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Visualization analysis of CBL application in Chinese and international medical education based on big data mining

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Abstract

Objective To employ big data mining to provide a visualization analysis of Case-Based Learning (CBL) application in Chinese and international medical education, with the aim of observing the potential applications of CBL.

Methods All included literature was obtained from the Web of Science (WoS) core collection database, Chinese core periodicals database, Chinese Social Sciences Citation Index (CSSCI), Chinese Science Citation Database of China National Knowledge Infrastructure (CNKI), Wangfang Database, and CQVIP Database. CiteSpace software (6.1.6R6) was used to conduct an in-depth investigation from four perspectives: quantitative analysis of literature, network analysis of co-occurring authors, network analysis of co-occurring research institutions, keyword clustering and burst analysis.

Results A total of 721 Chinese articles and 537 English articles were included, demonstrating an exponential growth trend. Notably, no author exhibited a prolific publication rate within a short timeframe. Bursting keywords in English literature encompassed topics related to students' learning, teaching curriculum, methods, and location. In contrast, Chinese literature focused on students' learning, teaching methods, courses, application fields as well as national policy and the Ministry of Education of the People's Republic of China (MOE) guidance. The keyword clusters include research on care, community practice, special projects and groups, teaching methods, and capacity development of participants in English literature. For Chinese literature, the clusters include research national policy guidance, teaching reform, mode and evaluation and various disciplines.

Conclusion CBL holds immense potential for implementation across diverse disciplines, community practices, and special projects within medical education. The practical application of CBL is continuously evolving in response to changing times and can be seamlessly integrated into different contexts influenced by environmental factors and policies.

Keywords Case-based learning, Visualization analysis, Chinese and international medical education, Big data

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Background

The core principle of CBL centers on the utilization of cases as foundational elements, problems as fundamental components, students as primary participants, and teachers as facilitators. Initially implemented in business management courses, CBL has now become a widely adopted pedagogical approach in medical education [1]. It encompasses various aspects such as teacher instruction [2], students' learning [3], case selection, and evaluation of teaching effectiveness [4]. By seamlessly integrating theoretical knowledge with clinical practical knowledge, CBL enhances students' clinical abilities and fosters critical thinking skills. Moreover, CBL serves as a prevalent instructional method within the Extension for Community Healthcare Outcomes (ECHO) project—an innovative videoconferencing initiative launched in May 2019 to provide online telementoring and CBL specifically focused on Intestinal failure [5]. Similarly, CBL is extensively employed in China, often alongside other teaching methodologies [6].

However, currently there is a dearth of literature reviews comparing CBL in Chinese and international medical education, as well as a lack of retrospective studies, making it challenging to comprehend the current state of CBL's application. To address these gaps, this study employs big data mining to provide a visualization analysis of CBL application in Chinese and international medical education by collecting and analyzing an extensive number of papers from various databases including WoS core collection database, Chinese core periodicals database, CSSCI database, CNKI, Wangfang Database, and CQVIP Database. Through literature visualization analysis and critical review techniques, key areas for CBL application in both contexts are identified. The comprehensive review utilizes the CiteSpace software (6.1.6R6), which is specifically designed for scientometrics and data visualization purposes. This information visualization software, Developed using Java language, offers wide applicability while objectively reflecting the characteristics, patterns, and distribution within related fields [7]. This paper applies CiteSpace software to analyze four perspectives: quantity analysis of literature; network analysis of co-occurring authors; network analysis of co-occurring research institutions; keywords clustering and burst analysis. Subsequently, this review focuses on highlighting similarities and differences in applied research content regarding CBL in medical education between China and other countries internationally. Based on the aforementioned review and analysis findings, a novel knowledge-oriented framework is proposed with the ultimate goal being to enhance the effective implementation of CBL in medical education (Fig. 1).

Review and analysis methodology

To investigate the current advancements in CBL applications within Chinese and international medical education, a comprehensive literature analysis was conducted on publications in both Chinese and English languages, English-language literature to represent international medical education.

Chinese literature search method

In this study, the Chinese core periodicals database, CSSCI database, and Chinese Science Citation Database of CNKI, Wangfang Database and CQVIP Database were utilized as statistical sources for Chinese literature data. The retrieval time was set from the database construction until October 27, 2023. The retrieval strategy involved focusing on main topics in CNKI and Wanfang Database: Topics = (case teaching[案例教学] + /or CBL) AND (medicine[医学]). For CQVIP Database, the retrieval strategy focused on title or keyword: title or keyword = (case teaching[案例教学] + CBL) AND (medicine[医学]). Initially, news reports, notices to contributors, newsletters, conferences, forums, and dissertations were excluded. Subsequently, a total of 190 articles from CNKI, 589 articles from Wanfang Database and 140 articles from CQVIP Database were retrieved. Finally, using NoteExpress software to eliminate duplicate publications in Chinese literature resulted in a final inclusion of 721 unique articles published between 1995 and 2023.

English literature search method

The WoS core collection database served as a statistical source for English literature data, with the retrieval time set from the database construction period until October 27, 2023. The retrieval strategy employed was (TS = ("Case-Based Learning" or "Case Based Learning")) AND TS = (medi*), while the search refinement language was limited to English. The literature type included both articles and review articles, resulting in a total of 537 articles retrieved. After eliminating duplicate papers using CiteSpace software, a final set of 537 valid papers were obtained, covering the time span from 1998 to 2023.

Software analysis method

Using CiteSpace 6.1.R6 software, we set the time span from 1998 to 2023 for English literature data and from 1995 to 2023 for Chinese literature data, with a partition length of 1 year for visualizing and analyzing node information such as author, institution, country, and keywords. The statistical analysis of document count was performed using Excel tables.

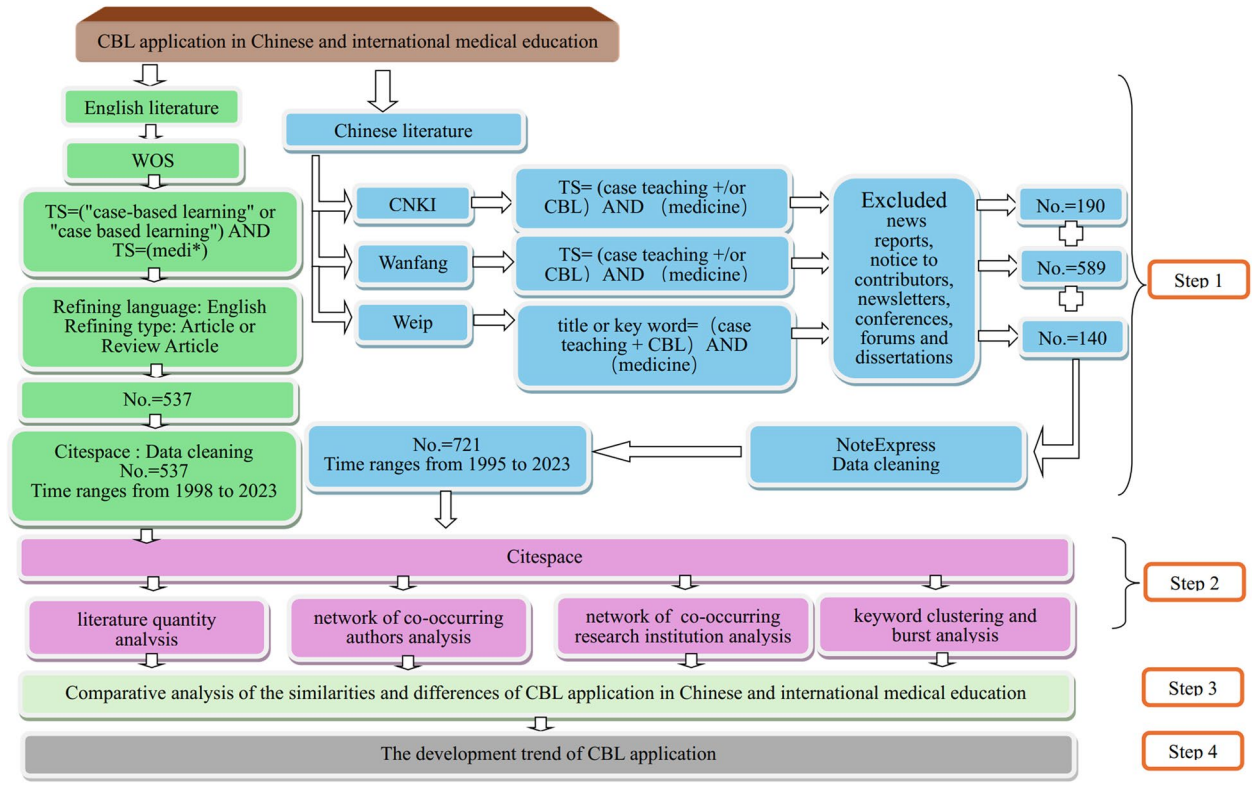

Fig. 1 The research framework

Literature analysis techniques

Publication trend analysis method

The publication quantity and growth trend in the field are clearly illustrated using curve diagrams and exponential growth equations.

Author contribution assessment

Applying Price's law to identify core authors who have made significant contributions in their respective fields, a high-producing author is defined as an individual who has published three or more papers.

Institutional co-occurrence analysis method

CiteSpace uses node size and centrality to reflect research hotspots in related fields. Node size indicates the number of publications issued by institutions, while the lines between nodes reflect the degree of cooperation between research institutions. Different colors represent different years, with warmer color, indicating more recent years.

Keyword analysis method

(1) Keywords co-occurrence analysis method

In the keyword co-occurrence analysis, keywords were merged based on their relevance to the research content. Given that "medical education" ("医学教育"in Chinese), "Case-Based Learning," and "case teaching" ("案例教学"in Chinese) serve as search strategy terms, they were omitted from the tables of high-frequency and high-centrality keywords in both Chinese and English literature, as well as from the classification of keyword bursts and clusters. It is important to note that high-frequency keywords do not necessarily pinpoint research hotspots with precision. In the keyword co-occurrence analysis, nodes with high centrality are highlighted by purple rings, the thickness of which represents the centrality value. This visual representation underscores potential cross-disciplinary connections and nascent links within the research field.

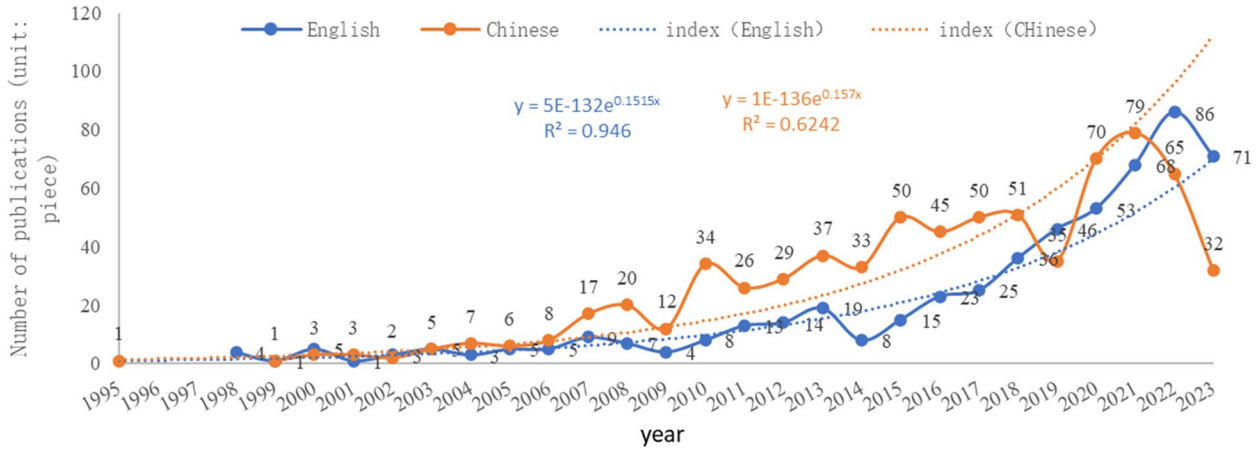

Fig. 2 Annual number of published medical education literature related to CBL. Note: the solid line denotes the actual publication counts per year, with the numbers on the line representing the exact figures. The dashed line (referred to as "index") illustrates the exponential curve indicating the publication trend

(2) Keywords burst analysis method

The term "keyword bursts" refers to a significant surge in the frequency of keyword occurrence, which enables the identification of cutting-edge content within the research field. In this study, we conducted a keyword bursts analysis to identify the top 25 keywords in both Chinese and English literature, which can be categorized into different groups based on their content.

(3) Keywords clustering and time diagram

The CiteSpace software was used to cluster keywords, and Panthfinder and Pruning were applied to the merged network to generate keyword clustering network diagram and keyword time diagram, and the top 50 keywords by annual frequency were employed for constructing the keyword clustering networks. The keyword clustering can be categorized into different groups based on their content.

Data cleaning and hominization

Author names have been standardized by correcting typographical errors and using full names instead of initials. Country names and affiliations have been verified and standardized, with institutions mapped to their respective countries and affiliation discrepancies resolved. Keywords have been cleaned by removing duplicates and spelling errors, and grouped under consistent terminology.

Result

Publication trend

The number and trend of published papers in a specific field can serve as indicators of the developmental stage, research trends, and knowledge maturity within that field. The increasing trend in the number of published papers reflects the overall growth pattern observed in Chinese and English literature (Fig. 2). The exponential function best describes this growth with high goodness-of-fit values: $y=1E\text{-}136e^{0.157\times}$ for Chinese literature ($R^2=0.6242$) and $y=5E\text{-}132e^{0.1515\times}$ for English literature ($R^2=0.946$). These findings suggest that the publication trend in English literature aligns more closely with an exponential function than that in Chinese literature, demonstrating a higher degree of fit.

According to the trend chart (Fig. 2), the application of CBL in medical education has undergone stages of initial, steady, and rapid development. The period from 1995 to 2006 marked the initial stage of CBL pedagogy, which the annual publication count did not exceed 10 papers. From 2007 to 2014, both Chinese and English literature experienced steady growth, with Chinese publications showing greater vigor than their English counterparts. Since 2015, CBL teaching has entered a stage of rapid development. Chinese literature peaked in 2021 with 79 articles, while English literature reached its zenith in 2022 with 86 articles.

Authors

The author knowledge map of Chinese and English literature was generated using CiteSpace software (Fig. 3). The analysis revealed that the network consisted of 532 nodes(N), 743 connections(E), and a density of 0.0053 for Chinese literature, while for English literature, there were 547 nodes, 371 connections, and a density of 0.0025. Overall, collaboration between researchers in Chinese and English literature was limited, with most studies being conducted independently. No author exhibited prolific publication output within a short timeframe.

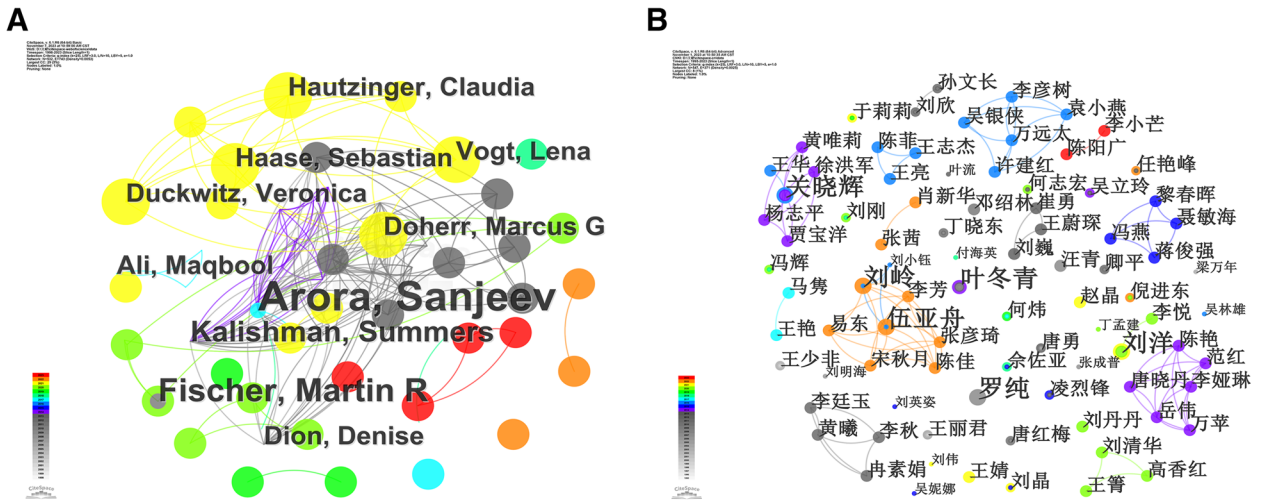

Fig. 3 Atlas of English (**a**) and Chinese (**b**) co-authors in medical education related to CBL. Note: **b**, In Chinese, the terms are organized as follows: "关晓辉" for "Xiaohui Guan", "刘岭"for Ling Liu (in Chinese), "伍亚舟" for Yazhou Wu, "叶冬青"for "Dongqing Ye", "罗纯"for "Chun Luo" and "刘洋"for "Yang Liu"

Table 1 Authors with more than or equal to 3 papers published in English and Chinese

English					Chinese				
No	**count**	**centrality**	**year**	**authors**	**No**	**count**	**centrality**	**year**	**Authors (Chinese)**
1	9	0	2007	Arora, Sanjeev	1	3	0	2010	Dongqing Ye (叶冬青)
2	5	0	2008	Fischer, Martin R	2	3	0	2014	Xiaohui Guan (关晓辉)
3	4	0	2007	Kalishman, Summers	3	3	0	2016	Ling Liu (刘岭)
4	3	0	2017	Ali, Maqbool	4	3	0	2020	Yang Liu (刘洋)
5	3	0	2021	Duckwitz, Veronica	5	3	0	2008	Chun Luo (罗纯)
6	3	0	2021	Hautzinger, Claudia	6	3	0	2016	Yazou Wu (伍亚舟)
7	3	0	2021	Vogt, Lena					
8	3	0	2007	Dion, Denise					
9	3	0	2021	Doherr, Marcus G					
10	3	0	2021	Haase, Sebastian					

According to Price's law, we identified six high-producing authors in Chinese literature and ten in English literature (Table 1 provides detailed information). All these authors had collaborative groups in English literature (Fig. 3a), however, only Xiaohui Guan ("关晓辉"in Chinese), Ling Liu ("刘岭"in Chinese), and Yazhou Wu ("伍亚舟" in Chinese) had established their own research networks specifically within the domain of Chinese literature (Fig. 3b).

Institution

Figure 4 shows that there were 382 nodes and 377 connections in the English publishing institution, with a density of 0.0052(Fig. 4a), and 384 nodes and 36 connections with a density of 0.0005 in Chinese publishing institutions (Fig. 4b). There are 5 institutions with the highest centrality, all of which are 0.01, while other institutions in English literature have a centrality of 0. In contrast, the centrality of all institutions in Chinese literature is 0, indicating less overall inter-agency cooperation. The institutions with a large number of publications are shown in Table 2.

In English literature, the University of Toronto ranked first with 15 articles. It was followed by three institutions with 7 papers each: the University of California,

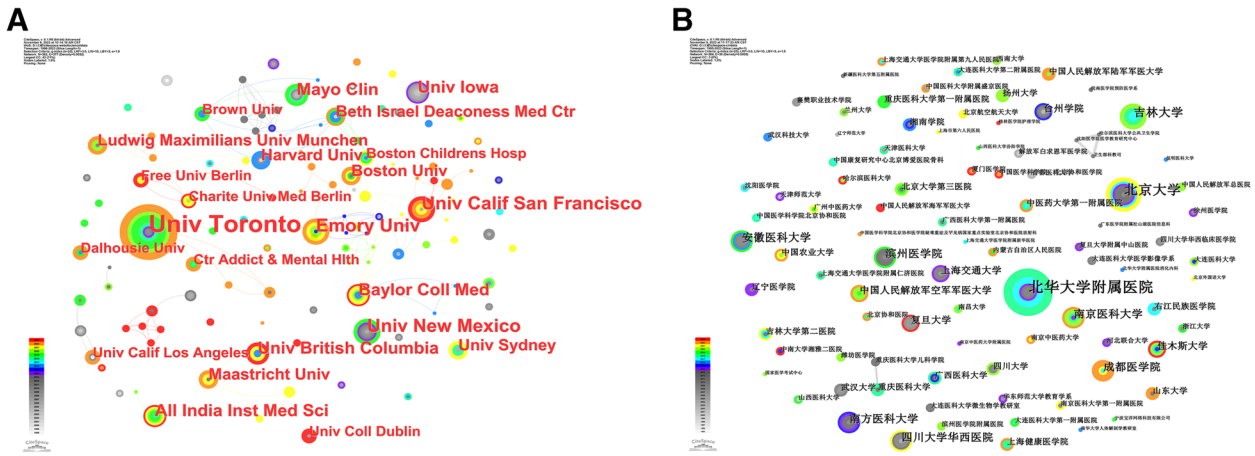

Fig. 4 Map of cooperative relationship in English (**a**) and Chinese (**b**) literature publishing institutions in medical education related to CBL. Note: **b**, In Chinese, the terms are organized as follows: "北华大学附属医院" for "Beihua University Affiliated Hospital", "北京大学" for "Peking University", "吉林大学" for "Jilin University", "四川大学华西医院" for "West China Hospital of Sichuan University", "南方医科大学" for "Southern Medical University", "滨州医学院" for "Binzhou Medical University", "成都医学院" for "Chengdu Medical College","安徽医科大学" for "Anhui Medical University", "南京医科大学" for "Nanjing Medical University", "上海交通大学" for "Shanghai Jiaotong University", "佳木斯大学" for "Jiamusi University", "复旦大学" for "Fudan University", "中国人民解放军空军军医大学" for "PLA Air Force Medical University" and "台州学院" for "Taizhou University"

San Francisco, the University of New Mexico, and Emory University. In Chinese literature, Beihua University Affiliated Hospital ("北华大学附属医院" in Chinese) ranked first with 11 papers.

Keywords analysis

Keywords co-occurrence

Table 3 displays the merged keywords, and the resulting keyword knowledge graph is depicted in Fig. 5. Table 4 lists the top 10 keywords by frequency and centrality. The co-occurrence analysis and chart reveal distinct high-frequency and high-centrality keywords in both the Chinese and the English literature. Although these keywords are commonly used in specific fields like nursing or clinical medicine, their application varies between the Chinese and English literatures. The English literature mainly concentrates on students' grades and course attitudes, whereas the Chinese literature emphasizes overall design and teaching reform.

Keywords bursts

As depicted in Fig. 6a and b, the top 25 keywords in both the Chinese and the English literature were identified through keyword bursts analysis. Furthermore, based on the content found in both the English and the Chinese literature, these burst keywords can be categorized into four distinct groups, as presented in Table 5.

In the domain of English literature, the initial category includes keywords associated with student learning, reflecting a sustained emphasis on this area throughout the literature search period, which spans from 2006 (with "instruction" as a key term and a burst intensity of 1.92) to 2020 (marked by "technology" with a burst intensity of 2.47). Furthermore, the literature continues to feature a steady stream of articles focused on student learning.

The second category encompasses keywords related to teaching courses, highlighting the positive impact of CBL on enhancing instruction across a variety of subjects. Notably, interprofessional education has shown the highest mutation intensity, with a value of 2.47. This trend began in 2014 and persisted until 2017, yielding several published papers so far.

The third category of keywords pertains to teaching methods, indicating the potential for implementing a diverse array of teaching approaches in conjunction with CBL. Significantly, the flipped classroom model has demonstrated the highest degree of evolution, with an intensity rating of 3.23, having been adopted in 2018 and prevailing during the period from 2020 to 2021.Over the past two years, there has been a marked evolution in the prominence of the terms "distance" and "social media," with a burst intensity of 2.31, observable since 2021.

The fourth category relates to geographical locations, such as the "United States" and "American college." The existing literature on this specific type of design is particularly relevant at the national level.

In Chinese literature, the first category of keywords is closely associated with national policies and the guidance provided by MOE, such as "curriculum ideology

Table 2 Institutions with ≥ 4 papers published in English and Chinese

English								Chinese			
No	**count**	**Year**	**Institution**	**number**	**count**	**Year**	**Institution**	**No**	**count**	**Year**	**Institution**
1	15	2011–2022	Univ Toronto	15	5	2007–2021	Univ Sydney	1	11	2011–2018	Beihua University Affiliated Hospital (北华大学附属医院)
2	7	2006–2023	Univ Calif San Francisco	16	4	2009–2023	Univ Coll Dublin	2	8	2010–2021	Peking University (北京大学)
3	7	2007–2019	Univ New Mexico	17	4	2016–2021	Boston Childrens Hosp	3	6	2017–2020	Jilin University (吉林大学)
4	7	2015–2022	Emory Univ	18	4	1999–2022	Univ Calif Los Angeles	4	5	2005–2021	West China Hospital of Sichuan University (四川大学华西医院)
5	6	2018–2023	All India Inst Med Sci	19	4	2016–2019	Brown Univ	5	5	2010–2015	Southern Medical University (南方医科大学)
6	6	2005–2019	Mayo Clin	20	4	2018–2022	Ctr Addict & Mental Hlth	6	5	2010–2019	Binzhou Medical University (滨州医学院)
7	6	2016–2023	Baylor Coll Med	21	4	2021–2023	Free Univ Berlin	7	5	2017–2022	Chengdu Medical College (成都医学院)
8	6	2016–2023	Univ British Columbia	22	4	2020–2023	Charite Univ Med Berlin	8	5	2010–2019	Anhui Medical University (安徽医科大学)
9	6	2004–2014	Univ Iowa	23	4	2016–2022	Dalhousie Univ	9	5	2014–2022	Nanjing Medical University (南京医科大学)
10	5	2013–2022	Maastricht Univ					10	4	2008–2014	Shanghai Jiaotong University (上海交通大学)
11	5	2002–2022	Beth Israel Deaconess Med Ctr					11	4	2015–2023	Jiamusi University (佳木斯大学)
12	5	2012–2022	Ludwig Maximilians Univ Munchen					12	4	2008–2023	Fudan University (复旦大学)
13	5	2013–2022	Boston Univ					13	4	2019–2022	PLA Air Force Medical University (中国人民解放军空军军医大学)
14	5	2002–2016	Harvard Univ					14	4	2004–2015	Taizhou University (台州学院)

Table 3 Keywords displayed and merged

English		Chinese	
Displayed Keywords	**Merged Keywords**	**Displayed Keywords (Chinese)**	**Merged Keywords (Chinese)**
case-based learning	Case Based Learning	case teaching (案例教学)	Cases; (案例) case analysis (案例分析); case teaching (范例教学); case study (案例研究)
medical education	undergraduate medical education; education	teaching mode (教学模式)	teaching methods(教学方法和教学法)
medical student	student	medical education (医学教育)	medical students(医学生); teaching(教学); application; medical colleges(医学院校); medicine(医学); students (学生); medical teaching (医学教学) and medical course (医学课程)
		curriculum ideological and political education(课程思政)	ideological and political teaching (思政教学)

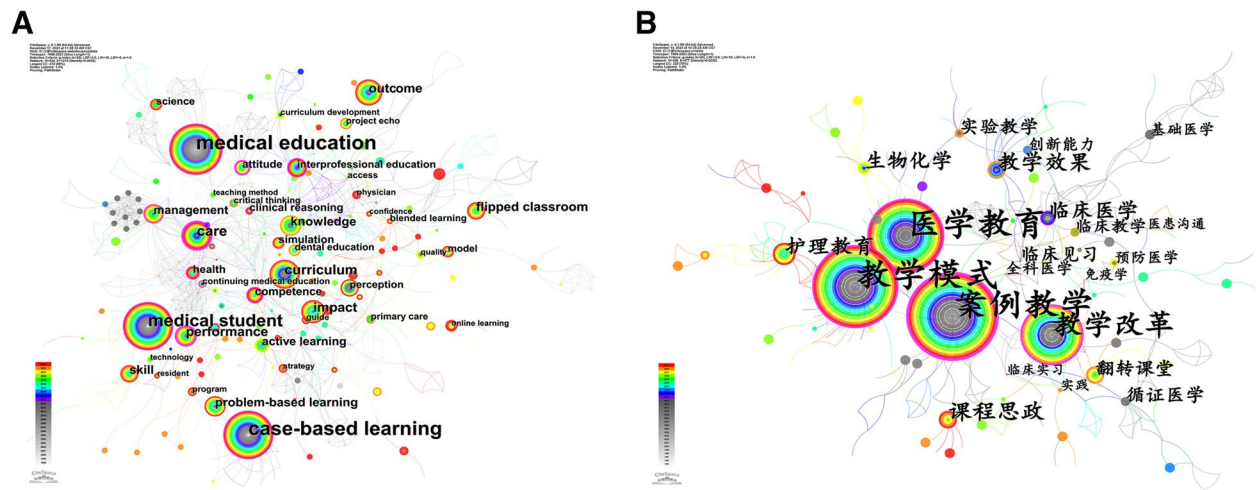

Fig. 5 Knowledge map of keyword co-occurrence of English (**a**) and Chinese (**b**). Note: **b**, In Chinese, the terms are organized as follows: "案例教学" for "case teaching", "医学教育" for "medical education", "教学模式" for "teaching models", "教学改革" for "teaching reform", "护理教育" for "nursing education", "生物化学" for "biochemistry", "实验教学" for "experimental teaching", "教学效果" for "teaching effectiveness", "创新能力"for "innovative ability", "临床医学" for "clinical medicine", "医患沟通" for "doctor-patient communication", "基础医学" for "basic medicine", "临床见习" for "clinical clerkship", "全科医学" for "general medicine", "预防医学" for "preventive medicine", "免疫学" for "immunology", "课程思政" for "ideological and political education in courses", "临床实习" for "clinical internship", "翻转课题" for "flipped topics", "循证医学" for "evidence-based medicine" (mentioned twice), and "实践" for "practice"

and politics" and "quality education". Among these, "curriculum ideology and politics" exhibits the highest intensity at 7.83, starting in 2020. This demonstrates its close alignment with national policies.

The second category of keywords pertains closely to the evaluation and methods employed in teaching, such as "teaching effectiveness," "flipped classroom," and "mind mapping." "Flipped classroom" and "mind mapping" emerged as prominent keywords in 2019.

The third category pertains to teaching courses and application fields, encompassing prominent keywords such as "clinical medicine," "practical teaching," "nursing teaching," "biochemistry," "evidence-based medicine," and "narrative medicine." These keywords are frequently encountered, aligning with the practicality of teaching.

Keywords clustering and time diagram

Figure 7a and b represent the cluster diagrams, while Fig 7c and d depict the time diagrams with red dots indicating keyword bursts. The clusters are coded starting from zero, where cluster #0 is the largest one that gradually decreases in size thereafter Table 6.

The network consists of a total of 534 nodes connected by 1315 edges with a density value of 0.0092. In terms of English literature, the largest connected component comprises 472 nodes, accounting for 88% of the entire network. Modularity is measured at 0.8164, and the Weighted Mean Silhouette stands at 0.927. For Chinese literature, the network consists of 457 nodes and 577 edges, with a density of 0.0055. The maximum

Table 4 High-frequency and High- centrality keywords in Chinese and English literature

		High-frequency				High- centrality			
No		**count**	**Centrality**	**Year**	**Keywords**	**count**	**Centrality**	**Year**	**Keywords**
1	Chinese	47	0.24	2003	teaching reform (教学改革)	47	0.24	2003	teaching reform (教学改革)
2		19	0.03	2020	Curriculum ideology and politics (课程思政)	5	0.17	2003	Clinical practice (临床实习)
3		17	0.05	2008	teaching effect (教学效果)	15	0.15	2006	clinical medicine (临床医学)
4		15	0.15	2006	clinical medicine (临床医学)	4	0.15	2011	Effectiveness evaluation (效果评价)
5		15	0.09	2005	Nursing Education (护理教育)	3	0.15	2007	gynaecology and obstetrics (妇产科)
6		14	0.04	2010	Biochemistry (生物化学)	10	0.13	2006	clinical internship (临床见习)
7		10	0.03	2019	flipped classroom (翻转课堂)	3	0.1	2007	临床知识
8		10	0.13	2006	clinical internship (临床见习)	15	0.09	2005	Nursing Education (护理教育)
9		10	0.09	2008	evidence-based medicine (循证医学)	10	0.09	2008	evidence-based medicine (循证医学)
10		10	0.05	2010	experiment teaching (实验教学)	8	0.09	2007	Clinical teaching (临床教学)
1	English	41	0.21	1998	care	29	0.32	2003	performance
2		37	0.06	1998	curriculum	41	0.21	1998	care
3		31	0.07	2010	impact	15	0.21	2000	attitude
4		29	0.32	2003	performance	15	0.19	2000	clinical reasoning
5		28	0	2013	outcome	9	0.16	2006	continuing medical education
6		27	0.03	2018	flipped classroom	19	0.15	2006	management
7		24	0.05	2003	skill	18	0.13	2007	competence
8		23	0.01	2005	problem-based learning	13	0.13	2014	interprofessional education
9		22	0.08	2005	knowledge	15	0.12	2005	health
10		19	0.15	2006	management	3	0.12	2002	instruction

Year indicates the year in which it appears

connection component comprises 324 nodes, accounting for 70% of the entire network. The Q value is calculated as 0.8481, while the S value stands at 0.9719. A Q value greater than 0.3 indicates significant clustering within the module structure, whereas an S value close to 1 signifies higher homogeneity in the network and increased reliability in clustering results when S reaches a threshold of 0.7. These findings highlight the significance of clustering modularity and its efficiency.

The 14 clusters in English literature can be categorized into four groups: (1)Research on care(2 clusters), including #0 care and #13 primary care.(2) Research on community practices and special projects and populations(3 clusters), including #1 community of practice, #10 project echo and #11 teacher education.(3)Research on teaching methods (5 clusters), including #2 blended learning, #4 evidence-based practice, #5 problem-based learning, #9 CBL and #12 game experiment.(4)Research on competence development of participants(4 clusters), including #3 attitude, #6 clinical competence, #7 decision making and #8 clinical reasoning.

In contrast, the clustering content of Chinese literature can be classified into three categories: (1) Teaching applications related to national policy guidance (1 cluster),#10 Ideological and political teaching clustering.(2) Application of CBL in educational reform, methods and evaluation (6 clusters),including #0 teaching method, #1 case teaching, #2 teaching reform, #4 scenario simulation, #8 cross training, and #13 learning interest clustering. (3) Application of CBL across various disciplines(7 clusters), including #3 Basic medicine, #5 evidence-based medicine, #6 Nursing education, #7 experimental teaching, #9 doctor-patient communication, #11 General Medicine and #12 Biochemical cluster.

Discussion

Publication trend

The application of CBL in medical education has mirrored the progression observed in other natural science domains, undergoing stages of initial development, steady growth, and rapid expansion. During the initial stage from 1995 to 2006, CBL pedagogy was in its nascent form, with limited publications. From 2007 to 2014, a phase of steady growth was observed, with Chinese publications showing more significant growth than

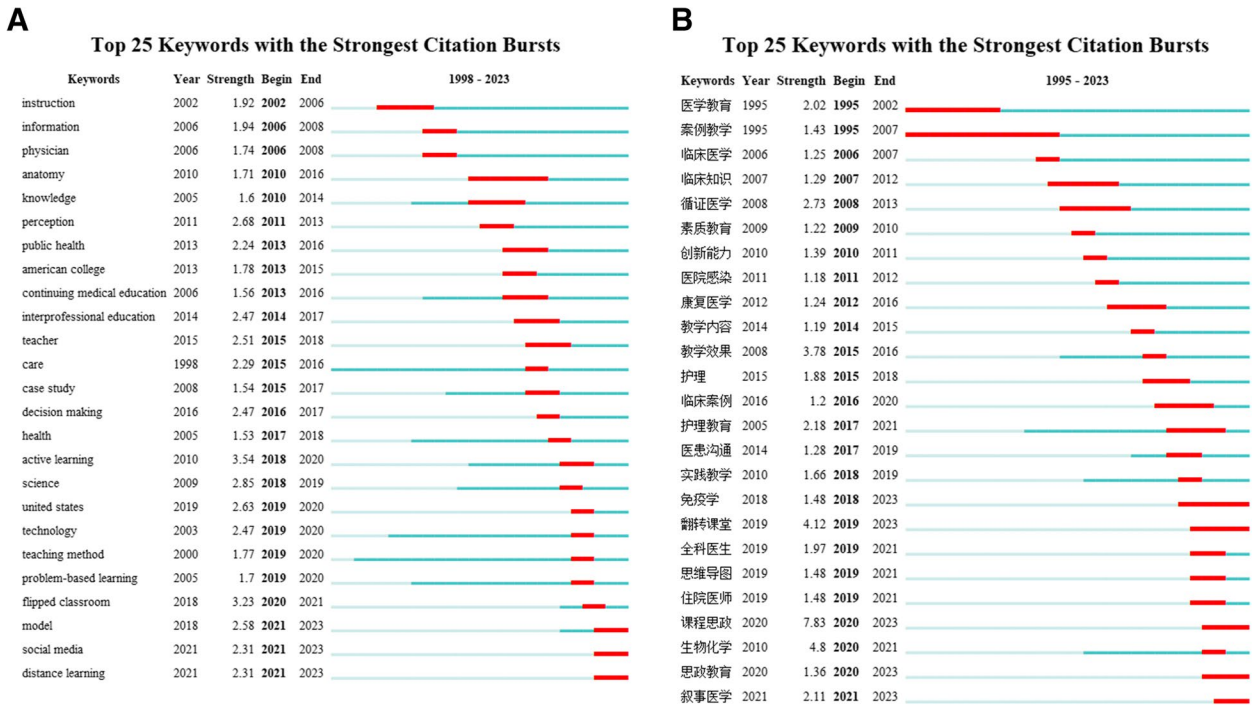

Fig. 6 Top 25 keywords with strongest citation bursts in English (**a**) and Chinese (**b**) literature. Note: **b**, In Chinese, the translations are as follows: "医学教育" for "medical education", "案例教学" for "case teaching", "临床医学" for "clinical medicine", "临床知识" for "clinical knowledge", "循证医学" for "evidence-based medicine", "素质教学" for "quality education", "创新能力" for "innovative ability", "医学感染" for "medical infection", "康复医学" for "rehabilitation medicine", "教学内容" for "teaching content", "教学效果" for "teaching effect", "护理" for "nursing", "临床案例" for "clinical case", "护理教育" for "nursing education", "医患沟通" for "doctor-patient communication", "实践教学" for "practical teaching","免疫学" for "immunology", "翻转课堂" for "flipped classroom", "全科医生" for "general practitioner", "思维导图" for "mind map", "住院医师" for "resident physician", "课程思政" for "ideological and political education in courses", "生物化学" for "biochemistry", "思政教育" for "ideological and political education", and"叙事医学" for "narrative medicine"

English counterparts. This period saw the CBL teaching model evolve rapidly from single applications to mixed implementations encompassing multiple teaching models. Initially employed primarily in fundamental disciplines such as tissue and embryology, CBL gradually extended its reach into more clinical fields [8]. English literature on CBL encompasses diverse publication types and introduces innovative teaching, methods including the integration of CBL mode with games [9].

Since 2015, CBL teaching entered a stage of rapid development. Chinese literature, with a total of 79 articles, is projected to peak in 2021, emphasizing the combination of CBL with other teaching modes such as sandwich method [10], problem-based teaching method [11] and virtual simulation teaching [12]. English literature, on the other hand, with a total of 86 articles, reached its zenith in 2022. It has often kept pace with contemporary trends in science and technology by exploring various themes and incorporating novel elements like WeChat [13], 3D printing [14] and virtual environment teaching [15].

Author co-occurrence analysis

The author serves as the fundamental driving force behind research, and identifying prolific authors and core groups provides an overview of the research field. Compared to natural science, the number of published papers in this field is significantly lower. This phenomenon can be attributed to the inherent characteristics of medical education itself; namely, its exploration phase tends to be relatively lengthy with most endeavors spanning at least one semester or six months. When an effective teaching method is discovered, it is often continued for some time rather than immediately introducing another approach. This is in contrast to natural science, where a single author has published 93 papers within just 11 years [16]. In our study, the highest number of publications by a single author in both Chinese and English is merely 9, and the field exhibits a publication centrality value of 0, indicating no burst authors emerging within a short period. For example, Fischer Martin RL, whose publications rank second in quantity, has been engaged in teaching

Table 5 The classification of keywords bursts and keywords cluster

No.	**Keywords bursts**			
	English		**Chinese**	
	classification	**Keywords bursts**	**classification**	**Keywords bursts(Chinese)**
1	keywords related to students' learning	Instruction; information; knowledge; perception; decision making; science; technology	keywords related to students' learning	innovation ability(创新能力); clinical knowledge(临床知识); content of course(教学内容); teaching effect (教学效果);resident doctor(住院医师)
2	keywords related to the teaching curriculum	Physician; anatomy; public health; continuing medical education; interprofessional education; care; health	keywords are closely related to teaching methods	Case teaching(案例教学);flipped classroom (翻转课堂); mind mapping (思维导图);clinical case(临床案例);
3	keywords related to teaching methods	Teacher; case study; active learning; teach method; problem-based learning; flipped classroom; model; distance learning; social medica	keywords related to teaching courses and application fields	clinical medicine(临床医学); evidence-based medicine(循证医学); hospital infection (医院感染);rehabilitation medicine(康复医学); care(护理); nursing education(护理教育); Doctor-patient Communication(医患沟通); practical teaching(实践教学); immunology(免疫学);general family medicine(全科医学);biochemistry(生物化学); narrative medicine(叙事医学);
4	keywords is location-related	united sates; American college	keywords closely related to the national policy and the guidance of the Ministry of Education of the People's Republic of China	quality education (素质教育); curriculum ideology and politics (课程思政); ideological and political education(思政教育)
	Keywords cluster			
1	the research on care	# 0 care* and # 13 primary care	the research related to national policy guidance	#10 the ideological and political teaching (思政教学)
2	the research on community practice and special projects and groups	#1 community of practice; # 10 project echo(project Extension for Community Healthcare Outcomes); #11 teacher education	the research on teaching reform, mode and evaluation	#0 teaching methods(教学方法); #1 case teaching(案例教学); #2 teaching reform(教学改革); #4 scenario simulation(情景模拟); #8 cross-culture(交叉培养); #13 learning interest (学习兴趣)
3	the research on teaching methods	# 2 blended learning; # 4 evidence-based practice; # 5 problem-based learning; # 9 case-based teaching; # 12 games – experimental	the research related to various disciplines	#3 basic medicine(基础医学); #5 evidence-based medicine(循证医学); #6 nursing education(护理教育); #7 experimental teaching(实验教学); #9 doctor-patient communication(医患沟通); #11 general family medicine(全科医学); #12 biochemistry(生物化学)
4	the research on the capacity development of participants	# 3 attitude; # 6 clinical competence; # 7 decision making; # 8 clinical reasoning		

* was active during the period between 1998 and 2006

research from 2008 to 2020. In 2008, he conducted team-based and case-oriented teaching research [17], while in 2020 he attempted to introduce digital teaching methods [18]. However, only six articles were published over this twelve-year span. This suggests that the research in medical education is more focused on long-term, sustained efforts rather than rapid, high-volume output.

Research institution analysis

The institutions with the highest number of Chinese and English literature publications primarily consist of universities or university-affiliated institutions. The University of Toronto leads in terms of English papers, with 15 papers published consistently from 2011 to 2022, focusing on the application of CBL in community health service teaching. Their research also encompasses

(See figure on next page.)

Fig. 7 Shows the keyword clustering diagram of **a** and **b**, while **c** and **d** are the keyword clustering time diagram. Below the time line are the top 2 or 3 keywords that are cited most frequently in a particular year, and the most frequently cited keywords are lower. Note: **b**: In Chinese, the terms are as follows: "教学方法" translates for "teaching methods", "案例教学" for "case teaching","教学改革" for "teaching reform", "基础医学" for "basic medicine", "情景模拟" for "scenario simulation", "循证医学" for "evidence-based medicine", "护理教育"for "nursing education", "实验教学" for "experimental teaching", "交叉培养" for "interdisciplinary training", "医患沟通" for "doctor-patient communication", "思政教学" for "ideological and political teaching", "全科医学" for "general medicine", "生物化学" for "biochemistry", and "学习兴趣" for "interest in learning". **d**, In Chinese, the terms are organized as follows: First Row#0: "医学教育" for "medical education", "卫生管理" for "health management", "案例开发" for "case development", "教学模式" for "teaching model", "案例法" for "case method", "教学案例" for "teaching case", "教师素质" for "teacher quality", "教学目标" for "teaching objectives", "参与式" for "participatory", "设计思路" for "design concept", "处方" for "prescription", "专题讲座" for "special lectures", "英美法系" for "Anglo-American legal system", "四川大学" for "Sichuan University", "学生能力" for "student ability", "案例学习" for "case learning", "高等院校" for "higher education institutions", "教学医院"for "teaching hospitals", "法学思考" for "legal thinking", "人文知识" for "humanities knowledge", "多元" for "diversity", "死亡原因" for "causes of death", "妇产科学" for "obstetrics and gynecology", "微生物学"for "microbiology", "合理应用" for "rational application", "学生学习"for "student learning", "产科教学" for "obstetrics teaching", "健康教育" for "health education", "人才培养" for "talent cultivation", "公共管理" for "public administration", "假设检验" for "hypothesis testing", "尸体标本" for "cadaver specimens", "志愿者" for "volunteers", "任务驱动" for "task-driven", "实训" for "practical training", "患者安全" for "patient safety", "人文素养" for "humanistic quality", "思维导图" for "mind map", "住院医师" for "resident physician", "培养路径" for "training pathway", "喉癌" for "laryngeal cancer", "耳聋" for "deafness", "发展现状" for "current development status", "伤寒论" for "Treatise on Cold Damage Disorders", "医工结合" for "integration of medicine and engineering", "应急处置" for "emergency response","成果转换" for "outcome transformation". Second Row#1: "案例教学" for "case teaching", "基本特征" for "basic characteristics", "互动性" for "interactivity", "实践性" for "practicality", "古代医学" for "ancient medicine", "古代数学" for "ancient mathematics", "标准化" for "standardization", "价值观念" for "values", "再造" for "reconstruction", "实施" for "implementation", "发展历史" for "historical development", "兽医教育" for"veterinary education ", "外科手术" for "surgical operations", "教研组" for "teaching and research groups", "教学领域" for "teaching fields", "循证" for "evidence-based", "效果评价" for "effect evaluation", "数字化" for "digitization", "分析能力" for "analytical ability", "中医学" for "traditional Chinese medicine", "医学研究"for "medical research", "功能状态" for "functional status", "人生保险" for "life insurance", "学习效果" for "learning outcomes", "互动式" for "interactive", "实验内容" for "experimental content", "教学观" for "teaching philosophy", "教学互动" for "teaching interaction", "学习过程" for "learning process", "全景片" for "panoramic images", "发展历程" for "development process", "健康中国" for "Healthy China", "实验设计" for "experimental design", "决疑法"for "method of resolving doubts". Third Row#2: "课程设置" for "curriculum design", "临床实习" for "clinical internship", "教学改革" for "teaching reform", "教学理念" for "teaching philosophy", "牙周病学" for "periodontology", "素质教育" for "quality education", "流行病学" for "epidemiology", "实践" for "practice", "医患关系" for "doctor-patient relationship", "医学检验" for "medical laboratory science", "临床实践" for "clinical practice", "医疗机构" for "medical institutions", "外科护理" for "surgical nursing", "医疗纠纷" for "medical disputes", "教材编写" for "textbook compilation", "临床案例" for "clinical cases", "探索" for "exploration", "专业认证" for "professional certification", "司法鉴定" for "forensic identification", "留学生" for "international students", "法医学" for "forensic medicine", "免疫学" for "immunology", "学习态度" for "learning attitude", "内经选读" for "Selected Readings from the Inner Canon", "合作教学" for "cooperative teaching","生物学" for "biology". Fourth Row#3: "预防医学" for "preventive medicine", "模拟实验" for "simulation experiments", "学科领域" for "disciplinary fields", "临床医学" for "clinical medicine", "临床知识" for "clinical knowledge", "教学实践" for "teaching practice", "基础医学" for "basic medicine", "职业道德" for "professional ethics", "科学技术" for "science and technology", "医学道德" for "medical ethics", "学科关系" for "interdisciplinary relations", "微细结构" for "microstructure", "本科专业" for "undergraduate major", "课程体系" for "curriculum system", "专业课程" for "professional courses", "导学" for "guided learning", "案例导学" for "case-based guided learning", "授课" for "teaching", "临床应用" for "clinical application", "双语教学" for "bilingual teaching", "学习效率"for "learning efficiency", "实验动物" for "laboratory animals", "分屏显示" for "split-screen display". Fifth Row#4: "临床见习" for "clinical clerkship", "兴趣" for "interest", "学习能力" for "learning ability", "儿科学" for "pediatrics", "教学效果" for "teaching effectiveness", "临床医生" for "clinical physicians", "心内科" for "cardiology", "寄生虫学" for "parasitology", "实训考试" for "practical training examination", "动物医学" for "veterinary medicine", "军校学员" for "military academy students", "口腔内科" for "oral internal medicine", "临床思维" for "clinical thinking", "接触镜学" for "contact lens studies", "临床医师"for "clinical physicians", "临床技能" for "clinical skills", "交流" for "communication", "护士" for "nurses", "情景模拟" for "scenario simulation", "翻转课堂" for "flipped classroom", "临床专业" for "clinical specialty", "学习通" for "Learning Pass", "整合课程" for "integrated courses", "动物伦理" for "animal ethics", "医学进步" for "medical progress". Sixth Row#5: "山东大学" for "Shandong University", "思维能力" for "thinking ability", "教学形式" for "teaching methods", "教育处方" for "educational prescription", "教育效果" for "educational outcomes", "循证医学" for "evidence-based medicine", "临床试验" for "clinical trials", "伦理审查" for "ethical review", "培训知识" for "training knowledge", "医院感染" for "hospital infection", "互联网" for "Internet", "多媒体" for "multimedia", "口腔医学" for "stomatology", "生理学" for "physiology", "培训时间" for "training time", "学习时间" for "learning time", "公共卫生" for "public health", "医师培训" for "physician training", "心脏病学" for "cardiology". Seventh Row#6: "评估" for "assessment", "护理教育" for "nursing education", "个人判断" for "personal judgment", "人文医学" for "humanistic medicine", "三位一体" for "trinity", "信度" for "reliability", "指标体系" for "indicator system", "德尔菲法" for "Delphi method","同理心" for "empathy","临床推理" for "clinical reasoning", "叙事医学" for "narrative medicine", "中医妇科" for "traditional Chinese gynecology", "平行病历" for "parallel medical records", "护教协同" for "nursing and teaching collaboration","临床沟通" for "clinical communication", "护患沟通" for "nurse-patient communication". Eighth Row#7: "科学研究" for "scientific research", "教学研究" for "teaching research", "实践教学" for "practical teaching", "创新能力" for "innovative ability", "实验教学" for "experimental teaching","护理专业" for "nursing profession", "医学统计" for "medical statistics", "创新思维"for "innovative thinking", "中药化学" for "Chinese herbal chemistry", "临床能力" for "clinical ability","图库" for "image library", "整合医学" for "integrated medicine". Ninth Row#8: "医学院" for "medical school", "学习生活" for "study and life","妇产科" for "obstetrics and gynecology","急诊医疗" for "emergency medicine", "全科医生" for "general practitioner", "交叉培养" for "interdisciplinary training", "培养效果" for "training effectiveness", "健康管理" for "health management". Tenth Row#9: "影像教学" for "imaging teaching", "临床教学" for "clinical teaching", "儿科医学"for "pediatrics", "教育培养" for "educational training","实习医生" for "intern physicians", "医患沟通"for "doctor-patient communication", "实训课程" for "practical training courses", "德国" for "Germany", "医学交流" for "medical exchange". Eleventh Row#10: "案例集" for "case collection", "思政教育" for "ideological and political education", "课程思政" for "course-based ideological and political education", "立德树人" for "moral education and talent cultivation", "思政育人" for "ideological and political education for talent development", "免疫预防" for "immunoprevention", "教学设计" for "teaching design". Twelfth Row#11: "传统教学" for "traditional teaching","岗位培训" for "job training", "全科医师" for "general practitioner","全科医学" for "general medicine", "教学方式" for "teaching methods","教育" for "education", "信息技术" for "information technology", "家庭医学" for "family medicine". Thirteenth Row#12: "中医院校" for "traditional Chinese medicine colleges", "生物化学" for "biochemistry","医护专业" for "medical and nursing professions", "仁文化" for "benevolent culture", "高职院校" for "higher vocational colleges", "参与度" for "participation", "要素法" for "element method","绪论" for "introduction". Fourteenth Row#13: "学习兴趣" for "interest in learning", "医学人才" for "medical talents", "教学过程" for "teaching process", "医学学习" for "medical learning" (repeated), "教学内容" for "teaching content", "基础学科" for "basic disciplines"

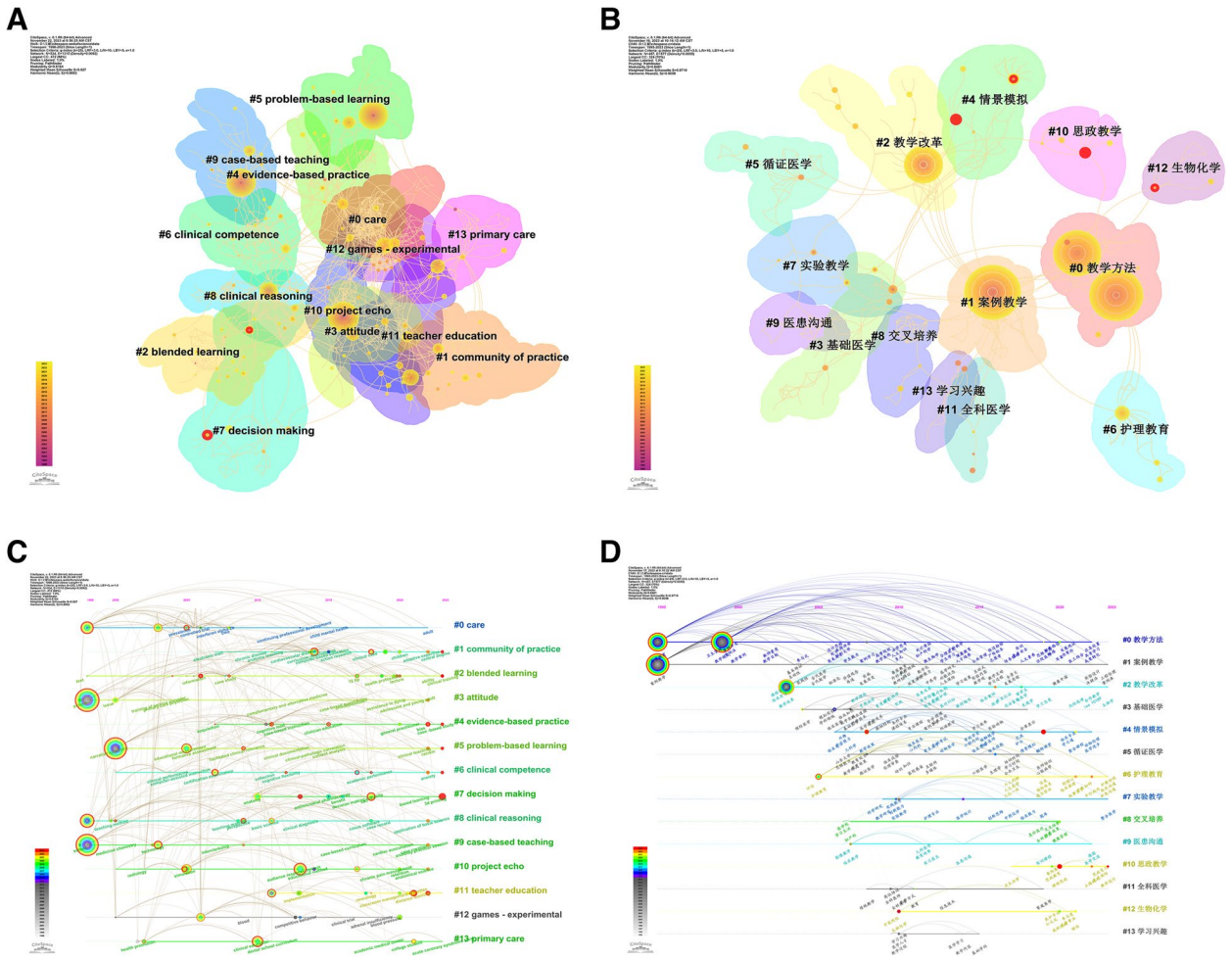

Fig. 7 (See legend on previous page.)

physiotherapist and resident training, dermatology instruction, end-of-life care assistance, immunization courses, and coronary heart disease studies. Following closely are the University of California, San Francisco; the University of New Mexico; and Emory University, each having published seven papers. Notably, over the past two years, the University of California, San Francisco has emphasized keeping pace with contemporary advancements by exploring medical school curriculum reform and enhancing integration between basic science and clinical science disciplines as well as radiotherapy expertise. The virtual conference conducted through Zoom's artificial intelligence-powered platform effectively combines CBL teaching outcomes.

The Beihua University Affiliated Hospital ranked first in the number of Chinese publications (11 papers) published annually from 2011 to 2018, primarily focusing on the application of CBL in otorhinolaryngology, orthopedics, imaging, and other disciplines as well as resident training. Other publications also predominantly explore the implementation of CBL across various fields of education. Overall, it is evident that English literature research in this area is more advanced than its Chinese counterparts, highlighting the need for interdisciplinary integration and diverse teaching methodologies to foster continuous development and innovation.

Keyword analysis

Keyword co-occurrence analysis

The co-occurrence of keywords in both Chinese and English literature reveals distinct research foci. English literature tends to concentrate on students' academic performance and course attitudes, reflecting a student-centered approach. In contrast, Chinese literature emphasizes overall design and teaching reform, indicating a system-oriented approach to educational improvement. This difference may stem from the varying educational contexts and research priorities in these regions.

Keyword bursts analysis

In the field of English literature, the first category of keywords is centered on student learning. Notably, Singh K and colleagues have effectively implemented Team-based Learning (TBL), CBL, and flipped classroom approaches in anatomy education. Their study underscores the significant impact of integrating active and engaging learning strategies on enhancing the acquisition of anatomical knowledge. Students are particularly active in preparing muscle presentations, drawing on their creativity, curiosity, and intellectual capabilities [19].

The second category of keywords related to teaching courses. Students have actively engaged in collaborative knowledge construction through online interprofessional CBL implementation; however, they expressed a preference for offline collaborative practice, which they believe better fosters team bonding—a key component of effective collaboration [20].

The third category of keywords focuses on teaching methods. As recently as 2021, Germany was actively developing a novel radiology curriculum for medical research aiming for national consensus on incorporating multiple teaching modes into their educational framework, including CBL and the flipped classroom [21]. Although most literature suggests that CBL combined with other teaching methods improves teaching quality and student motivation, Maia D et al., through meta-analysis, have noted a very low level of certainty regarding the evidence for CBL in conjunction with other pedagogical approaches, indicating a need for further research to draw more robust conclusions [22].

Over the past two years, there has been a significant evolution in the prominent terms "distance" and "social media", closely linked to the global outbreak of the novel coronavirus. Notably, these terms are often used interchangeably. As highlighted by Grady Z.J. et al. on March 17, 2020, due to the COVID-19 pandemic, medical students were advised by the Association of American Medical Colleges to disengage from clinical settings. Consequently, to ensure continuous education, a virtual elective course in surgery was introduced [23]. This marked the beginning of remote learning practices. Additionally, social media platforms are increasingly being utilized for professional purposes such as scientific updates, networking opportunities, and CBL [24]. It is worth noting that different countries have adopted social media applications based on national contexts, for example, Instagram [25] is used by Wake Forest University in the United States, while WeChat [26] is widely used in China and WhatsApp [27] is popular in many other regions.

The fourth category relates to geographical locations. According to Furlan AD's report, a lack of adequate knowledge and training among healthcare providers hinders the effective management of chronic pain. To address this issue, ECHO (Community Healthcare Outcomes Expansion) utilizes CBL and video conferencing to connect specialists with providers in underserved areas, thereby enhancing healthcare providers' self-efficacy and knowledge [28].

In Chinese literature, the first category of keywords is closely linked to national policies and the guidance provided by MOE. Medical education also adheres to national policies. In 2020, the MOE released the Outline of Curriculum Ideology and Politics Construction in Colleges and Universities. 2009 marked a significant push for quality education, emphasizing students' innovative spirit and practical abilities.

The second category of keywords pertains closely to the evaluation and methods employed in teaching. The emergence of flipped classroom and mind mapping signifying that teaching is inseparable from the assessment of teaching outcomes and reforms in instructional approaches.

The third category pertains to teaching courses and their application fields, encompassing several prominent keywords. The validation and implementation of a teaching method necessitate its application across diverse disciplines.

In summary, the emergence of keywords in Chinese and English literature shows both similarities and differences. Moreover, significant disciplinary, pedagogical, and national factors influence the occurrence of key words within a specific timeframe. These factors include global and domestic policies such as distance learning, social media applications, the ECHO project, and the rise of ideological and political courses in China. However, it is important to note that English literature tends to provide more extensive accounts on students' learning experiences compared to Chinese literature which primarily focuses on summarizing teaching effectiveness.

Keywords cluster analysis

In the English literature, studies on care have explored various aspects of medical education and healthcare delivery. Hong et al. conducted a comparative study on the impact of unfolding nursing cases versus usual nursing cases on teaching effectiveness. Their findings revealed that unfolding nursing cases significantly enhance the critical thinking ability of nursing undergraduates compared to usual nursing cases [29]. Seymour R et al. investigated healthcare for individuals with disabilities, highlighting that CBL offers significant opportunities to address disability discrimination and better equip students to handle negative attitudes contributing to health disparities among this population [30]. Electronic consultation (eConsult), which involves

asynchronous communication between primary care providers (PCPs) and specialists, is increasingly used in healthcare systems to streamline care delivery and enhance patient access. Deeds et al., through 35 semi-structured interviews and six focus groups with various primary care providers from seven academic medical centers (AMCs) affiliated with the Association American Medical Colleges (AAMC), found that eConsult improved comprehensiveness in primary care while also addressing knowledge gaps among PCPs through CBL [31]. Furthermore, the reach of this type of healthcare into rural areas is expanded through the implementation of distributed community engaged learning (DCEL), a unique medical education model developed by the Northern Ontario School of Medicine. The DCEL approach encompasses various strategies such as CBL, community-based medical education, electronic distance education, rural-based medical education (including the preceptor model), allowing students to explore cases from physicians' perspectives within classroom and clinical settings in Northern Ontario [32].

In research on community practices and special projects and populations, CBL is widely used in community of practice and workplace learning, covering training content related to chronic pain, problem-based learning, and interdisciplinary approaches [33]. For example, Tosi LL et al. successfully implemented CBL in telehealth assistance for rare bone diseases on a global scale [34]. Additionally, CBL is extensively applied in the Extension for Community Healthcare Outcomes (ECHO) project [35, 36], which incorporates educational technology, coaching methodologies, curriculum development strategies, and career advancement initiatives that are variably employed or represented within ECHO and similar programs [37]. Pre-service training for teachers presents challenges that can be addressed by CBL. Heemsoth T et al. conducted pre-service teacher training using video- and text-based teaching cases focused on "teaching games for understanding," yielding promising results for physical education teachers [2]. Kramer C et al. advocate that CBL is a promising approach to integrate theory with practice within teacher education programs [38]. These applications of CBL highlight its versatility in enhancing educational and professional development across various settings and populations.

The clustering of research on teaching methods introduces the joint application and comparative situations of CBL with other teaching methods. Blended learning merges online and offline instruction, integrating e-learning with traditional methods [39–41]. Though CBL can be incorporated into preclinical curricula, it cannot fully replace didactic learning [42]. To change clinical behaviors, CBL is often combined with evidence-based practice [43, 44]. CBL has been used in clinical teaching [45], clinicopathology courses [46], and general medical education initiatives [43, 47], but requires active participation from teachers and medical students. Problem-based learning, CBL, and narrative approaches can be applied in various disciplines and training programs [48]. Case-based teaching and curricula focus on instruction delivery, while CBL emphasizes student engagement. Lecture-based learning and blended learning with case studies are often integrated with other methods. During COVID-19, Zottmann JM et al. successfully digitized an interactive, case-based teaching model for Clinical Case Discussion, which was well-received and showed potential for enhancing clinical reasoning abilities [18]. Jiang Z et al. implemented LBL, CBL, PBL, RBL, and TBL in online dental education during the pandemic, finding higher student satisfaction with LBL and CBL. Jiang Z et al. implemented LBL, CBL, PBL, research-based learning (RBL) and team-based learning (TBL) in online dental education during the pandemic, finding that students were more satisfied with LBL and CBL [49]. Educational games may improve health professionals' performance, but a 2013 review by Akl EA et al. found inconclusive evidence regarding their effectiveness [50]. Additionally, game strategies have been linked to knowledge retention, attitude improvement, and job satisfaction among healthcare workers.

In research on competence development of participants, the literature on CBL encompasses a range of topics. These include students' attitudes towards cross-professional learning [3], case cooperative learning [51], and their experiences and views on using 3D printing for learning coronary heart disease [52]. Additionally, there is research students' career attitudes [53], and the positive correlation between exam scores in lecture-based and case-based integrated learning and career attitudes. Additionally, implicit attitudes transmitted through generations in the medical education system have also been identified [54], referring to unwritten knowledge passed down from teaching physicians to future generations. Studies explore radiology residents' attitudes toward patient-centered nursing principles [55], and medical students' views on malpractice. Satisfaction with CBL programs has been assessed [56], as have attitudes toward CBL in the physiology curriculum [46] and primary care providers' (PCPs) attitudes towards obesity. Intervention training has been shown to improve negative attitudes toward obesity and boost confidence in helping patients control their weight [57].

Clinical competence is crucial for healthcare professionals. Gupta et al. found that integrating virtual patients with CBL offers a more engaging approach for school doctors' clinical skills than traditional paper cases,

Table 6 Top 14 clustering keywords in English and Chinese literature

ID	Size	S	mean (Year)	Terms (mutual information)	ID	Size	S	mean (Year)	Terms(Chiness) (mutual information)
0	45	0.985	2009	care (12.01, 0.001); continuing medical education (cme) (10.53, 0.005); infection (10.53, 0.005); mortality (10.53, 0.005); continuing professional development (10.53, 0.005)	0	63	0.989	2012	Teaching method(教学方法) (17.56, 1.0E-4);medical education(医学教育) (17.45, 1.0E-4); teaching(教学) (12.55, 0.001); teaching mode(教学模式) (7.65, 0.01); medical student(医学生) (6.09, 0.05)
1	41	0.939	2015	community of practice (13.2, 0.001); workplace learning (11.71, 0.001); chronic pain (8, 0.005); problem-based/case-based learning (8, 0.005); interdisciplinary (5.84, 0.05)	1	45	0.952	2011	Case teaching(案例教学) (27.23, 1.0E-4); practicalness(实践性) (7.35, 0.01); traditional Chinese medicine(中医学) (7.35, 0.01); case method of instruction(案例教学法) (4.2, 0.05); case analysis(案例分析) (3.88, 0.05)
2	39	0.878	2014	blended learning (12.84, 0.001); contact lens (12.33, 0.001); group work (12.33, 0.001); case studies (8.6, 0.005); academic achievement (6.97, 0.01)	2	34	0.957	2013	Reform in education(教学改革) (29.77, 1.0E-4); reform(改革) (10.57, 0.005); medical dispute(医疗纠纷) (8.84, 0.005); explore(探索) (8.84, 0.005); practice(实践) (8.84, 0.005)
3	36	0.956	2009	attitude (9.92, 0.005); education (7.66, 0.01); assessment (6.61, 0.05); cancer (6.61, 0.05); physiology (5.85, 0.05)	3	28	0.968	2009	Foundation medicine(基础医学) (16.01, 1.0E-4); clinical medical(临床医学) (12.26, 0.001); teaching practice(教学实践) (10.64, 0.005); case teaching(案例式教学) (6.96, 0.01); moral education(道德教育)(5.3, 0.05)
4	34	0.89	2014	evidence-based practice (13.37, 0.001); clinical pathology (9.62, 0.005); clinician education (7.97, 0.005); general practitioner (6.67, 0.01); clinical teacher (6.67, 0.01)	4	27	0.966	2014	Scenario(情景模拟) (14.87, 0.001); clinial intership(临床见习) (14.87, 0.001);teaching(教学效果)(12.58, 0.001); pediatrics(儿科学) (9.88, 0.005); flipped classroom(翻转课堂) (9.88, 0.005)
5	34	0.865	2013	problem-based learning (40.75, 1.0E-4); case-based learning (24.38, 1.0E-4); case-based learning (cbl) (7.12, 0.01); problem-based learning (pbl) (7.12, 0.01); narrative approach (3.56, 0.1)	5	21	0.99	2011	Evidence-based medicine(循证医学) (20.01, 1.0E-4); teaching purpose(教学目的) (6.6, 0.05); thinking ability(思维能力) (6.6, 0.05); multimedia(多媒体) (6.6, 0.05); scientific medthods(科研方法)(6.6, 0.05)
6	33	0.92	2011	clinical competence (19.24, 1.0E-4); undergraduate education (9.56, 0.005); clinical performance (9.56, 0.005); radiology teaching (6.64, 0.01); generalizability theory (6.64, 0.01)	6	18	0.989	2018	Nursing education(护理教育) (21.35, 1.0E-4); narrative medicine(叙事医学) (13.02, 0.001); nursing student practice(护生实习) (6.48, 0.05); surgical nursing(外科护理学) (6.48, 0.05); clinical communication(临床沟通) (6.48, 0.05)
7	32	0.887	2016	decision making (12.01, 0.001); clinical case-based learning (11.51, 0.001); active learning (7.96, 0.005); flipped classroom (6.53, 0.05); educational practice (5.99, 0.05)	7	13	0.958	2013	Experiment teaching(实验教学) (27.69, 1.0E-4); innovation ablity(创新能力) (20.66, 1.0E-4); medical immunology(医学免疫学) (8.28, 0.005); mixed teaching(混合式教学) (6.81, 0.01); Chinese medicine chemistry(中药化学) (6.81, 0.01)
8	32	0.922	2011	clinical reasoning (21.85, 1.0E-4); dental education (11.42, 0.001); educational methodology (6.64, 0.01); casus software (5.14, 0.05); population health (5.14, 0.05)	8	12	0.939	2012	Cross-culture(交叉培养) (8.39, 0.005); school(学校) (8.39, 0.005); medical college(医学院) (8.39, 0.005); model(模型) (8.39, 0.005); cultivation effect(培养效果) (8.39, 0.005)
9	31	0.938	2012	case-based teaching (9.32, 0.005); case-based curriculum (9.32, 0.005); medical students (7.33, 0.01); lecture-based learning (5.71, 0.05); case-based blended learning (5.71, 0.05)	9	10	0.94	2013	Doctor-patient communication(医患沟通) (23.15, 1.0E-4); clinical teaching(临床教学) (15.32, 1.0E-4); education and training(教育培养) (7.6, 0.01); medical communication(医学交流) (7.6, 0.01); clinical thinking ability(临床思维能力)(7.6, 0.01)
10	31	0.902	2011	project echo (12.13, 0.001); educational technology (11.35, 0.001); instruction (11.35, 0.001); curriculum (6.2, 0.05); professional development (5.67, 0.05)	10	10	0.979	2020	ideological and political teaching(思政教学) (20.01, 1.0E-4); curriculum ideological and political(课程思政) (20.01, 1.0E-4); case collection(案例集) (13.27, 0.001); ideological and political education(思政教育) (13.27, 0.001); ideological and political theory courses(思想政治理论课) (6.6, 0.05)

Table 6 (continued)

ID	Size	S	mean (Year)	Terms (mutual information)	ID	Size	S	mean (Year)	Terms(Chiness) (mutual information)
11	25	0.916	2018	teacher education (12.79, 0.001); distance learning (7.41, 0.01); physical education (6.38, 0.05); game-centered approach (6.38, 0.05); petri nets (6.38, 0.05)	11	9	0.985	2011	General family medicine(全科医学)(23.88, 1.0E-4); community participation research(社区参与研究) (7.83, 0.01); family medicine(家庭医学) (7.83, 0.01); teaching methods(教学方式) (7.83, 0.01); health service research(卫生服务研究) (7.83, 0.01)
12	23	0.982	2013	games—experimental (15.25, 1.0E-4); retention (psychology) (15.25, 1.0E-4); humans (15.25, 1.0E-4); attitude of health personnel (15.25, 1.0E-4); job satisfaction (15.25, 1.0E-4)	12	8	1	2017	Biochemistry(生物化学) (17.22, 1.0E-4); higher vocational college(高职院校) (15.79, 1.0E-4); application and practice(应用与实践) (7.83, 0.01); moral education system(德育体系) (7.83, 0.01); participation(参与度) (7.83, 0.01)
S means Sihouette									
13	20	0.984	2011	primary care (15.46, 1.0E-4); clinical education (9.33, 0.005); e-consults (6.52, 0.05); rural health workforce (6.52, 0.05); practitioner (6.52, 0.05)	13	8	0.986	2011	Learning interest(学习兴趣) (16.05, 1.0E-4);students' comprehensive ability(学生综合能力)(7.96, 0.005); medical statistics teaching(医学统计学教学) (7.96, 0.005); histology and embryology teaching(组织学与胚胎学教学) (7.96, 0.005); medical talents(医学人才) (7.96, 0.005)

enhancing clinical reasoning and experience transfer [4]. Amid the COVID-19 pandemic, CBL has become more popular among medical students [58], a notable increase in the evaluation of clinical performance in fields like radiology education [59].

Decision-making skills are vital in clinical practice, and can be enhanced through active learning methods incorporating clinical case studies [60]. The combination of the flipped classroom and CBL also improves decision-making skills [61]. Teaching approaches involving real or specialized patient exposure, technology-enhanced CBL, and graphical clinical cases representations provide learners opportunities to enhance their clinical reasoning. These approaches also allow them to explore interactions between diseases and social determinants, as well as conflicting treatment approaches [62].

In the Chinese literature, teaching applications aligned with national policy guidance constitute applied research that follows this guidance. The main goal is to improve the professional quality education for medical students, enhance their training in medical ethics and scientific research integrity, fully leverage the ideological and political role of this course, and cultivate a spirit among medical students that emphasizes saving lives and healing injuries [63].

The application of CBL in educational reform, methods, and evaluation highlights its utility for enhancing teaching practices. Diverse teaching methods boost students' interest in pathogen biology and immunology, deepen their understanding, and foster a sense of responsibility and mission for further exploration and discovery, while also building a strong foundation for clinical thinking ability [64]. As a follow-up approach, the combination of PBL for practical courses and CBL for theoretical courses not only develops medical students' clinical thinking ability but also increases teachers' enthusiasm for educational reforms [65]. Integrating a WeChat platform flipped classroom with PBL and CBL teaching methods in thoracic surgery clinical practice has shown positive outcomes and is recommended for undergraduate students in clinical medicine [66]. Cross-training through application cases, special report meetings, and scientific research practices outperforms traditional training, aiding in the development of multidisciplinary health management talents to meet societal healthcare needs [67].

In terms of CBL application across disciplines, combining the case teaching method with evidence-based medicine instruction improves outcomes. Understanding evidence-based medicine concepts and skills is crucial for clinical medical students' use of research evidence, independent learning, and clinical practice [68]. Biochemistry, a fundamental discipline, highlights teachers' role in effective instruction, as seen in keywords published in 2020 [69]. Narrative, contrasting with evidence-based medicine, has seen a keyword mutation. Online moral education case integration based on medical narrative significantly enhances nursing students' critical thinking and empathy [70].

In terms of keyword clustering methods, English and Chinese literature share similarities but also exhibit differences in their approaches. Both types of literature have been widely utilized across various disciplines. They encompass national policy applications and explorations into teaching method changes, effectiveness, and student ability assessment. However, a key distinction lies in the broader application scope of English literature, including public projects such as the ECHO project and conference training.

Although this study is comprehensive, it has several limitations. First, the literature search, despite using multiple databases, may have missed some relevant studies due to regional terminology variations or exclusion of grey literature, such as unpublished dissertations or conference proceedings, which may introduce selection bias. Second, the data mining techniques, including CiteSpace software, rely on accurate and consistent data input. Errors or inconsistencies in the original data, such as misspelled keywords or incorrect author affiliations, could skew the analysis results. Moreover, the clustering and burst analysis methods may not fully capture the field's complexity, possibly overlooking emerging low-frequency topics or inaccurately reflecting certain keywords' long-term significance. Third, the study focuses on quantitative analysis, which may not fully capture qualitative aspects like theoretical depth or empirical study quality. A more in-depth qualitative analysis could provide additional insights, but this was beyond the scope of this review. Lastly, the review is based on data collected up to October 27, 2023. Given the rapid evolution of medical education and CBL, new studies published after this date may present different trends or findings. Thus, the conclusions should be considered in light of these limitations and updated with new data.

Conclusion

Based on the preceding discussion, we can draw the following conclusions:

(1) The application of CBL in medical education, as in other natural sciences, shows exponential growth. However, due to the unique nature of teaching development, collaboration among researchers and institutions is limited, with most practices occur-

ring within individual units, primarily contributed by universities and their affiliates.

(2) Co-occurrence and keyword cluster analysis show that CBL has vast potential for implementation across various disciplines, community practices, and special projects in medical education.

(3) The emergence of keywords suggests that the practical application of CBL is evolving with the times. It can be seamlessly integrated into different contexts influenced by environmental factors and policies, such as becoming an integral part of online courses during pandemics or in the 5G era.

(4) In educational practice, CBL can be effectively combined with diverse teaching methods, such as flipped classroom approaches, PBL, LBL, and RBL.

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Authors' contributions
Junyan Yue and Yun Shang carried out the studies, participated in retrieve literature, and drafted the manuscript. Zhiping Zhu and Changhua Liang performed the statistical analysis and participated in its design. Qingwu Wu, Junqiang Zhao, Huifang Wang and Hongkai Cui participated in acquisition, analysis, or interpretation of data and draft the manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

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Competing interests
The authors declare no competing interests.

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