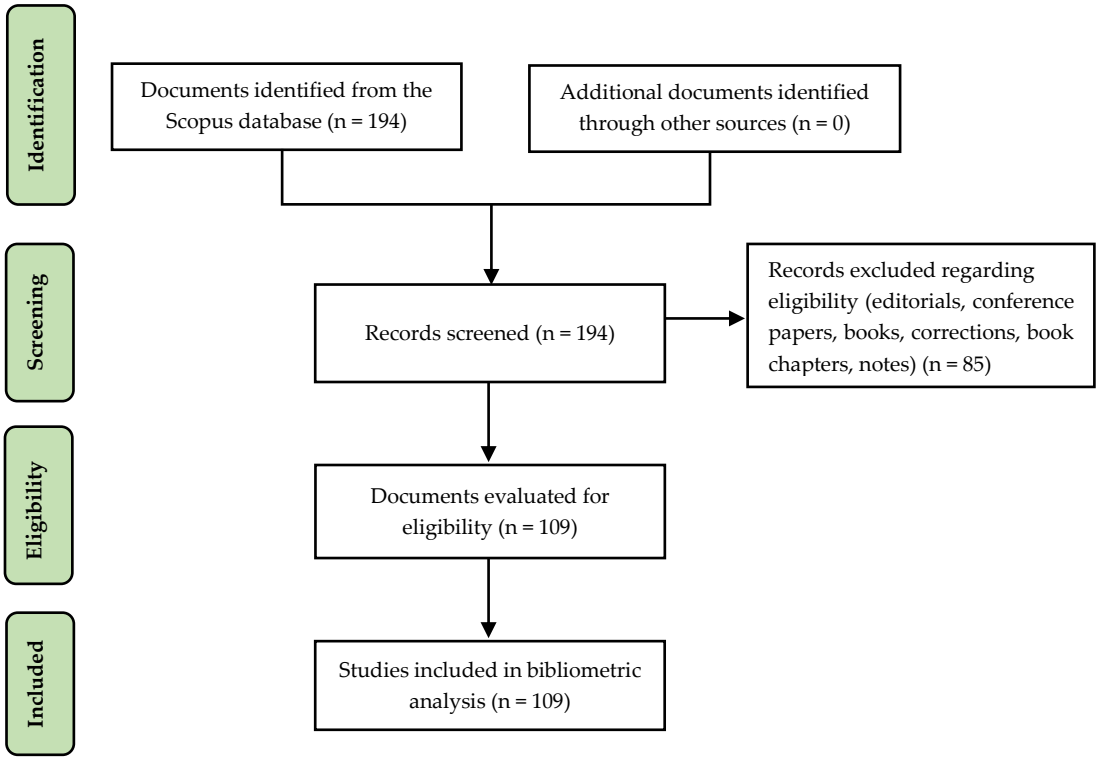
Data Analysis

A computer tool named VOS (Visualization of Similarities) viewer, developed by Van Eck and Waltman (2010), is designed to generate and exhibit bibliometric maps. While other tools like Histcite, SPSS, and Pajek can also be utilised for bibliometric mapping (Chen, 2003; Skupin, 2004), VOSviewer places a stronger emphasis on graphical representation. For instance, it is capable of constructing maps of authors or journals based on keywords, co-citations, and co-occurrence data. One notable advantage of VOSviewer is its ability to handle large datasets, accommodating over 100 items. It exhibits excellent performance in viewing and creating maps using VOS mapping techniques, which are seamlessly integrated into the VOSviewer software. The three forms of visualization that can be displayed are network, overlay, and density visualization.

Figure 1 provides a detailed breakdown of the data collection process utilised by researchers, employing the PRISMA flow diagram.

Figure 1

PRISMA flow diagram



The following details the study's data search process as shown in the prism flow diagram, which was created up until the 2020 revision shown in Figure 1. Figure 1 shows that there are four phases, namely identification, screening, eligibility, and included:

Identification

Identification involved conducting literature searches in the Scopus database, and refining the search to include keywords, abstracts, and research question titles. This stage yielded a total of 194 documents.

Screening

During the screening or selection phase, literature sources that aligned with the study's objective, subject, or research question were identified. Criteria for inclusion and exclusion had been previously established. Any literature sources that did not meet the inclusion criteria (n=85) were disregarded.

Eligibility

At this stage of the process, it was important to further investigate any material that matched the title and keywords. As a result, 109 articles that met the requirements were identified.

Included

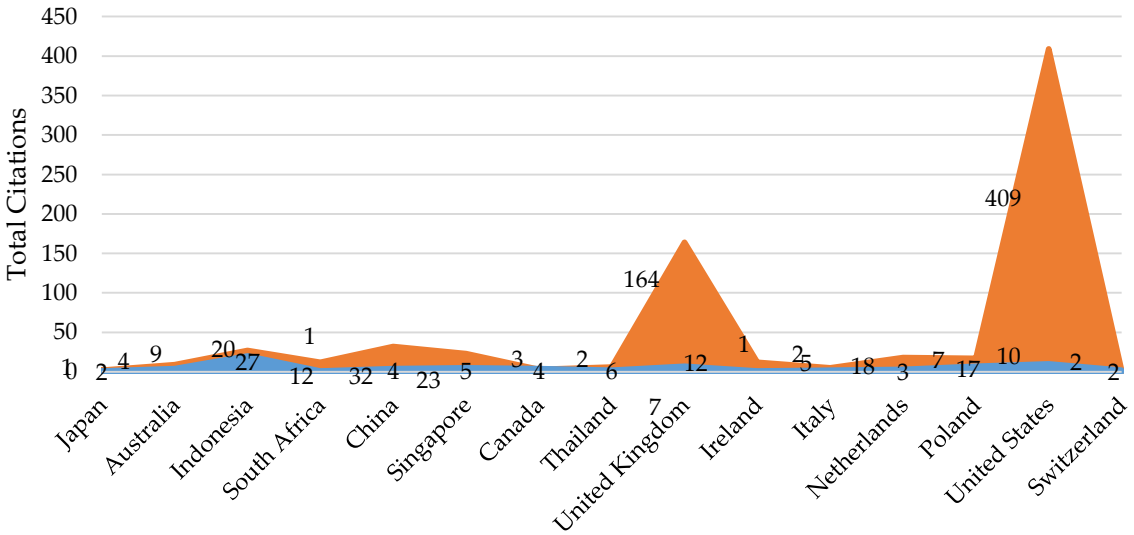
All literature sources that passed the screening or selection stage were then subjected to further analysis.

Findings

Figure 2 displays the findings regarding countries and the number of publications and citations in the field of chemistry education. It illustrates the growth of documents, citations, and research on blended learning from various countries. The publication of works on blended learning in chemistry is becoming increasingly common in various nations. Research on blended learning in chemistry, as published in Scopus-indexed journals, has shown steady growth over the years. The United States emerges as the country with the highest number of citations for blended learning publications, totaling 409 citations.

Figure 2

Number of publications and citations by country



Frequently Cited Articles

The most frequently cited article on blended learning was written by "Baepler P., Walker J.D., Driessen M." with 394 citations, and 10th place was written by "Ping G.L.Y., Lok C., Wei Yeat T.,

Cherynn T.J.Y., Tan E.S.Q." with 14 citations. In their paper published in *Computers & Education*, Baepler et al. (2014) compared the learning outcomes of traditional classes with active learning classes. They reported that student contact with lecturers in active learning classes could be reduced by two-thirds and students achieved better learning outcomes compared to learning outcomes in traditional classes and student perceptions of active learning classes were more favorable. In addition, Ping et al. (2018) evaluated three mobile applications that are freely available on the Apple App Store and Google Play Store. They found that apps were most effective when used in a blended learning environment and that higher frequency of app use also supported improved student performance. The top 10 most frequently cited articles can be seen in Table 2.

Table 2

10 most frequently cited articles

Authors	Title	Cites
Baepler P., Walker J.D., Driessen M. (2014)	It's not about seat time: Blending, flipping, and efficiency in active learning classrooms	394
Lapitan L.D., Jr., Tiangco C.E., Sumalinog D.A.G., Sabarillo N.S., Diaz J.M. (2021)	An effective blended online teaching and learning strategy during the COVID-19 pandemic	83
Williams N.A., Bland W., Christie G. (2008)	Improving student achievement and satisfaction by adopting a blended learning approach to inorganic chemistry	37
Bortnik B., Stozhko N., Pervukhina I., Tchernysheva A., Belysheva G. (2017)	Effect of virtual analytical chemistry laboratory on enhancing student research skills and practices	24
Heilesen S.B., Josephsen J. (2008)	E-learning: Between augmentation and disruption?	24
Yang L., Sun T., Liu Y. (2017)	A bibliometric investigation of flipped classroom research during 2000-2015	22
Campbell C.D., Challen B., Turner K.L., Stewart M.I. (2020)	#Drylabs20: A new global collaborative network to consider and address the challenges of laboratory teaching with the challenges of Covid-19	18
Hurst G.A. (2020)	Systems thinking approaches for international green chemistry education	18
Bernard P., Broś P., Migdał-Mikuli A. (2017)	Influence of blended learning on outcomes of students attending a general chemistry course: Summary of a five-year-long study	15
Ping G.L.Y., Lok C., Wei Yeat T., Cherynn T.J.Y., Tan E.S.Q. (2018)	"Are chemistry educational apps useful?" - A quantitative study with three in-house apps	14

In this bibliometric analysis, we also present the 10 most recently published articles in the field of blended learning. The most recent article on blended learning was written by Al Mamun M.A., Lawrie G., and Wright T.; their article was published in *Computers and Education* in 2022. Al Mamun et al. (2022) investigated the nature of students' interactions with learning content in guided inquiry-based and online independent learning environments. As a result, the researchers found that previous online experience influenced students' behavioral efforts and previous subject knowledge influenced students' cognitive efforts. The 10th article was written by Kuroki N. and Mori H.; their article was published in the *Journal of Chemical Education* in 2021. In their study, Kuroki and Mori (2021) designed a physical chemistry laboratory course to help undergraduate chemistry students maintain their knowledge of physical chemistry. The researchers found that students were excited about the new

course that comprehensively covered experiments, computing, and data science. Table 3 lists the 10 most recently published articles related to blended learning in chemistry.

Table 3

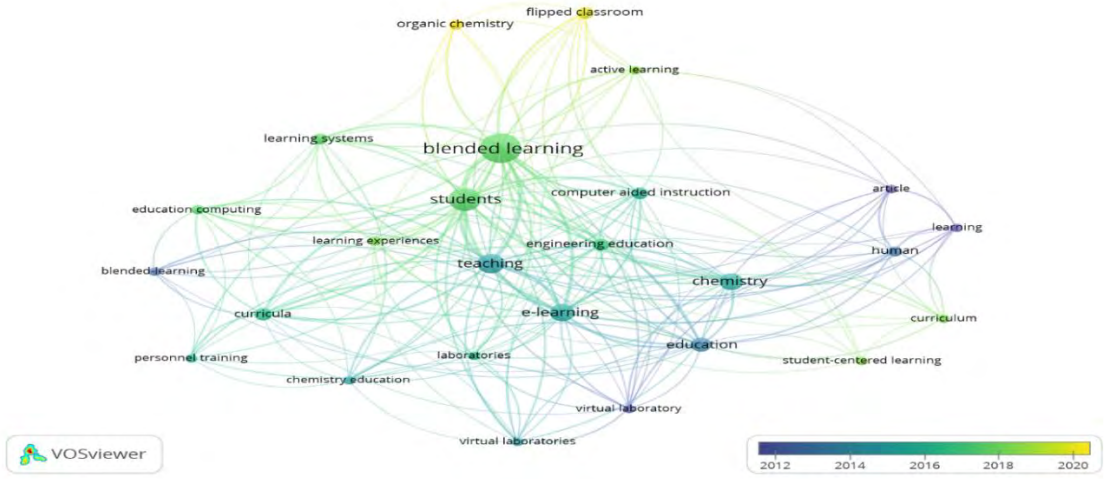
10 most recently published articles

Authors	Title	Year
Al Mamun M.A., Lawrie G., Wright T.	Exploration of learner-content interactions and learning approaches: The role of guided inquiry in the self-directed online environments	2022
Aidoo B., Macdonald M.A., Vesterinen V.-M., Pétursdóttir S., Gísladóttir B.	Transforming teaching with ICT using the flipped classroom approach: Dealing with COVID-19 pandemic	2022
Ang J.W.J., Ng Y.N.	Effect of research-based blended learning with scrum methodology on learners' perception and motivation in a laboratory course	2022
Kędzierski W., Wawrzykowski J., Jamioł M., Kankofer M.	Effects of tutoring in teaching basic subjects to veterinary students	2022
Reyes C.T., Kyne S.H., Lawrie G.A., Thompson C.D.	Implementing blended first-year chemistry in a developing country using online resources	2022
Yin B., Yuan C.-H.	Detecting latent topics and trends in blended learning using LDA topic modeling	2022
Lapitan L.D., Jr., Tiangco C.E., Sumalinog D.A.G., Sabarillo N.S., Diaz J.M.	An effective blended online teaching and learning strategy during the COVID-19 pandemic	2021
Fonseca C.S.C., Zacarias M., Figueiredo M.	MILAGE LEARN+: A mobile learning app to aid the students in the study of organic chemistry	2021
Dai N.V., Trung V.Q., Tiem C.V., Hao K.P., Anh D.T.V.	Project-based teaching in organic chemistry through blended learning model to develop self-study capacity of high school students in Vietnam	2021
Kuroki N., Mori H.	Comprehensive physical chemistry learning based on blended learning: A new laboratory course	2021

Figure 3 illustrates how the analysis of blended learning writing keywords using VOSviewer reveals the appearance of various relevant articles, including "student," "education," "teaching," "engineering education," "chemistry," "e-learning," and others.

Figure 3

Network visualisation map of author keywords



This mapping aims to identify the information that has been utilised by multiple researchers over the past decade. Through a keyword analysis of blended learning publications related to chemistry education, it was found that terms such as "blended learning," "chemistry," and "online learning" are the most commonly used. Cluster 1, highlighted in green, represents the primary research trend in this field. The four keyword clusters' specifics, as determined by VOSviewer's analytical findings, are as follows:

1. Eight keywords comprise the first cluster (green): blended learning, curriculum, chemical education, e-learning, education computers, learning systems, personnel training, and teaching. The term "teaching" appears frequently.
2. Seven keywords make up the second cluster (purple), including "article," "chemical," "curriculum," "education," "human," "learning," and "student-centre-learning." Human is a term that frequently arises.
3. Six keywords make up the third cluster (light green): computer-aided teaching, flipped classroom, active learning, organic chemistry, and student. Keywords such as blended learning are frequently used.
4. Five keywords are grouped in the fourth cluster (dark green colour): engineering education, labs, learning experiences, virtual laboratories, and virtual laboratory. Teaching is a term that frequently emerges.

Discussion

The utilisation of bibliometric methods in researching blended learning remains relatively uncommon. Consequently, this study employs bibliometric analysis, utilising data from Scopus and VOSviewer databases to examine papers published between 2012 and 2022. The research focuses on scientific publications concerning blended learning in science indexed by Scopus and appearing in journals. Over the preceding decade, from 2012 to 2022, there were 194 such publications. Through Scopus filters, 85 irrelevant works were excluded to ensure the quality and relevance of the data. These criteria align with previous findings by Halverson (2012) and Yang et al. (2017), which highlight journal articles as the primary document type in blended learning research. Following the exclusion of irrelevant works, a total of 109 articles were identified. Examination of research output reveals a rapid increase in articles and research attention between 2016 and 2018, consistent with findings from Cheng et al. (2014) and Güzer and Caner (2014). This underscores the importance of further exploring how educators and administrators can cultivate effective blended learning environments. Additionally, the

study finds that English predominates as the language of scientific publications in the Scopus database during the study period, echoing previous research by Sweileh et al. (2017) and Ferguson et al. (2011). Given that blended learning intersects with the social sciences, it is unsurprising that over half of the papers analysed belong to this disciplinary category.

The present study indicates a noticeable upward trend in the number of documents pertaining to blended learning research over the past decade. This pattern undoubtedly provides practical and theoretical contributions for researchers and educators. Recent studies underscore the numerous benefits of blended learning. By leveraging technology, learners can engage in flexible learning experiences anytime and anywhere, transcending the constraints of time and location. Moreover, blended learning fosters stronger connections between students and teachers, enhances engagement, and promotes higher academic achievement. Additionally, it cultivates students' digital literacy skills (Cahyana et al., 2023; Dewi et al., 2022), preparing them to navigate online learning communities effectively as lifelong learners. The evolution of competencies and the integration of technological advancements in education have propelled blended learning to the forefront as a fundamental pedagogical approach. Its ability to facilitate meaningful interactions amidst a digital landscape underscores its importance in contemporary learning environments. The increasing research interest in blended learning is reflected in its growing citation impact, indicating its significance in technology-mediated education. Several studies in this field have demonstrated a substantial influence on citation counts, suggesting a growing recognition of blended learning's relevance and efficacy (Omar et al., 2021). These may be possible reasons for the increasing number of publications in the area of blended learning over the years.

Citation patterns, publication trends, and author keywords are thoroughly examined. The findings indicate a continuous growth in research concerning blended learning in chemistry, reflected in the increasing number of publications indexed in Scopus journals. In 2020, there were 109 citations related to blended learning in chemistry education. The articles frequently cited as references play a pivotal role in shaping scientific advancements and research directions positively. Interestingly, terms such as "analysis" and "online learning" are infrequently utilised in the context of blended learning in chemistry education. Instead, terms like "e-learning," "online learning," "collaborative learning," and "reverse classroom" dominate the discourse. Moreover, the majority of blended learning research in this domain originates from the United States and the United Kingdom.

The author's keyword analysis and network visualization of shared events reveal the most popular keywords. However, certain research papers delve into aspects such as perception, involvement, and achievement. Further exploration of blended learning trends concerning student engagement, perception, and academic performance warrants additional research. Yang et al.'s (2017) study supports the notion that the United States leads in the number of publications in this field.

The outcomes of bibliometric analyses may vary depending on the database used (such as WoS or Google Scholar) and the inclusion of additional search terms (e.g., e-learning). Consequently, the study exclusively examines papers with author keywords, which can be utilised to display keyword networking. Moreover, to identify highly cited works produced between 2012 and 2022, with the majority published between 2021 and 2022, a citation criterion of fewer than 200 citations was established. Given these constraints, all analyses, discussions, and findings presented in this paper should be interpreted within this framework (Raman, 2021).

While Scopus encompasses numerous journals, it primarily provides access to more recent articles with potentially lower impact (Chadegani et al., 2013). Consequently, it is recommended to explore other scientific databases, such as the WoS, to access a broader range of peer-reviewed articles that can enhance the scalability of the approach further. Experimenting with different keyword combinations can also augment exposure and retrieve the most recent quotations related to blended learning. Additionally, for a comprehensive examination of the literature, it is advisable to conduct bibliometric analysis concurrently with a systematic literature review. This combined approach ensures a more thorough investigation of the body of literature on blended learning.

Reviewing the bibliometric analysis of articles conducted by previous researchers over the past decade provides valuable reference material indicating that blended learning can effectively enhance student learning outcomes while facilitating teachers' proficiency in utilising increasingly sophisticated technology. We anticipate that research on blended learning will continue to progress, especially in countries where information technology is rapidly advancing. Ultimately, these nations are expected to enhance their educational policies to integrate technological advancements, thereby paving the way for the widespread adoption of blended learning strategies (Raman, 2021).

Conclusions and Suggestions

Research articles on blended learning in chemistry education have shown a consistent increase in publications indexed by Scopus over the years. The United States leads with the highest number of articles, totaling 409 citations. The COVID-19 pandemic accelerated interest in blended learning as an alternative to remote learning, particularly in chemistry education, with 2020 seeing the most significant references to blended learning-related literature, totaling 109 citations. A notable article by Baepler P., Walker J.D., and Driessen M., published in 2014, received the most citations and significantly influenced the advancement of knowledge and research opportunities in chemistry education with blended learning.

This study employs bibliometric analysis, utilising data from the Scopus database to examine papers published between 2012 and 2022. Out of 194 initially identified papers, 109 were selected after excluding irrelevant works through Scopus filters, providing a foundation for further research. Keyword analysis reveals that terms like "online analysis" and "learning" are seldom used in blended learning in chemistry, suggesting potential areas for future exploration. However, terms such as "online learning," "e-learning," "collaborative learning," and "reverse classroom" are frequently employed. Furthermore, blended learning research in chemistry education is predominantly conducted in the United States and the United Kingdom. Overall, the most cited articles contribute positively to scientific developments and research prospects, underscoring the ongoing growth and significance of blended learning in this field.

Indeed, utilising keywords like "online analysis" and "learning" can serve as a valuable guide for further research. Alternatively, the scarcity of studies on online learning could be argued, highlighting numerous opportunities for investigation in this area. This underscores the vast scope available for studying this subject. To achieve a more comprehensive knowledge mapping, the authors suggest conducting additional studies employing alternative techniques and data sources, such as Google Scholar or others. Expanding the research scope beyond Scopus and utilising different methodologies could provide a more nuanced understanding of the topic and uncover previously unexplored insights.

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