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Knowledge Map of Learner Characteristics in Blended Learning: A Bibliometric Analysis

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ABSTRACT

The study of learner characteristics in blended learning has consistently emerged as a central theme in the global discourse on blended learning, and occupies a central position in research in international fields of education and psychology. The aim of this study is to explore the research focal points, trends, and cutting-edge developments related to learner characteristics in blended learning. CiteSpace was used to visually analyse 2,672 high-quality literature articles related to learner characteristics in blended learning in the Web of Science database spanning from 2014 to 2023. The data obtained from the Web of Science database includes titles, abstracts, years, keywords, authors, academic institutions, journals, and citation counts. To facilitate visualization, we employed CiteSpace visualization software for literature analyses, knowledge mapping, collaborative network analyses, cluster analyses and keyword bursts. A total of 2672 articles related to learner characteristics in blended learning were identified. The highest number of articles were published in the United States (400 papers), followed by China (396 papers) and Australia (247 papers). The most commonly occurring keywords were 'higher education', 'engagement', 'performance', 'satisfaction', and 'online learning'.

Keywords:
Learner characteristics, blended learning, bibliometrics, CiteSpace

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1. Introduction

The investigation of learner characteristics in blended learning has been a consistent theme within the global field of blended learning and is a focal point of research in the international domains of education and psychology. Early studies on learner characteristics in blended learning have yielded abundant research outcomes.

Wang Gaihua [1] developed the CEVR model (cognition, emotion, volition, behavior) to describe blended learning participants. The model includes four dimensions: cognition, emotion, volition and behavior, and shows their interrelationships and mutual influences. Wang Gaihua believes that in the context of blended learning, the combination of learners' psychological processes and learning behaviors form a complex and interrelated system, as shown in Figure 1. Therefore, the CEVR model

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can serve as a basis for understanding learner characteristics in blended learning. Cognition refers to the cognitive processes involved in blended learning, including perception, recognition, awareness, attention, memory, thinking and imagination. It is mainly reflected in four aspects: learning strategies, learning styles, sense of spatial orientation and metacognition. Emotion refers to learners' emotional experiences during blended learning. It mainly includes learning attitudes and learning anxiety. Volition refers to the conscious process by which learners set learning goals and plans, resist temptations, overcome difficulties and actively regulate their behavior to achieve expected psychological outcomes in blended learning. It mainly involves learning motivation and learning self-efficacy. Behavior is the sum of observable activities undertaken by learners in blended learning that are driven by motivation to achieve specific learning outcomes. This extract describes a learning activity dominated by mental processes. Learners' internal psychological characteristics, including cognition, emotion and volition, are interrelated and influence each other. Wang Gaihua's research shows that there is a relationship between learners' internal psychological characteristics and their external learning behavior. Learners' internal psychological characteristics can influence their external behaviors, and these behaviors can reflect their psychological characteristics [1,2].

Fig.1. The CEVR model

A systematic review of learner characteristics in blended learning will not only help to provide a more comprehensive understanding of the trajectory and cutting-edge developments in this area of research, but is also essential for improving the effectiveness of research efforts in this area.

Literature bibliometrics analysis is a commonly used quantitative research methodology. Citespace software is a highly esteemed visualization tool in the field of literature information analysis. This study, based on the method of bibliometric analysis, uses the Web of Science database as a data source. Using Excel and the scientific metrics tool Citespace software, the literature on learner characteristics in blended learning is examined. By focusing on the following three research questions, the aim of this study is to identify the current status, hot topics and trends in research on learner characteristics in blended learning. The intention is to provide practical and valuable guidance for further research in this area.

i) What are the changes in the subject basis of learner characteristics in blended learning research and who are the major contributors (e.g., authors, institutions, and countries) to learner characteristics in blended learning research?

ii) What are the main research topics and hotspots in learner characteristics in blended learning research?
iii) What are the research frontiers and emerging trends in learner characteristics in blended learning research?

2. Material and Method

2.1 Data Sources

The publication data utilized in this study are sourced from the Web of Science Core Collection (WoS), compiled by Thomson Reuters [3]. The WoS Core Collection database is the most commonly used and authoritative research literature search engine [4]. This database adheres to rigorous selection criteria, employing an expert peer-review system. The literature included in the collection possesses a certain level of objectivity, accurately reflecting the standard and quality of research papers [5]. It has transformed into a comprehensive instrument for globally searching and evaluating significant research outcomes, covering articles, conference abstracts, books, and published materials [3,6]. Many studies have indicated that WoS serves as an ideal data source for conducting scientometric analyses of literature [7-9].

As Citespace software can analyze literature using only one data source, the researchers opted for Web of Science (WoS) as the primary data source due to its extensive coverage and compatibility with CiteSpace software [10]. To ensure that the knowledge map is representative and reliable, a literature search period of ten years or more is usually chosen [4,5,11-13]. A longer period provides sufficient documents for reliable statistical analysis and trend assessment. After several search tests, the researchers searched the literature based on the CEVR model using the Web of Science Advanced Search as follows: search formula = “TS=("blended learning" OR "blending learning" OR "flexible learning" OR "hybrid learning" OR "blended teaching" OR "blending teaching" OR "mixed teaching") AND TS=("learners' characteristics" OR "characteristics of learners" OR "learner's characteristic" OR "learner characteristic" OR "learner's character" OR "student characteristic" OR "characteristics of learners" OR "motivation" OR "autonomy" OR "engagement" OR "Prior learning experience" OR "satisfaction" OR "behavior" OR "behaviour" OR "strategies" OR "strategy" OR "style" OR "styles" OR "metacognition" OR "self-efficacy" OR "self-efficiency" OR "spatial orientation" OR "spatial location " OR "space positioning" OR "space location" OR "space orientation" OR "spatial position" OR "spatial positioning" OR "space position" OR "self efficacy")”; language = "English"; document types = "article" and "review article"; the publication dates were from 2014–2023; the sources were the SCI-Expanded (Science Citation Index Expanded, 1900–present), SSCI (Social Science Citation Index, 1900–present), and ESCI (Emerging Sources Citation Index,2015–present). The search date was 15 January 2024. After excluding irrelevant literature, a total of 2678 relevant works were retrieved. Therefore, these 2678 pieces of literature were used as research data for the bibliometric analysis.

2.1 Research Methodology

Knowledge mapping, also known as science mapping, is a graphic that integrates co-occurrence analysis and visualization techniques aimed at visualizing the quantitative and structural relationships between knowledge elements within a discipline [12,14,15]. The tools primarily used for knowledge mapping analysis are CiteSpace, VOSviewer, HistCite, Sci2 and SciMAT [14]. CiteSpace is a Java-based information visualization software that visually represents the structure and distribution of scientific knowledge in specific domains [3,13]. It was developed by Dr. Chaomei Chen at Drexel University in the United States and is widely used in the fields of scientometrics and informatics [4,5]. The novelty of this approach is its analysis of potential motivations behind the evolution of a specific field through the intermediary centrality of key points in scientific literature [3]. This enables the identification of emerging trends in the development of specific domains [16]. CiteSpace has the capability to analyze various co-occurrence networks, including articles, authors, keywords, as well as turning points, research frontiers, and focal points [3,5,12].

This study employed bibliometric methods, CiteSpace 6.2.R3 visualization tool, and Origin 2022 software to conduct a visual analysis of the publication quantity, authorship, and research hotspots in the field of learner characteristics in blended learning. Visual representations, including charts for country, institution, author collaboration network, and keywords, were generated.

The process of data screening and visualization conforms to the flowchart in Figure 2. First, we imported a dataset of 2678 papers into CiteSpace, removing duplicates. The parameters in CiteSpace were configured as follows: timespan = 2014-2023; year per slice = 1; node type = author/institution/country/keyword/reference; threshold selection criteria = the top 50 results for each time slice. We set the other parameters by default. Finally, we clicked "Go" to analyze nodes and establish links.

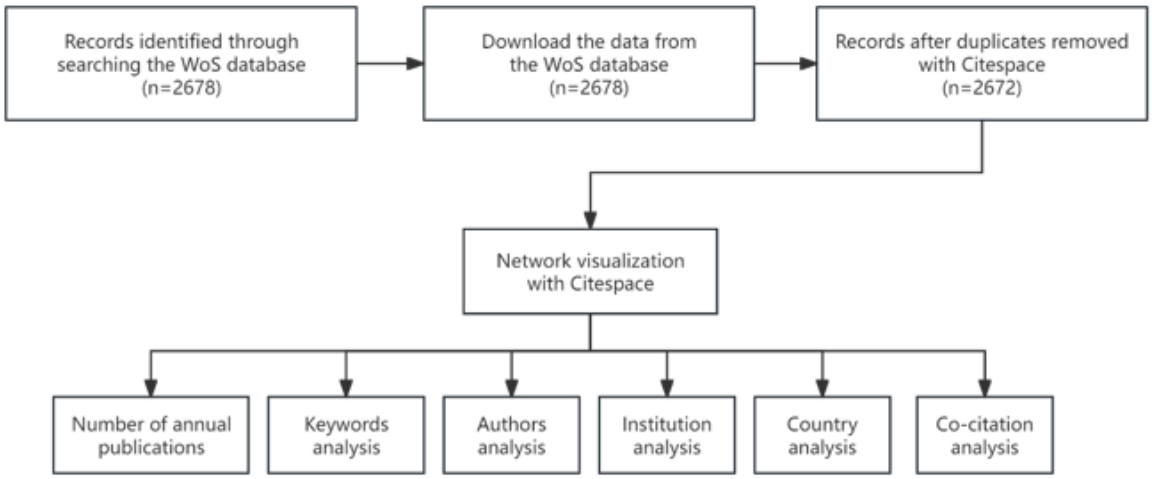

Fig.2. Process of Data Screening and Visualization

3. Finding and Dicussions

3.1 Basic Information on Publications

3.1.1The distribution of publication outputs year by year

The number of publications serves as a key indicator for assessing the developmental trends in research on learner characteristics in blended learning. By analysing the annual number of papers, we can gain an overall understanding of the development stages and trends of this research [6]. In other words, an increase in the number of publications indicates an increase in scientific knowledge [17]. As shown in Figure 3, from 2014 to 2018, there was a gradual increase in the number of research papers on learner characteristics in blended learning, indicating a growing academic interest in the subject. From 2018 to 2022, there was a rapid increase in the number of published papers, reaching a peak of 601 in 2022, indicating that learner characteristics in blended learning has become an important research topic since 2018, attracting more attention from scholars. From 2022 to 2023, the number of research papers stabilised, indicating a sustained academic interest in the field.

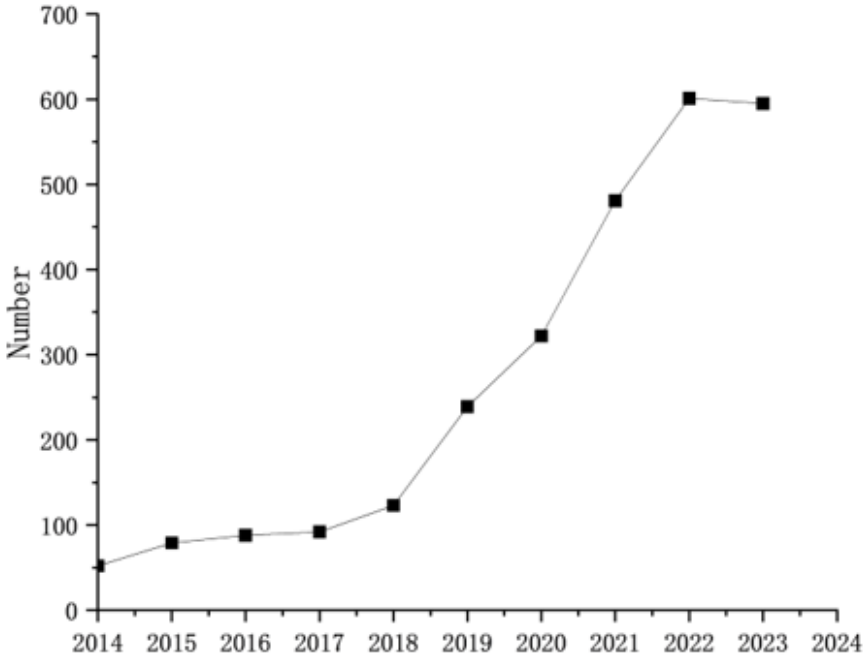

Fig.3. Number of papers published in the field of learner characteristics in blended learning from 2014 to 2023

3.1.2 Distribution of publications by author

Author co-occurrence analysis is an effective way of identifying the core authors within a given field, as well as assessing the intensity of collaboration and mutual citation patterns between authors, thus exploring the impact of author and team collaboration. The number of publications is represented visually by the size of the nodes, with larger nodes indicating a greater number of publications. The thickness of the link lines reflects the intensity of collaboration between authors, with thicker lines indicating closer collaborations. The chronological aspect of the publications is represented by the colour depth. Using CiteSpace to generate a visual network diagram (Figure 4), a total of 401 nodes and 306 links were identified, resulting in a network density of 0.0038. Of all the nodes, three prominent nodes are clearly visible, represented by Zhu, Chang, Graham, Charles R, and Iqbal, Javed. Based on Price's Law, prolific authors in this field are defined as those who have published three or more papers. The statistical analysis shows that there are 24 prolific authors in the dataset. Table 1 shows the top 5 prolific authors ranked by number of publications.

Figure 4 shows that Zhu, C., together with Vanwing, T., De Greef, M., Cocquyt, C., Machumu, H., Pynoo, B., Philipsen, B., Tondeur, J., Vanslambrouck, S., Diep, N. A., and Blieck, Y., form a collaborative group. Car, J., together with Car, L., Saxena, N., and Kyaw, B. M., form another collaborative group. In addition, there are some smaller collaborative groups, but the nodes within these groups are connected by only one line, indicating a limited collaboration involving 2-3 individuals and suggesting a relatively weaker collaborative force. At the same time, Graham, C.R., Park, Y., and Hwang, G., among others, conducted early research on learner characteristics in blended learning. Deboer, J., Ogata, H., Tang, C. M. and others represent emerging forces in the field. A comprehensive overview of the entire network reveals numerous isolated nodes with no links between different groups, indicating a significant lack of scholarly collaboration among authors in this area. Internationally, research on learner characteristics in blended learning is still in a relatively fragmented state.

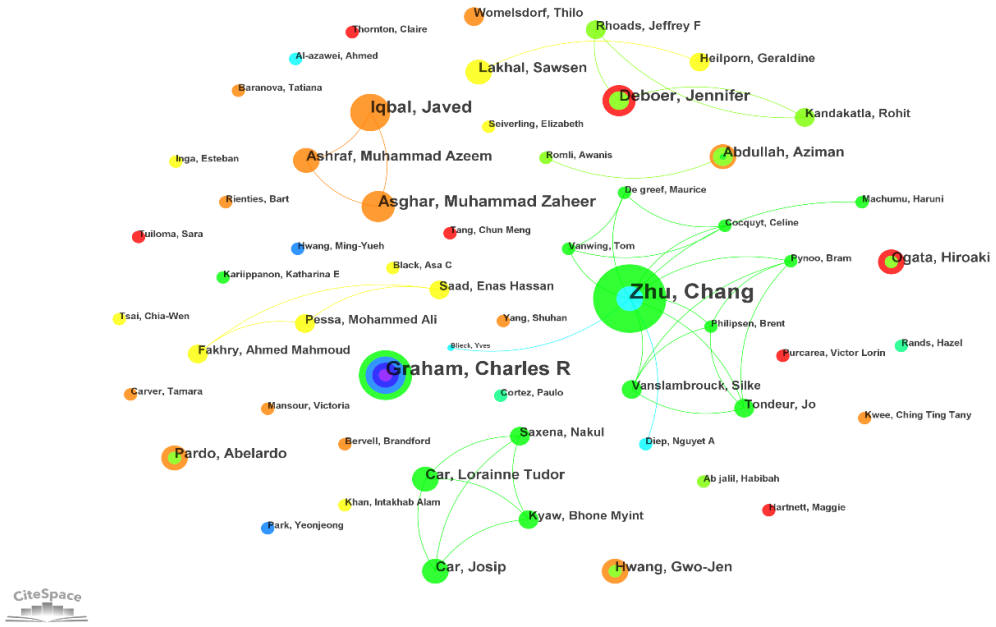

Fig.4. Author co-occurrence network

Table 1
Top 5 authors ranked by number of publications

No.	Author	Frequency	Year
1	Zhu, Chang	11	2017
2	Graham, Charles R	8	2014
3	Iqbal, Javed	6	2022
4	Asghar, Muhammad Zaheer	5	2022
5	Deboer, Jennifer	5	2020

3.1.3 Distribution of publications by institution

Authors engage in research within a specific academic field by publishing papers or participating in scholarly activities. Consequently, the research content and level of an institution is to some extent manifested through academic publications. The publication status of the top 12 core research institutions is shown in Table 2. In CiteSpace, node size and centrality reflect research hotspots in the respective field. The Institution module in CiteSpace is used to analyse the publishing institutions of the literature, with a threshold of 14. Figure 5 shows a total of 374 nodes, 386 links and a density of 0.0055. The size of the nodes represents the publication volume of an institution, with larger nodes indicating a higher publication volume and vice versa. Centrality measures the importance of nodes, reflecting their significance. Thus, the higher the centrality of an institution, the greater its publication volume compared to other institutions. Figure 5 shows the main institutions in the field of learner characteristics in blended learning, and the level of collaboration between research institutions is clearly shown by the connections between the nodes.

In terms of publishing institutions, the Egyptian Knowledge Bank (EKB), the University of London, the Ministry of Education and Science of Ukraine and others are representative (Table 2). The leading institution is the Egyptian Knowledge Bank (EKB) with 34 publications. In addition to a detailed analysis of the impact of individual differences on academic performance, this institution also focuses on the potential impact of different teaching modes on student performance in blended learning environments [18-20]. Furthermore, this institution is dedicated to studying the application of

modern educational technologies in blended learning scenarios and their potential impact on students' grades and learning experiences [21].

This is followed by the University of London and the Ministry of Education and Science of Ukraine, both with 29 publications. When analysing the geographical distribution of research institutions, a dominant research pattern emerges internationally, characterised by a 'university-led, research institute-supported' model. Universities, as the backbone of research, dominate the top ten institutions with eight positions, well ahead of research institutes. It is noteworthy that most of the nodes have multiple links, indicating a concentrated collaborative network and widespread collaborative research between institutions.

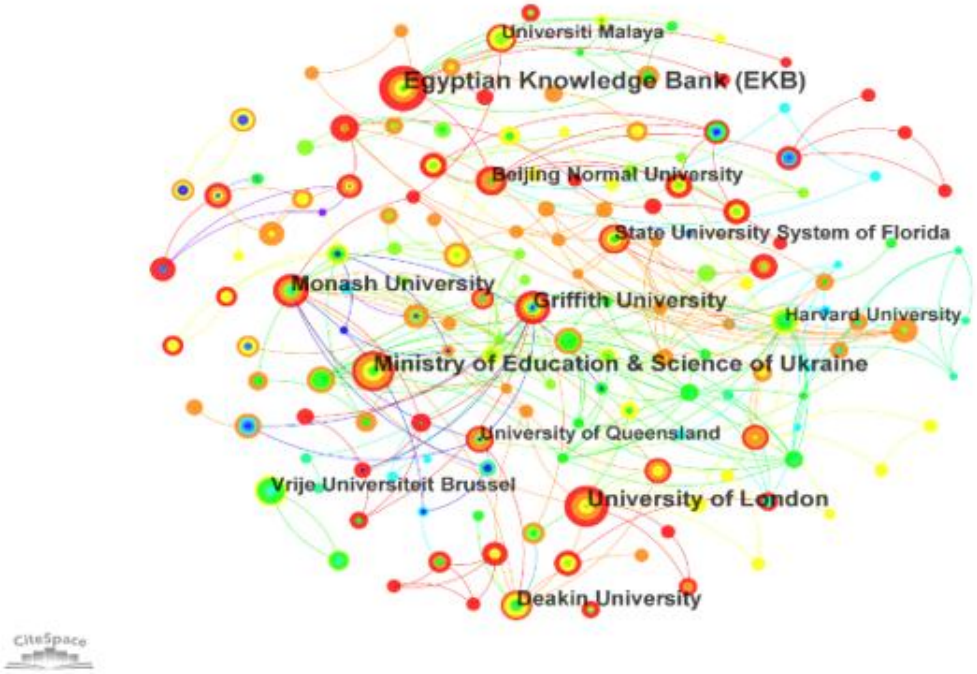

Fig.5. Institution co-occurrence network

Table 2
Top 12 institutions ranked by number of publications

No.	Institutions	Frequency	Centrality	Year
1	Egyptian Knowledge Bank (EKB)	34	0.04	2016
2	University of London	29	0.07	2020
3	Ministry of Education & Science of Ukraine	29	0	2019
4	Griffith University	23	0.02	2014
5	Monash University	22	0.09	2015
6	Deakin University	19	0.03	2014
7	State University System of Florida	16	0.04	2016
8	Beijing Normal University	16	0.05	2017
9	Vrije Universiteit Brussel	16	0	2017
10	Harvard University	14	0.09	2017
11	University of Queensland	14	0.04	2015
12	Universiti Malaya	14	0.03	2020

3.1.4 Distribution of publications by countries/regions

In the co-occurrence network of countries/regions (Figure 6), there are a total of 123 nodes and 645 links, with a density of 0.0225. This indicates a substantial level of collaboration and communication among countries/regions, forming a highly connected academic network. In the context of learner characteristics in blended learning, there is evident close collaboration and knowledge sharing among countries/regions, propelling rapid advancements in this field. All papers related to the research on learner characteristics in blended learning come from 123 countries/regions, with the number of papers published exceeding 100 in 6 countries. This underscores the global nature of research interest in this field, receiving widespread international collaboration and attention. The active participation of numerous countries/regions reflects the extensive global attention and research dedicated to blended learning as an instructional model. The six countries/regions with publication counts surpassing 100 may be considered major contributors to this field, indicative of their sustained commitment and profound interest in the study of blended learning.

Fig.6. Country/Region co-occurrence network

From Table 3, it is evident that the United States leads with 400 papers, followed by the People's Republic of China (396 papers), and subsequently Australia (247 papers) and England (220 papers). Despite the highest publication count, the United States ranks fourth in centrality (0.17), suggesting that, while prolific in literature production, its influence in the research field of learner characteristics in blended learning needs enhancement. The People's Republic of China, ranking second in publication count, has a centrality of 0, indicating significant potential for improvement in influence. Likewise, the centrality of other countries and regions is relatively low, indicating that most countries and regions have limited influence and collaboration in terms of impact and cooperation. Strengthening international collaboration, promoting interdisciplinary research, and enhancing research quality are potential avenues to effectively transform publication quantity into academic influence.

Table 3
Top 10 Countries/Regions ranked by number of publications

No.	Country/Region	Frequency	Centrality	Year
1	USA	400	0.17	2014
2	PEOPLES R CHINA	396	0	2014
3	AUSTRALIA	247	0.06	2014
4	ENGLAND	220	0.24	2014
5	SPAIN	139	0.06	2014
6	INDIA	101	0.2	2014
7	CANADA	99	0	2014
8	MALAYSIA	94	0.17	2015
9	TAIWAN	87	0	2014
10	GERMANY	86	0.33	2014

3.2 Analysis of Research Hotspots and Trends
3.2.1 Keyword co-occurrence analysis

Keywords provide a concise and refined representation of an article's core content. When a specific keyword appears repeatedly in the literature of a field, the research topic represented by that keyword is considered a hotspot in the field. This study analyses the keywords in international research on learner characteristics in blended learning over the past decade and constructs a corresponding co-occurrence knowledge map (refer to Figure 7). The knowledge map displays circular nodes that represent keywords of papers. The size of the circle corresponds to the frequency of the keyword.

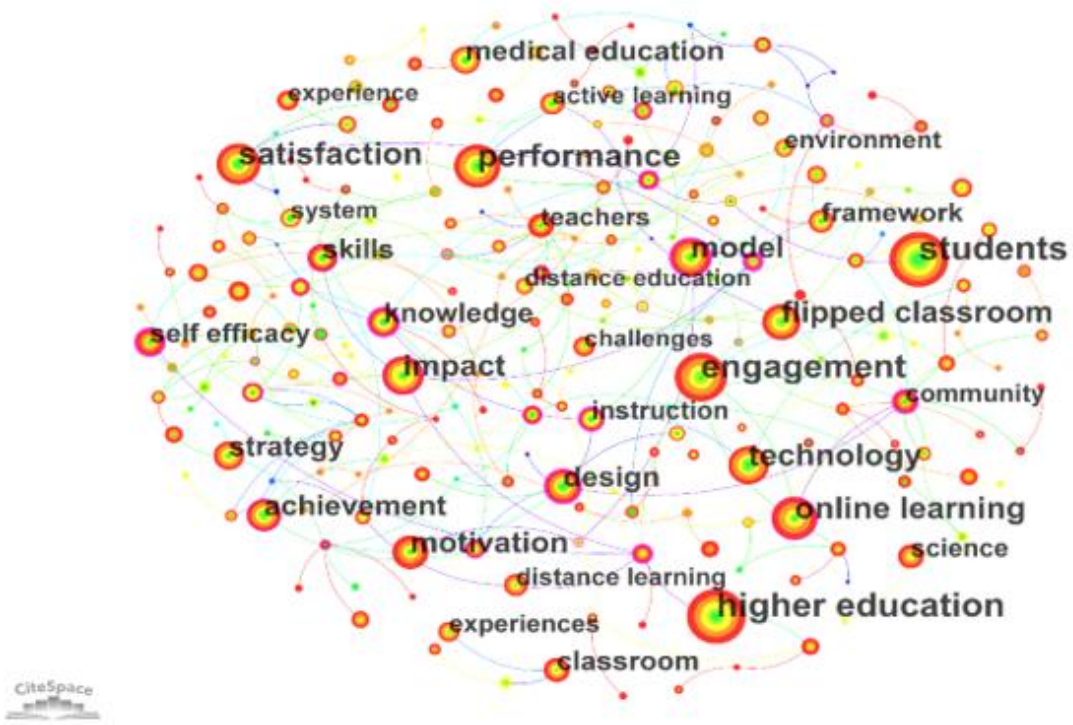

Fig.7. Keyword co-occurrence network

The keywords in this study were standardized by removing the search keywords 'blended learning' and 'hybrid learning'. Additionally, broader, repetitive, and incomplete keywords such as 'students', 'perceptions', 'classroom', 'outcm', and 'university' were eliminated. The study compiled

a list of the top twenty high-frequency keywords in learner characteristics research in blended learning internationally over the past decade (refer to Table 4). Simultaneously, it analysed the data objectively.

Table 4
Top 20 Keywords ranked by number of publications

NO.	Frequency	Centrality	Year	Keywords
1	365	0.02	2014	higher education
2	291	0.05	2014	engagement
3	241	0.02	2014	performance
4	212	0.02	2014	satisfaction
5	202	0.1	2014	online learning
6	187	0	2014	technology
7	176	0.04	2014	flipped classroom
8	174	0.01	2014	impact
9	169	0.03	2014	model
10	155	0.03	2014	motivation
11	128	0.09	2014	achievement
12	125	0.1	2014	design
13	114	0.04	2014	strategy
14	111	0.07	2015	medical education
15	105	0.08	2014	knowledge
16	97	0.16	2014	skills
17	93	0.15	2014	classroom
18	87	0.29	2014	self efficacy
19	84	0	2015	framework
20	76	0.03	2016	science

Combining the information from Figure 7 and Table 4, it can be seen that research on learner characteristics in blended learning at an international level over the last decade has included several high-frequency keywords, including 'higher education', 'engagement', 'performance', 'satisfaction', ' online learning', 'technology', 'flipped classroom' and others. The high frequency of the keyword 'higher education' indicates a predominant focus on higher education in the research. This could be due to the widespread use of blended learning in universities and research institutions, which has attracted more research attention to the characteristics of learners in higher education.

Scholars have focused their attention on different key aspects of learners in blended learning environments, such as 'engagement', 'performance', 'satisfaction', 'impact', 'motivation', 'achievement', 'strategy', 'knowledge', 'skills', 'self-efficacy', among others. This highlights the deep interest within the academic community in the multidimensional characteristics of learners in blended learning. It also indicates a scholarly emphasis on monitoring learners' academic performance or learning achievements, including knowledge acquisition and skill mastery [22-27]. In addition, scholars have focused on assessing student satisfaction as a measure of their acceptance of blended learning models. They have used analyses of students' participation and motivation levels to reveal the extent of their engagement in learning activities [28-31].

Scholars' continuous attention to innovation and development in the field of education is reflected in high-frequency keywords such as 'online learning', 'flipped classroom', and 'traditional classroom'. These keywords not only demonstrate the innovative application of technology in teaching but also indicate a trend of rethinking educational methods. Scholars aim to compare online learning, flipped classrooms, and traditional classrooms in terms of academic performance, learning

motivation, and knowledge acquisition. Comparative studies are used to decipher similarities and differences. Some scholars also research the online learning component within blended learning, exploring effective integration of online learning elements in diverse teaching environments. Research in this area highlights the importance of online learning as a means of providing additional learning resources. It utilises diverse teaching materials, such as videos, simulated experiments, and online discussions, to offer students more flexible learning opportunities. This series of studies aims to deepen the understanding of blended learning models, providing educators with scientific guidance to align teaching practices with students' needs and adapt to societal development.

The keywords 'technology', 'models', 'design' and 'framework' indicate a strong interest within the academic community in the use of technology in blended learning, as well as different instructional designs, models and frameworks for blended learning. This indicates that researchers are dedicated to providing more effective blended learning experiences to encourage students to engage more deeply in the learning process [32-37].

Finally, keywords such as 'medical education' and 'science' indicate that research is focused on teaching practices in the fields of medicine and science. These studies aim to advance the frontiers of medical and science education, providing valuable insights and experiences for future educational reform and disciplinary development [38-42].

3.2.2 Keyword cluster analysis

Keyword clustering is the process of identifying network clusters formed by keywords with similar research topics within a particular field [4]. The connotations of each cluster are determined by the high-frequency title terms included in the respective articles. In CiteSpace, the nodes of the same cluster are represented using convex hulls or boundary lines. Clusters are numbered starting from 0, where Cluster #0 is the largest, and Cluster #1 is the second-largest, and so on.

The keyword clustering network graph was generated using the Pathfinder algorithm based on a 10-year literature dataset, with a slicing interval of 1 year (Figure 8). Only publications ranking among the top 50 in annual frequency were used to construct the network for each year. The network consists of 12 clusters, with a total of 241 nodes and 894 links. The three largest connected components contain 239 nodes, which make up 99% of the entire network. The clustering values generated by CiteSpace indicate a significant effect of clustering the network, with a degree of modularity $Q = 0.787 > 0.3$. This suggests a clear delineation of the research domain on learner characteristics in blended learning within the context of keyword clustering. $S = 0.926 > 0.7$ represents a very high homogeneity of the network and convincing clustering results. The silhouette values for each cluster are greater than 0.7, indicating that the results are robust and meaningful (Table 6). The analysis identified 12 major clusters within the co-citation mapping, as shown in Figure 8.

Figure 8 and Table 5 show that research on learner characteristics in blended learning mainly focuses on twelve themes: active learning, higher education, blended learning, community of inquiry, online learning, teacher education, self-regulated learning (SRL), medical education, system, machine learning, systematic review, and learning analytic. The clustering modules align well with the ranking of keyword co-occurrence frequencies.

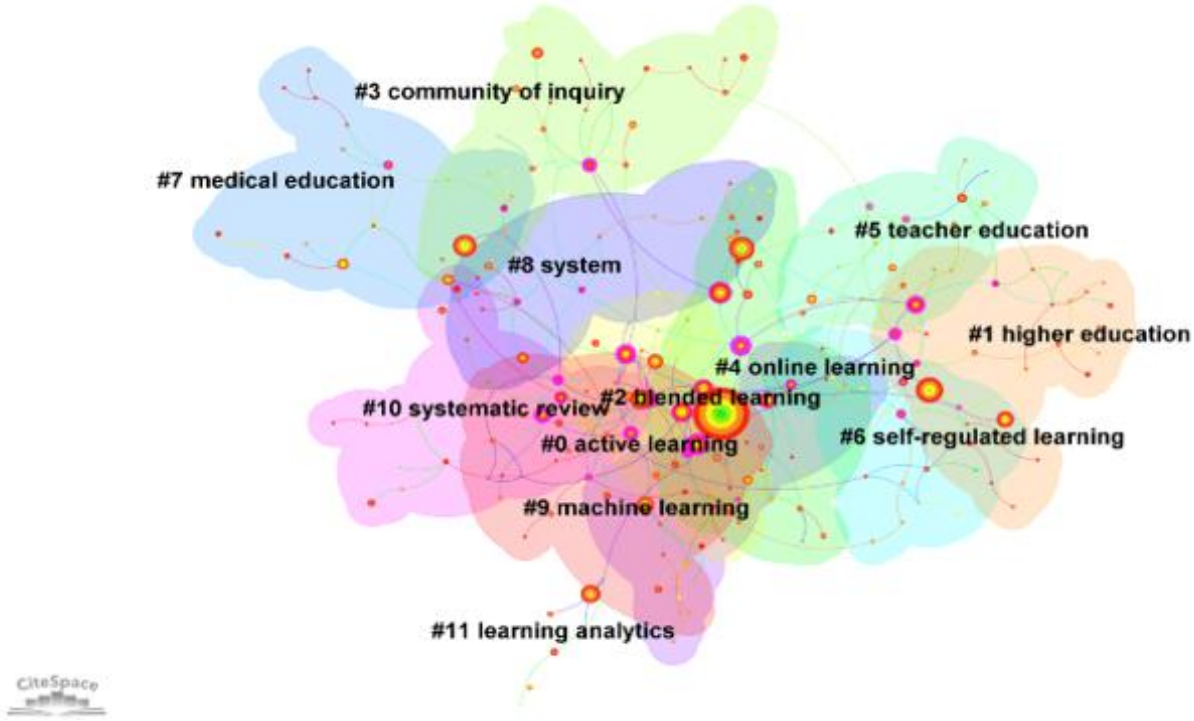

Fig.8. Keyword cluster analysis network

Table 5
The twelve largest clusters sorted by size

Cluster ID	Size	Silhouette	Mean (Year)	Cluster Label (LLR)
0	29	0.944	2016	active learning
1	28	0.905	2019	higher education
2	25	0.832	2017	blended learning
3	24	0.946	2018	community of inquiry
4	21	1	2017	online learning
5	20	0.747	2019	teacher education
6	18	0.986	2018	self-regulated learning (srl)
7	18	0.984	2019	medical education
8	18	0.955	2018	system
9	17	0.838	2020	machine learning
10	16	0.917	2019	systematic review
11	5	1	2016	learning analytics

CiteSpace can conduct further analysis on clustered keywords and generate a timeline view. This view introduces time into the network, emphasizing the historical trajectory and temporal span of keyword development within each cluster [43].

By setting the time slice to one year and selecting the timeline view, it is possible to observe the evolution of various clustering hotspots related to learner characteristics in blended learning. This is demonstrated in Figure 9.

Cluster #0 active learning: This cluster has persisted from 2014 to 2023, indicating that researchers have consistently maintained their focus on active learning. Passive involvement of students in the learning process has been linked to insufficient retention of knowledge and a failure to achieve genuine learning. Some researchers suggest that student motivation issues can be addressed by adopting active learning methods, such as serious games, project-based learning, and blended learning [44].

Cluster #1 higher education: Research on learner characteristics in blended learning within higher education is a core area of study. The primary focus is to understand the impact of information technology in the higher education environment and how to effectively integrate and implement these technologies. Researchers often concentrate on individual characteristics of learners in this blended learning environment, especially their interactions with information technology. Current research focuses on the influence of information technology on learners' learning outcomes and performance in higher education. This involves analyzing the various information technology tools adopted by learners in blended learning and how these tools shape their academic performance. Researchers are also concerned with the most effective ways to implement information technology to enhance students' learning experiences and achievements [45-47].

Cluster #2 blended learning: Researchers focus primarily on predictive factors for the effectiveness of blended learning, such as self-regulated learning, attitude, and self-efficacy [18,48,49]. Additionally, attention is given to the challenges associated with implementing blended learning [50,51].

Cluster #3 community of inquiry: The Community of Inquiry (CoI) model is a framework used to study and understand online learning communities. It is widely applied in the research and design of online learning environments. Researchers have explored the experiences of redesigning blended learning courses using the CoI framework. They have investigated its three key elements: Social Presence, Cognitive Presence, and Teaching Presence [29,52-54].

Cluster #4 online learning: From 2014 to 2019, academics primarily focused on comparative research between blended and online learning [48,49]. However, since the global outbreak of COVID-19 in 2020, scholars have gradually shifted their research focus to how to smoothly transition from traditional face-to-face or blended learning to fully online teaching [55,56]. The research findings suggest that online learning served as a temporary substitute in response to COVID-19, but it cannot completely replace traditional face-to-face learning [57]. It is recommended to adopt a blended learning model to provide a more rigorous learning environment.

Cluster #5 teacher education: The research conducted between 2015 and 2022 primarily focused on students' evaluations and perceptions of the teacher's role in blended learning environments, as well as the factors that influence teacher motivation [21,58,59].

Cluster #6 self-regulated learning: The theory of self-regulated learning (SRL) is used to understand the reasons for different levels of academic performance among university students [60]. Research shows a correlation between self-regulated learning strategies (SRLS) and academic performance in mixed learning environments, demonstrating the predictive ability of these strategies for participants' learning outcomes in courses [49,61-64]. The study examines changes in students' perceptions of flexibility, intrinsic motivation, and self-efficacy beliefs within learning environments [65]. It also investigates the interaction effects of these student variables on learning performance [66,67].

Cluster #7 medical education: Since 2015, there has been a growing interest in medical education among researchers, with a focus on areas such as clinical skills, digital technologies, and palliative care. Studies often compare blended learning with traditional or online education to evaluate its impact on medical students' knowledge, skills, and satisfaction [68,69]. Research suggests that blended learning is an effective way to enhance medical students' knowledge, skills, and satisfaction [68-71]. The implementation of blended learning is successful when individual student characteristics and the environmental and cognitive components of the delivery method are taken into consideration [72].

Cluster #8 system: Since 2015, the research has focused on keywords such as 'strategy', 'beliefs', 'school', and 'learning engagement'. Some scholars in the academic domain argue that the

educational system is a complex organization [73]. To gain a comprehensive understanding of its background, dynamics, and the interactions among participants, especially in the context of technological innovation, a multi-faceted and hierarchical analytical approach is necessary.

Research findings suggest that the integration of Augmented Reality (AR) into teaching has a significant impact on students' overall learning achievements [74,75]. This highlights the positive influence of technological innovation in the field of education. Additionally, the blended learning approach developed through learning management systems demonstrates enhanced practicality and effectiveness in fostering interaction among students, peers, teachers, and course materials [76]. This integrative learning method offers a flexible and interactive educational environment.

Cluster #9 machine learning: Cluster #9 machine learning: Since 2016, research has focused on machine learning, covering key terms such as 'mobile learning', 'data mining', 'educational technology', 'analytics', 'educational innovation', 'algorithm', and others. Digital technology is essential in higher education, significantly impacting students' learning experiences and closely correlating with their behaviors, emotions, and cognitive engagement [77].

Over the past decade, with the rapid advancement of technology, numerous innovative digital technologies have been introduced into blended learning environments, further diversifying the forms and methods of education. One important digital technology in this field is the Learning Management System (LMS), a software application commonly used for creating, managing, and delivering online learning content. By using Learning Management Systems and advanced data mining techniques, researchers can analyze students' learning behaviors in blended learning, providing education with more scientifically informed support and guidance [78,79]. The use of hypermedia resources can improve the effectiveness of Learning Management Systems in blended learning, providing students with a more comprehensive learning experience and facilitating more efficient learning [80]. In addition to Learning Management Systems, various other digital technologies, such as online teaching platforms, mobile devices, virtual and augmented reality, learning analytics, and adaptive learning systems, contribute to the construction of a diverse digital learning ecosystem [81-85]. The integration of these technologies offers students more flexible and personalised learning methods, helping to meet the diverse learning needs of different student groups.

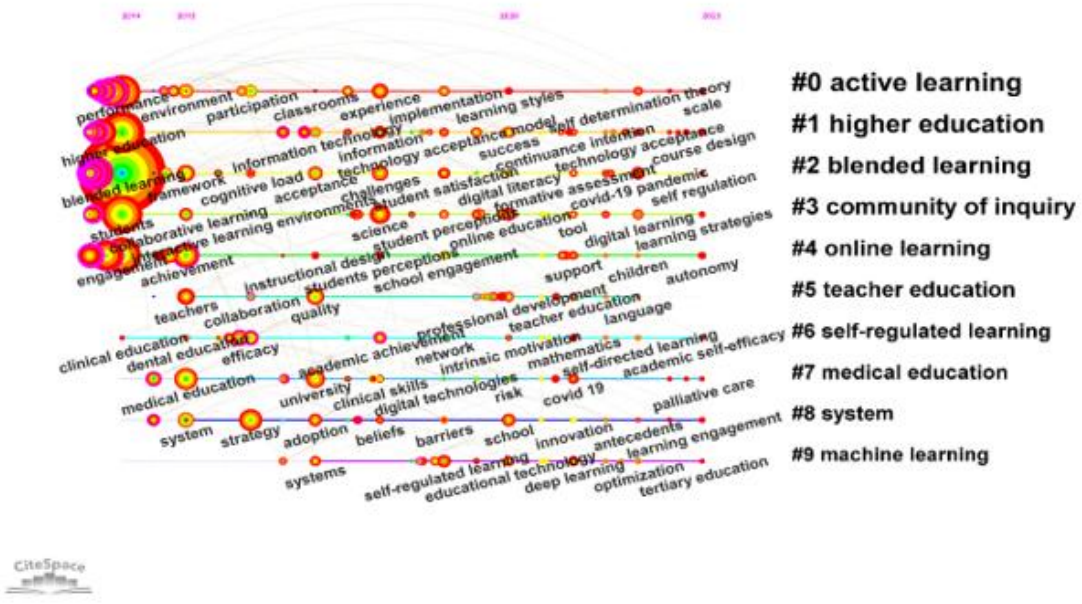

Fig.9. Timeline view of research topics

3.2.3 Analysis of emerging trends

The burst of keywords refers to words that undergo a sudden increase or high frequency of usage within a specific period. The emergence of burst keywords can indicate the future direction of research [86]. To investigate recent international trends and frontiers in the research on learner characteristics in blended learning, we employed the mutation detection algorithm in CiteSpace. Burst keywords were extracted from the titles, abstracts, and keywords of the selected articles in the database. A table displaying the burst keywords (Table 6) was generated.

Table 6
Keywords with the strongest citation bursts for the last 5 years

Keywords	Year	Strength	Begin	End	2014 - 2023
learning management system	2019	4.14	2019	2021	
systematic review	2019	3.2	2019	2020	
courses	2019	2.64	2019	2020	
barriers	2019	2.64	2019	2020	
flipped learning	2015	5.78	2020	2021	
learning styles	2020	3.77	2020	2021	
classification	2017	3.51	2020	2021	
mobile learning	2020	3.39	2020	2021	
social media	2020	2.63	2020	2023	
student	2021	4.25	2021	2023	
time	2021	3.45	2021	2023	
mathematics	2021	3.19	2021	2023	
learning motivation	2021	2.92	2021	2023	
styles	2021	2.66	2021	2023	

In terms of the duration of emergence, keywords with a longer duration include "social media," "student," "time," "mathematics," "learning motivation," and "styles," most of which began to appear in 2020. These keywords have evolved into hotspots and frontier directions in the research on learner characteristics in blended learning in recent years.

Hot topic 1: social media. Social media has had a profound impact on human communication and social interaction, particularly in the field of education, especially in online and blended learning formats. The global COVID-19 pandemic in 2020 has further accelerated this trend. A groundbreaking study in the field of sports science in Spain has introduced TikTok as a teaching tool. The study found that TikTok had a positive impact on student motivation, learning engagement, and skill development, particularly in the areas of creativity and curiosity. Therefore, it is recommended to include TikTok in the undergraduate sports expression course in sports science, utilizing its positive educational potential, particularly its alignment with expressive and creative content through music and movement in the curriculum [87]. According to Greenhow and Galvin [88], integrating social media into online education plans can help maintain connections between students and teachers, increase student engagement, and make remote learning more intimate. Therefore, social media can be considered a useful supplement to traditional online teaching methods. It is important to note that this suggestion is subjective and should be considered as such. A study was conducted to investigate students' perceptions of remote learning using asynchronous Learning Management Systems (LMS) and synchronous video conferencing technologies (such as Google Meet, Microsoft Teams, or Zoom). The results indicated that students appreciated having access to asynchronous content and real-time interaction with online users, including course instructors. The study highlights the significance of ongoing interaction with students and providing suitable support conditions to

enhance the learning process continuously [46]. Simultaneously, research has explored how social media stimulates the development of the statistics learning community and guides the changing roles of teachers and students in blended learning environments. The results reveal that the Problem-Oriented Problem Solving (QOPS) approach makes the learning community more interactive and cohesive, as reflected in various Social Network Analysis (SNA) measures. These studies offer valuable insights into the current use of social media in education, providing inspiration for the future development of blended learning and online education [89].

Hot topic 2: student. In recent years, there has been a growing international research focus on students, with the aim of understanding their performance and experiences in blended learning environments. This research provides valuable insights for a deeper exploration of the educational field. One study, which specifically addressed 'Learning Analytics', introduced a novel concept by integrating learning data and student personality data. The text emphasizes the significance of enhancing the accuracy of academic performance predictions and designing effective educational interventions. This perspective highlights the crucial role of individual learning tendencies in achieving precise education, providing theoretical support for a better understanding of student needs [90]. Additionally, appropriate assessment strategies are essential in online and blended learning to ensure academic integrity. The impact of online proctoring on students' self-reported cheating tendencies and potential negative effects, including exam anxiety, perceived exam difficulty, and performance, was extensively investigated in a study. The research found that online proctoring did not affect cheating tendencies, exam difficulty, or performance. However, students reported higher levels of exam anxiety. The study highlights the influence of factors such as learning strategies, digital literacy, reliable technology access, gender, and economic pressure on students' levels of exam anxiety. It also emphasizes the negative impact of online proctoring on students' exam anxiety, which should be considered before deciding to use it [91]. On the other hand, flipped classrooms (FC) are an innovative teaching method that aims to enhance student learning outcomes. FC is expected to improve teaching quality by leveraging the advantages of both online and face-to-face learning, adapting to students' needs, interests, and common expectations [92]. Other studies also suggest that blended teaching can improve students' autonomy and classroom participation, supporting the development of clinical skills and higher-order thinking skills [93]. These research findings highlight the significance of students in various instructional settings, offering valuable insights for enhancing student engagement, satisfaction, and academic performance.

Hot topic 3: time. In recent years, scholars have conducted extensive research on the amount of time learners spend on online learning, furthering theoretical analyses of blended learning. Previous studies have identified students' online learning time in blended learning as a predictive indicator of academic performance [94-96]. Jovanović *et al.,* [97] conducted research to explore the predictive factors of learners' academic success in blended learning. The study found that students' overall online learning time is a general indicator of their activity level in the online portion of the course. This study offers valuable insights for the future design of blended learning and the formulation of teaching strategies, providing a new perspective for a deeper understanding of learners' academic performance in blended learning.

Hot topic 4: mathematics. In recent years, scholars have conducted research on blended learning in mathematics-related courses. Blended learning is a trend widely applied in higher education due to its advantages, leveraging both traditional face-to-face and fully online instruction. One study conducted an in-depth investigation into the self-efficacy of non-mathematics major students in the field of mathematics. This study investigated students' experiences in a blended-designed mathematics module, which combined online content with face-to-face instruction. The findings, based on a mixed-methods analysis involving student surveys, discussion forums, and module grades,

suggest that blended learning not only improved students' academic self-efficacy in mathematics but also enhanced their overall learning experiences. The benefits of the online platform were attributed to the private and low-pressure learning environment it provides, which enables individuals to master technical skills and access social resources in a classroom setting [98]. Another study described an embedded case study that integrated 'blended' teaching with traditional courses in a student-centered positive learning environment, including social activities on the platform. Through the creation of a learning environment, tools, and teaching/learning sequences in an authentic educational setting, instructional phenomena were developed to enhance the task design of mathematics courses, thereby impacting students' mathematical performance. The quantitative results demonstrated significant benefits in the use and coordination of multiple symbolic representations. A positive trend emerged in the learning of the subject. Satisfaction tests indicated that alternative teaching methods were effective for the majority of students [99].

Hot topic 5: learning motivation. Since 2020, international research has been focused on exploring the factors that influence learner satisfaction in blended learning, with a particular emphasis on learning motivation. Scholars have examined the impact of these variables on student satisfaction through three key dimensions: perceived usefulness, perceived ease of use, and learning motivation. The research findings indicate that perceived ease of use has a positive impact on perceived usefulness. Furthermore, both perceived usefulness and perceived ease of use have positive effects on learning motivation, which ultimately leads to learner satisfaction. Additionally, perceived usefulness plays a positive mediating role between perceived ease of use and learning motivation [100]. On the other hand, previous studies have investigated the correlation between student learning motivation and learning outcomes in blended learning environments. The research found a positive correlation between intrinsic and extrinsic motivation and learning outcomes. Intrinsic motivation was found to be more beneficial for enhancing students' English language skills and fostering psychological development [101]. In a study investigating the correlation between perceived precision teaching and student learning performance, researchers found a direct positive relationship between perceived precision teaching and self-efficacy and learning motivation. Self-efficacy and learning motivation were positively associated with cognitive, instructional, and social aspects, which indirectly influenced learning performance [102]. Finally, several studies have investigated the factors that influence students' academic self-efficacy in blended learning through the establishment of comprehensive models. These factors include intrinsic motivation, extrinsic motivation, teacher support, performance expectations, and facilitative conditions. Wei *et al.,* [103] found that these factors are significant predictors of academic self-efficacy in blended learning. Overall, these studies provide empirical evidence and theoretical explanations for understanding the impact of learning motivation in a blended learning environment. When implementing blended learning, teachers should pay special attention to students' perceived usefulness, ease of use, and methods to inspire learning motivation. This will enhance students' academic self-efficacy and academic performance.

Hot topic 6: styles. Over the past three years, there has been a significant increase in research literature on learners' learning styles in blended learning. Learning styles, which are considered a characteristic of learners, are deemed crucial by some scholars for assessing the effectiveness of different blended learning styles in fostering students' practical skills, shaping attitudes, and promoting scientific thinking [104]. Research suggests that different learning styles may be more effective in certain contexts [105]. However, studies also indicate significant differences in abilities among various types and combinations of learning styles, and not all learning styles have a significant impact on academic performance [106]. These studies provide an in-depth understanding of

individual differences among learners in blended learning, while also providing valuable guidance for developing more targeted designs and instructional strategies in blended learning.

4. Conclusion

This study uses bibliometric analysis with Citespace software to visually represent the current status, hotspots, and trends in research on learner characteristics in blended learning worldwide. The analysis includes knowledge maps and other representations. Additionally, the study explores future research directions based on the development trends in this domain.

Research on learner characteristics in blended learning has developed rapidly since 2018. An analysis of the research status reveals the following findings:

i) Within the scope of quantity statistics, Zhu, C. is the most prolific author, followed by Graham, C. R, Iqbal, J., and others. There are 24 authors with a publication frequency exceeding 3.

ii) Overall, there is close collaboration among most research institutions internationally, but there is relatively less research involving cross-national collaboration. In terms of time, collaborative relationships among research institutions mostly formed after 2017, with limited collaboration before 2017.

iii) The number of publications is highest in the United States (400 papers), followed by the People's Republic of China (396 papers), Australia (247 papers), and the United Kingdom (220 papers). The centrality of most countries/regions is relatively low, indicating limited influence and collaboration in terms of impact and cooperation for the majority of countries and regions.

An analysis of the thematic trends in learner characteristics in blended learning reveals the following:

i) From the co-occurrence analysis of keywords, it is evident that engagement, performance, satisfaction, technology, flipped classroom, model, and motivation have consistently been significant research focal points in learner characteristics in blended learning.

ii) Keyword clustering analysis results show that research hotspots in learner characteristics in blended learning mainly focus on active learning, higher education, community of inquiry, online learning, teacher education, self-regulated learning (SRL), medical education, system, and machine learning. These areas cover a wide range of research topics. Research on learner characteristics in blended learning has broad coverage, demonstrating a certain level of breadth and depth. However, there is an issue of uneven distribution across various research domains.

iii) Keyword burst analysis results suggest that future frontiers in learner characteristics research in blended learning may focus on areas such as social media, students, time, mathematics, learning motivation, and styles.

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