Trend and effectiveness of blending learning in Chinese pharmaceutical education

Tianyi Li
Shandong University

Haina Wang (whn2013@sdu.edu.cn)
Shandong University

Research Article

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Abstract

Background: This study reviewed the trend and application effectiveness of blending learning in pharmaceutical education in China. In the post epidemic era, developing countries, including China, are in a critical period of digital transformation in education. Blending learning has been widely used in Pharmaceutical education in China. It is crucial to understand the development stage objectively and evaluate the teaching effect correctly.

Methods: Using CiteSpace.5.8.3 software, this paper analyzes the global development trend and hotspots of 1537 articles on blended learning collected in Web of Science database from 2000 to 2021. The research on the application of blended learning in Pharmaceutical specialty in China was systematically searched from the databases construction to August 2021. Review Manager5.4 software was used to analyze the included studies.

Results: According to visual analysis, blended learning, especially in theory and technology, has developed rapidly and is still a research hotspot in the field of education. A total of 21 studies were included in the meta-analysis. According to the analysis, compared with conventional teaching method, students' theoretical scores (MD=6.10, 95%CI[4.46, 7.75], $P < 0.00001$), experimental operation scores (MD=6.50, 95%CI[4.33, 8.67], $P < 0.00001$) and multiple learning abilities were improved in blending learning.

Conclusions: Based on the published articles, the effect of blending learning is better than traditional teaching method in pharmaceutical education in China in recent years. This teaching method can be used as an optional method of pharmacy teaching in China, but it needs to design the curriculum reasonably according to the environment of higher education in China.

Background

Blended learning (BL) is a method that combines traditional classroom learning with online learning and is characterized by student-centered, self-paced and flexible learning [1]. Developed on the basis of e-learning, blended learning organically combines traditional face-to-face learning and online learning. It aims to make full use of the rich online learning resources and powerful interactive and convenient functions, while giving full play to the role of teachers in guiding, inspiring and monitoring the teaching process, and giving full play to the initiative, enthusiasm and creativity of learning [2]. Many researchers have investigated the effectiveness of BL in medical and nursing courses in China [3–5]. Literature shows that BL, as a diversified teaching method, improves the effectiveness and efficiency of learning experience and promotes meaningful learning outcomes [6]. At present, the implementation path and strategy of BL are still hotly discussed, such as clarifying teaching objectives, optimizing learning experience, creating a good environment, and carrying out teaching feedback, so as to improve the application effect.

The post epidemic era is a critical period for developing countries to carry out digital transformation of education, with both opportunities and challenges. At this stage, developing countries generally face challenges such as imbalanced education resources, increasing education costs and teachers' lack of digital ability [7]. Driven by social and cultural changes, technological innovation, government policy support and endogenous development needs of the education system, China is also in a critical period of digital transformation and upgrading of higher education [8]. Therefore, when studying teaching methods, it is necessary to understand the development stage objectively and evaluate the teaching effect correctly.

Blended learning, which combines face-to-face and online learning and engages students in technology-mediated learning, is considered as a teaching method to make learning more meaningful in the context of COVID-19 [9–13]. Based on the World Economic Forum's Future of Job Survey Report (2018), active learning and teaching approaches are among 2022's trend abilities [14]. The development of pharmaceutical education in China is relatively slow, and the education of chemical preparations is still in the leading position, aiming at cultivating talents in the field of pharmaceutical science [15]. Pharmaceutical education in developed countries has accumulated many valuable experiences in the past hundred years. Take the UK as an example. One is the admission standards independently set by institutions, such as academic

requirements, health questionnaire and personal statement. Second, it has case analysis, scenario simulation, lectures, seminars and e-learning package and other mature teaching forms. These all contribute to better meeting the actual needs of the pharmaceutical sector [16]. However, China still has room for development in these areas, such as the lack of career planning education for students, and the difficulty of comprehensively evaluating students' professional suitability based on their college entrance examination achievement.

Therefore, while blending learning is extensively employed in the field of pharmacologic education, it is necessary to focus on the hot spots and the most recent developments in the application process in real time. In one published article [17], only one Chinese research literature was included, which failed to fully report the research on BL in Chinese pharmaceutical education. The literature on blended learning in Chinese pharmacy education is characterized by a vast number of studies with small sample sizes and various assessment indicators, making it impossible to effectively verify the model's success through individual studies. As a result, it's critical to consider the following question: What is the application effect of blended learning in the context of Chinese pharmaceutical higher education? This paper systematically evaluated the impact of BL on the teaching effect of pharmaceutical education in China, which is helpful to fill the gap in the evaluation of the application effect of BL, and provides a strong reference for the development of pharmaceutical education worldwide.

Methods

Study design

We used CiteSpace.5.8.3 software to analyze the annual publication volume and trend, keyword co-occurrence network, and burst keywords of 1537 articles on blended learning collected in the Web of Science database from 2000 to 2021, so as to study the trends and hot spots of blended learning worldwide. A systematic review and meta-analysis were conducted in accordance with the guidelines of the *Cochrane Handbook for Systematic Reviews of Interventions* (V.5.1.0) [18] to verify the effectiveness of blended learning in pharmaceutical education in China.

Search strategy

We systematically searched the electronic databases Chinese National Knowledge Infrastructure (CNKI), VIP Information (Chinese database), Wan fang Data (Chinese database), and Web of Science from the establishment of the database to August 2021. The mesh-terms or key words (“Blended learning”)AND (“Pharmacy” OR “Pharmacy education”) were used for the search string. The literature search was conducted in August 2021. A total of 1135 articles were obtained through literature search.

Study selection

Inclusion criteria: (1)Study type: controlled trials; (2)Subjects: pharmaceutical college students, vocational college students and undergraduates in China; (3)The intervention was blending learning and the control group was conventional teaching method; (4)The test scores in the outcome indicators were expressed as mean ± standard deviation.

Exclusion criteria: (1) Unable to obtain the full text of the literature; (2) Incomplete original data; (3)No control group; (4)Included subjects other than pharmacy students.

According to inclusion and exclusion criteria, two researchers conducted literature screening independently. First, the researchers conducted a preliminary screening based on the title and abstract content, and then read the full text to eliminate articles with incomplete data and unusable research. When there are objections, the third party will participate in the discussion to decide whether to include. Data were extracted by two independent reviewers. The extracted contents included first author, publication year, teaching level, teaching content, sample size (intervention group and control group), intervention methods and evaluation indicators.

Quality assessment

Two researchers assessed the risk of bias, and the third researcher was consulted if there was any disagreement. Each result is indicated by "yes", "no" or "unclear". The quality evaluation content of bias risk are as follows: adequacy of the generation of the allocation sequence, concealment of allocation, blinding procedures, incomplete outcome data, selective outcome reporting, and other sources of bias. Information covered by these items was derived from published reports.

Statistical analysis

Rev Man5.4 software [19] was used for Meta analysis. The measurement data used mean difference (MD) or relative risk (RR) as effect indicators, and all effect sizes provided 95%CI [20]. Confidence interval is an interval estimate of a population parameter of the sample, and 95% CI measures the reliability of the measured value of the parameter. The fixed effect model or random effect model was used according to the heterogeneity. When $P \geq 0.1$ and $I^2 \leq 50\%$, statistical heterogeneity between studies was considered acceptable, and the fixed-effect model was used for meta-analysis. When $P < 0.1$ and/or $I^2 > 50\%$, heterogeneity is high, and random effects model is used for meta-analysis [21,22].

Results

Visual analysis of blended learning research

From 2000 to 2021 (retrieval date: December 2021), there were 1537 valid papers, including 1472 research papers and 65 review papers. As shown in Fig. 1, the research can be divided into three stages: from 2000 to 2005, there were few research papers published, with an average annual number of 5; the number of research articles published from 2006 to 2014 showed an upward trend; the third stage was a period of rapid development from 2015 to 2021, with more than 100 research articles published each year.

The essence of education is the transmission of knowledge, which is closely associated with the Internet for information accumulation, transmission and commutation [23]. In July 2015, the State Council issued the *Guidance Opinions on Actively Promoting 'internet plus' Action*, and more schools began to focus on the expansion of educational resources and educational service platforms, with the purpose of implementing a new networked blended-learning mode [24]. This has resulted in the rapid development of blended learning-related research since 2015. To date, blended learning remains a hot topic of research in the education field.

Fig. 2 depicts the keywords co-occurrence network in the field of blended learning research. There are 341 nodes, 957 connected lines, and a network density of 0.0165. Each node represents a keyword, and the node size is in direct proportion to its frequency. The darker the center color of the node is, the higher the centrality is assigned, and the higher the value is, the more central the keyword is in the whole network. Hot keywords in the field of blended learning model research are: the first category is theoretical and technical keywords, including education, online, skill, technology, etc., the second category is the key words of practical application, including curriculum, performance, perception, Instruction, satisfaction, etc.

This study analyzed burst keywords with CiteSpace to discover the cutting-edge terms in the field of blended learning. The Burst keywords map of blended learning research is shown in Fig.3. The strength of the burst keywords represents the degree of attention received by researchers, and the graph can also reflect the time when the node appeared, the time when the burst began, the time when the burst ended, and the time period of the burst, so as to analyze the development process of the frontier hot spots of blended learning.

The top 10 burst keywords were, in order, engagement (5.45), flipped classroom (4.68), technology (4.59), web (3.98), ict (3.93), feedback (3.91), and instruction (3.56), anatomy(3.56), clinical education(3.38), which indicates that the integrated application of web-based curriculum and flipped classroom mode and other teaching methods have received strong attention, as well as the blended learning has been carried out more widely in the field of medical education.

Web, feedback, communication and other words stand out for a long time, whereas engagement, flipped classroom, achievement, course and other words came to light recently. This showed that while the teaching practice and network platform construction of blending learning are developing, the research on the origin of education, such as educational technology and teaching effect, has also received attention in recent years.

The search results

A total of 1135 articles were obtained through literature retrieval. After eliminating duplicate and irrelevant articles, the remaining 52 articles were screened according to inclusion and exclusion criteria, and a total of 21 articles[25-45] meeting the requirements were obtained.

Characteristics of included studies

Among the included articles, twenty articles [26–45] reported the difference of theoretical scores between the experimental group and the control group, six articles [25, 27, 31, 41, 42, 45] reported the difference of experimental operation scores, two articles [27, 29] reported the differences in various learning abilities such as autonomous learning ability. The sample sizes ranged from 56 to 373 participants and the pooled sample size was 3527(experimental group = 1621, control group = 1906). All study outcomes were measured using theoretical scores, experimental operation scores or questionnaire surveys. Table 1 shows the characteristics of the 21 included studies. Table 2 shows the risk of bias assessment of the 21 included studies.

Effects of interventions on theoretical scores

Twenty-one studies [25–45] compared the effects of BL and conventional teaching method on theoretical scores of pharmacy students. A total of 3390 samples were included in the meta-analysis, including 1553 in the experimental group and 1837 in the control group. There was statistical heterogeneity among the studies ($P < 0.00001$, I^2=93%), and a random-effect model was used for meta-analysis. Mean difference (MD) is the difference between the mean of test group and the mean of control group. The results showed that the theoretical scores of students in the experimental group were better than those in the control group (MD=6.10, 95%CI[4.46, 7.75], $P < 0.00001$)(Fig. 4).

Due to the heterogeneity among studies of theoretical scores, sensitivity analysis was performed to verify the reliability of the results. After excluding six studies [25, 27, 31, 41, 42, 45], the pooled effect size favored the blended learning group (MD = 5.37, 95 %CI [4.16, 6.58], $P < 0.00001$).The effects observed in the primary analysis did not change.

The funnel plot of the 21 theoretical score analysis showed an obvious asymmetry, demonstrating possible publication bias(Fig. 5)

Table 1 The characteristics of the 21 included studies

Study ID	Published year	Teaching level	disciplines	Sample size (T/C)	Interventions	Comparator teaching approach	outcome indicator
Zheng & Zhang [25]	2020	Higher vocational	Comprehensive pharmacy training	68/69	B-Learning	Conventional teaching	
Jiang & Ning [26]	2020	Undergraduate	Molecular biology	40/47	B-Learning	Conventional teaching	
Zhang[27]	2020	Higher vocational	Pharmaceutics	40/38	B-Learning	Conventional teaching	
Liu et al. [28]	2017	Undergraduate	Clinical pharmacy	72/72	B-Learning	Conventional teaching	
Wu et al. [29]	2020	Junior College	Human anatomy and physiology	100/100	B-Learning	Conventional teaching	
Zhong& Cao[30]	2020	Undergraduate	Pharmacology	201/164	B-Learning	Conventional teaching	
Lin et al. [31]	2018	Junior College	Pharmaceutics	111/119	B-Learning	Conventional teaching	
Zhang et al. [32]	2020	Undergraduate	Natural pharmaceutical chemistry	130/160	B-Learning	Conventional teaching	
Zhang et al. [33]	2020	Undergraduate	Human histology	42/40	B-Learning	Conventional teaching	
Zhou et al. [34]	2019	Undergraduate	Integrated pharmaceutical knowledge and skills	28/28	B-Learning	Conventional teaching	
Chen[35]	2021	Undergraduate	Pharmacology	49/48	B-Learning	Conventional teaching	
Xiong et al. [36]	2018	Higher vocational	GMP practice and safety in production	31/36	B-Learning	Conventional teaching	
Xing et al. [37]	2021	Undergraduate	Pharmacology	86/93	B-Learning	Conventional teaching	
Sui et al. [38]	2020	Undergraduate	Analytical chemistry	58/152	B-Learning	Conventional teaching	
Jia et al. [39]	2021	Undergraduate	Physiology	18/38	B-Learning	Conventional teaching	
Sun et al. [40]	2020	Undergraduate	Medicinal chemistry	41/138	B-Learning	Conventional teaching	
Wang et al. [41]	2021	Undergraduate	Inorganic chemistry	188/185	B-Learning	Conventional teaching	
Li et al. [42]	2021	Undergraduate	Biopharmaceutical and pharmacokinetic experiments	141/203	B-Learning	Conventional teaching	
Gao [43]	2019	Junior College	Traditional Chinese medicine outline	58/56	B-Learning	Conventional teaching	

Cai et al. [44]	2021	Undergraduate	Anatomical physiology	90/92	B-Learning	Conventional teaching
Cai et al. [45]	2016	Undergraduate	Histoembryology	29/28	B-Learning	Conventional teaching

T experimental group,C control group, theoretical scores, experimental operation scores, questionnaire

Table 2 Risk of bias assessment of the 21 included randomized controlled studies

Study ID	Published year	Randomization	Allocation concealment	Blinding	Incomplete data report	Selective data report	Other bias
Zheng & Zhang [25]	2020	Unclear	Unclear	Unclear	None	None	None
Jiang & Ning [26]	2020	Unclear	Unclear	Unclear	None	None	None
Zhang[27]	2020	Unclear	Unclear	Unclear	None	None	None
Liu et al. [28]	2017	Yes	Unclear	Unclear	None	None	None
Wu et al. [29]	2020	Yes	Unclear	Unclear	None	None	None
Zhong& Cao[30]	2020	Yes	Unclear	Unclear	None	None	None
Lin et al. [31]	2018	Yes	Unclear	Unclear	None	None	None
Zhang et al. [32]	2020	Unclear	Unclear	Unclear	None	None	None
Zhang et al. [33]	2020	Yes	Unclear	Unclear	None	None	None
Zhou et al. [34]	2019	Unclear	Unclear	Unclear	None	None	None
Chen[35]	2021	Yes	Unclear	Unclear	None	None	None
Xiong et al. [36]	2018	Yes	Unclear	Unclear	None	None	None
Xing et al. [37]	2021	Unclear	Unclear	Unclear	None	None	None
Sui et al. [38]	2020	Unclear	Unclear	Unclear	None	None	None
Jia et al. [39]	2021	Unclear	Unclear	Unclear	None	None	None
Sun et al. [40]	2020	Unclear	Unclear	Unclear	None	None	None
Wang et al. [41]	2021	Yes	Unclear	Unclear	None	None	None
Li et al. [42]	2021	Unclear	Unclear	Unclear	None	None	None
Gao [43]	2019	Unclear	Unclear	Unclear	None	None	None
Cai et al. [44]	2021	Unclear	Unclear	Unclear	None	None	None
Cai et al. [45]	2016	Unclear	Unclear	Unclear	None	None	None

Effects of interventions on experimental operation scores

There were six studies [25,27,31,41,42,45] that used experimental operation scores as an evaluation index for the comparison between BL and conventional teaching method, with a cumulative sample size of 1219 cases, including 577 cases in

experimental group and 642 cases in control group. The results showed statistical heterogeneity among studies ($P < 0.00001$, $I^2 = 99\%$), so the random-effect model was used for meta-analysis. The experimental operation scores of the experimental group was better than that of the control group [MD=6.50, 95%CI (4.33, 8.67), $P < 0.00001$](Fig.6). The combined effect size did not change significantly after the single studies were removed one by one, indicating that the results of meta-analysis were relatively stable.

Effects of interventions assessed by questionnaires

Two studies [27, 29] set autonomous learning ability, knowledge application ability and teamwork awareness as evaluation indicators for the comparison between BL and conventional teaching method. The cumulative sample size was 278 cases, including 140 cases in the experimental group and 138 cases in the control group. Relative risk (RR) is essentially the rate ratio or risk ratio, which reflects the strength of the association with exposure. According to the results, the experimental group was superior to the control group in the above aspects, with statistical significance ($P < 0.05$)(Table 3).

Table 3 Meta-analysis of questionnaire survey results

questionnaire items	literature quantity	fixed effect model		random effects model	
		RR(95%CI)	*P*	RR(95%CI)	*P*
Autonomous learning ability	2	1.29(1.14~1.46)	<0.0001	1.29(1.14~1.46)	<0.0001
Knowledge application ability	2	1.22(1.09~1.36)	0.0007	1.22(1.09~1.36)	0.0007
Teamwork awareness	2	1.21(1.09~1.33)	0.0002	1.20(1.09~1.32)	0.0002
Interpersonal communication ability	2	1.27(1.11~1.45)	0.0005	1.27(1.11~1.45)	0.0004

Discussion

In visual analysis, the number of high-frequency highlighting words in application and effect evaluation is significantly less than that in theory and technology research, indicating that researchers generally pay more attention to the development of theory and technology in BL. Therefore, in the future research, it is necessary to actively carry out research on the evaluation of the effect of teaching methods.

The results of theoretical examination and practical operation of pharmacy students in BL group were better than those in traditional teaching method group. We also learned from two studies that BL method can improve students' performance in autonomous learning ability, knowledge application ability and teamwork awareness. To our knowledge, this is the first meta-analysis of the role of BL in pharmaceutical education in China.

Blended learning includes the mixing of learning theories, learning resources, learning environment and learning methods. The key of this method is how to mix, so as to achieve the optimal learning effect. There are several possible reasons to explain the analysis results. First of all, the online learning process will enable students to have more flexibility in learning time and learning style. For example, students can more easily adjust their study schedule to their needs, enabling them to distribute their learning time more suitably instead of limiting it only to the period before an exam, and they can study at the time of the day that is optimal for them[46]. Second, the main task of teachers has changed from imparting subject knowledge to developing students' ability. They no longer aim at instilling standard subject knowledge, but play the role of guiding and promoting students' learning[47]. Thirdly, in collective teaching, this method can meet students' individual learning needs as far as possible realize individualized teaching [48].

Through the analysis of the questionnaire survey, the results show that BL method is better than traditional teaching methods in improving students' autonomous learning ability, knowledge application ability and teamwork consciousness. In

BL method, attention should be paid not only to teachers' "how to teach" but also to students' "how to learn", so as to improve students' initiative and enthusiasm in learning. This can help students develop their abilities and gain rich learning experience.

In this study, the application effect of BL in Pharmaceutical education in China is consistent with the research results of medical and nursing education in recent years [3–5]. Compared with Balakrishnan A's study [17], this study focuses more on the effects of BL applied in pharmaceutical higher education in China. Although pharmaceutical higher education in China has made some progress at present, it still does not meet the needs of social, economic and health development. At present, the main problems are the lack of overall development plan for the training of professional talents, a large space for the development of the school level, and the teaching mode that not fully reflects characteristics of the specialty. By evaluating the effect of BL in Chinese pharmaceutical higher education, it can promote its development and help foreign scholars to understand Chinese pharmaceutical higher education.

From the development and hot spot analysis of blended learning, it can be seen that the research on BL has developed rapidly worldwide since 2015 and is still a hot spot in the field of education. This teaching method has attracted attention in two aspects, one is theory and technology, the other is practical application. No teaching method is panacea, so educators need to continue to explore. On the one hand, to improve the theoretical and technical teaching level of educators, to serve the practice and application; On the other hand, the experience and problems in practice are summarized and reflected to guide the theory and technology. As BL attracts more and more attention year by year, this teaching method is gradually applied to Chinese higher pharmacy education, and it is expected that this method will be further popularized and improved.

The 21 articles[25–45] included in this study were detailed in their descriptions of sample size and outcome indicators,but there was no clear explanation on blinding procedure and allocation concealment used for the trial operators, and the randomization grouping was not clear in some experiments.

There are still problems in the application of BL, which requires teachers to fully explore teaching resources, improve teaching methods and maximize the advantages of the methods, so as to improve students' learning effect [49]. Through blending learning, teachers can explain knowledge by using online resources and consolidate and transform knowledge by using offline classes. In this way, the student-centered effect can be achieved, and the breadth and depth of most students' learning can be effectively enhanced, thus contributing to the improvement of students' learning ability.

Limitations of this study: (1)The included studies generally lacked a scientific randomization method, while it was difficult to implement allocation concealment and blind procedure. 2 The professional curriculum differed across the included studies, leading to differences in the content of the courses and therefore the level of difficulty in mastering the courses. 3 The assessment criteria were inconsistent across the included studies, and a few may be subject to the subjective judgement of the instructor. 4 There were few foreign literature in accordance with the inclusive criteria,which may have affected the preciseness of the results of this study.

Inspirations of this study:The analyses of the included literature are all about the changes in theoretical scores or (and) experimental operation scores after the adoption of blended learning in a particular course, without doing a further research of the application of BL in detail. For example, the researchers can explore whether BL can achieve different teaching effects for the same course with different number of class hours, different course stages and different intensity. At the same time, a unified and standardized content of BL interventions can be established, such as the specific forms of classroom learning and the outcome indicators. In addition,in-depth interviews and questionnaires with students are necessary. Based on the students' attitudes toward blended learning, methods to enhance the effectiveness of BL application can be further explored. Future studies should strictly adhere to the requirements of RCT design to ensure the quality of the study and thus more scientifically evaluate the effectiveness of BL application in Chinese pharmacy education.

Conclusions

BL has become a popular teaching method in the field of higher education internationally. While network platform and practical teaching of BL continue to develop, the research on teaching effectiveness has also attracted increasing attention. The results of visual analysis suggest that educators should pay attention to how to use theory and technology to better serve teaching practice and evaluate the effect timely and scientifically while improving teaching theory and technology level. Meta-analysis results suggest and confirm that, compared with traditional lecture-based teaching, BL can improve Chinese pharmacy students' examination performance, but the heterogeneity of the studies needs to be considered. What can be improved in this study is that when collecting and screening data, researchers should timely record the reasons for data processing, including the reasons for including or excluding data, rather than just classifying data. At the same time, the type and content of instructional design should be judged more strictly, which is conducive to more detailed analysis of research results.

Abbreviations

BL
Blending learning
MD
Mean difference
RR
Relative risk

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this published article.

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Not applicable

Competing interests

The authors declare that they have no conflicts of interest.

Authors' contributions

TL and HW conceived the paper, and collected and analyzed the data. TL participated in the preparation of the manuscript. HW made the final revision to the manuscript. All authors read and approved the final manuscript.

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Figures

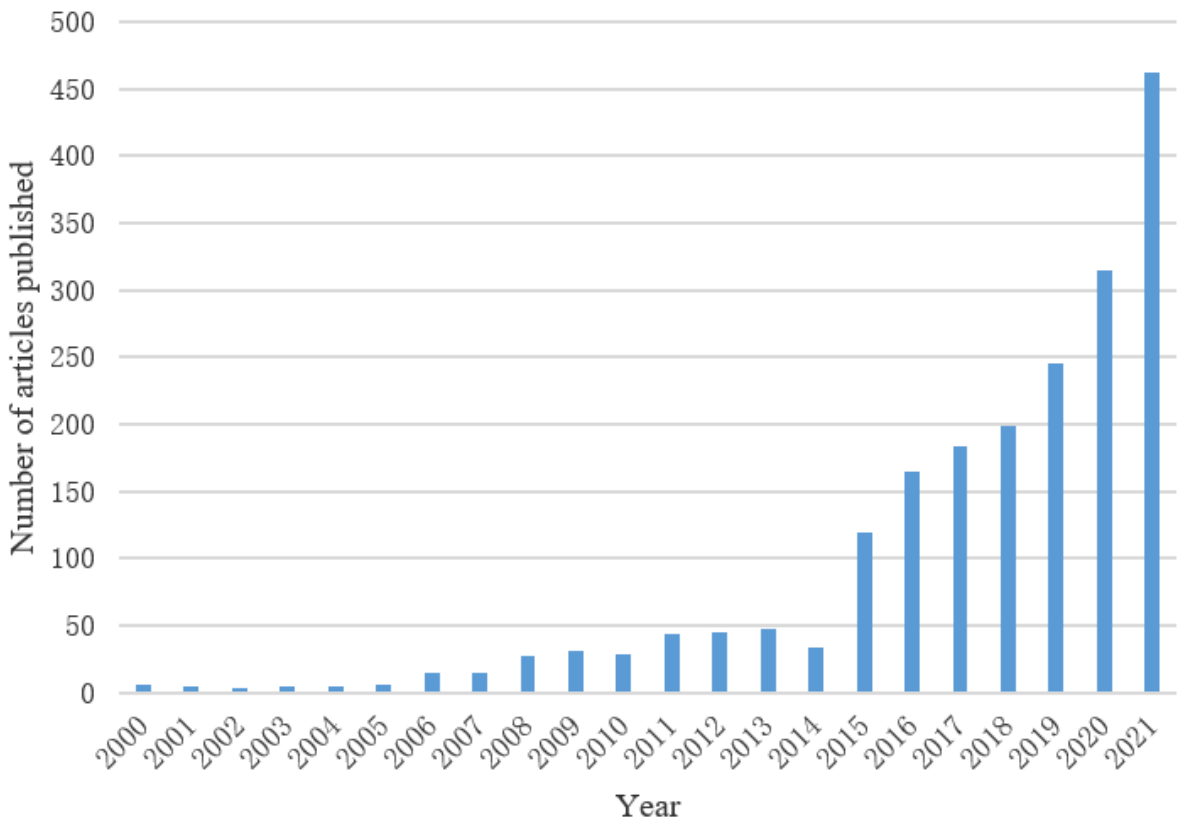

Figure 1

Annual number and trend of publications in the research field of blended learning

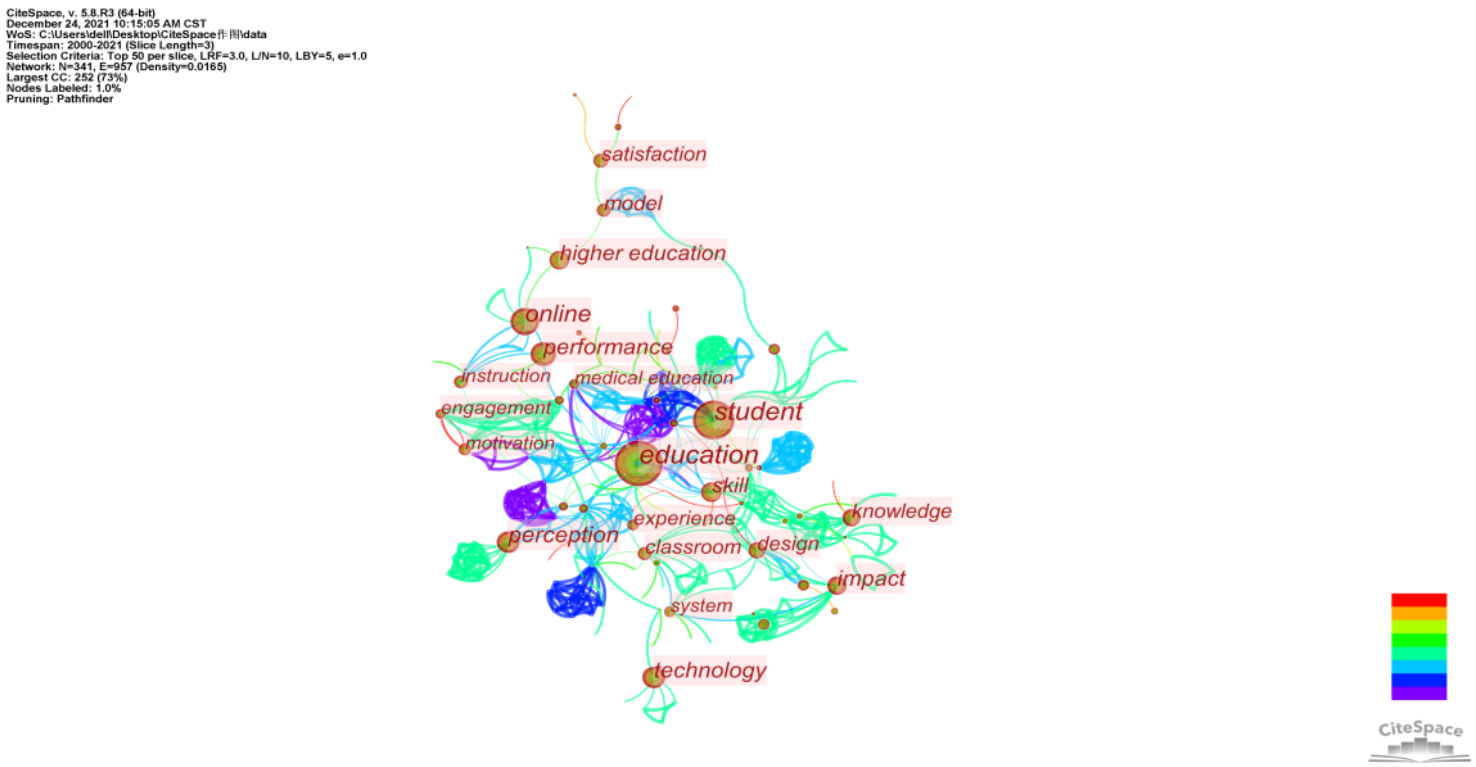

Figure 2

Keywords co-occurrence network in the research field of blending learning

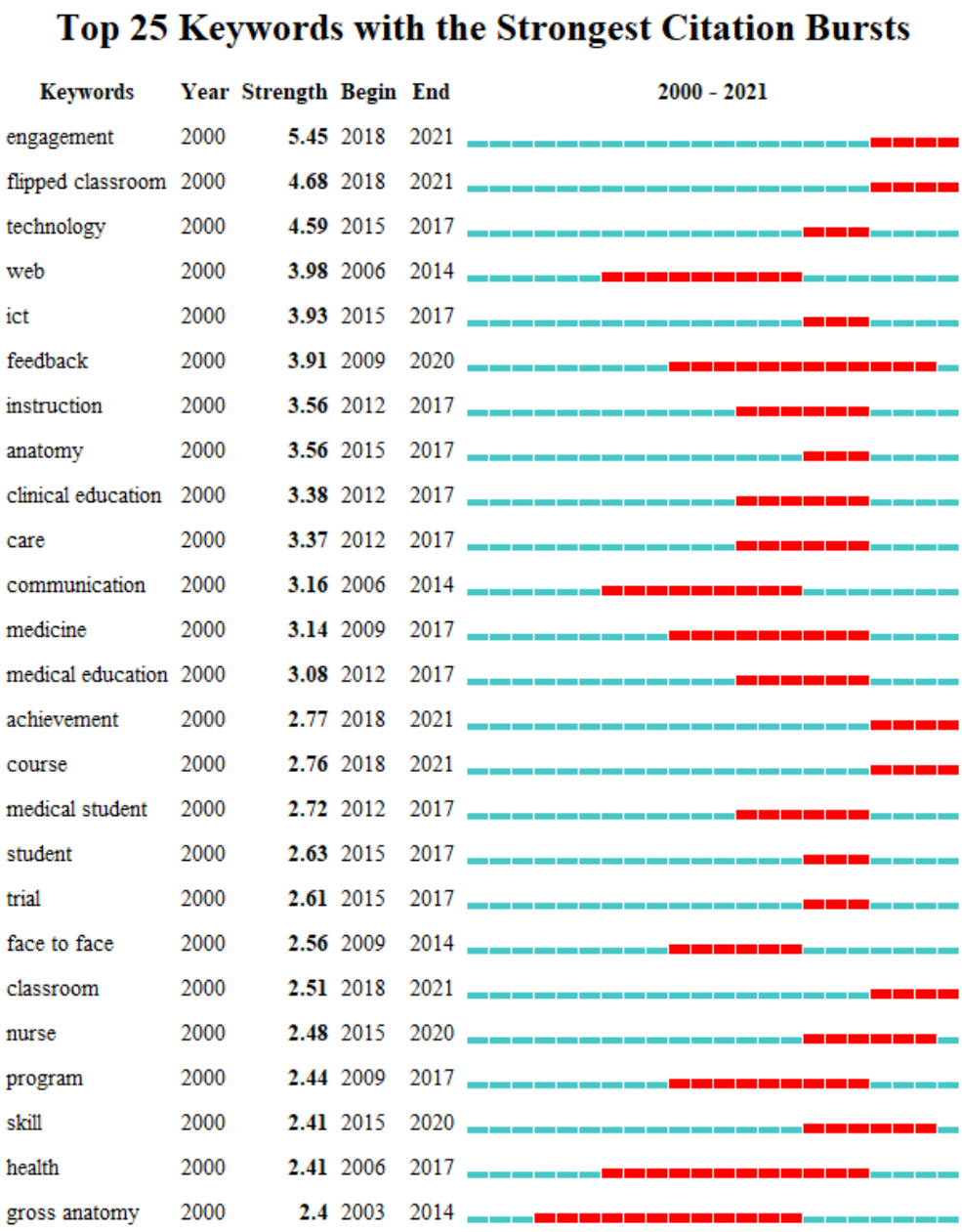

Figure 3

Burst keywords in the research field of blending learning

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Cai 2016	63.879	1.954	29	58.554	1.645	28	5.8%	5.32 [4.39, 6.26]
Cai 2021	68.9	12.07	90	65.05	13.9	92	4.5%	3.85 [0.07, 7.63]
Chen 2021	74.21	8.46	49	70.55	6.94	48	4.9%	3.66 [0.58, 6.74]
Gao 2019	82.05	9.39	58	75.55	10.12	56	4.6%	6.50 [2.91, 10.09]
Jia 2021	86.9	2.1	18	74.4	2.2	38	5.7%	12.50 [11.30, 13.70]
Jiang 2020	81.55	8.31	40	79.48	8.62	47	4.6%	2.07 [-1.49, 5.63]
Li 2021	70.6	12.5	141	65.5	14.1	203	5.0%	5.10 [2.27, 7.93]
Lin 2018	87	10.3	111	78.2	9.7	119	5.1%	8.80 [6.21, 11.39]
Liu 2017	88	16.01	72	73.31	13.29	72	3.9%	14.69 [9.88, 19.50]
Sui 2020	56.1	4.9	58	52.6	4.2	152	5.7%	3.50 [2.07, 4.93]
Sun 2020	31.18	3.8	41	30.8	3.7	138	5.7%	0.38 [-0.94, 1.70]
Wang 2021	47.17	7.75	188	44.33	10.37	185	5.5%	2.84 [0.98, 4.70]
Wu 2020	79.96	10.56	100	74.4	9.73	100	5.0%	5.56 [2.75, 8.37]
Xing 2021	89.23	4.21	86	81.25	3.32	93	5.7%	7.98 [6.86, 9.10]
Xiong 2018	76.12	6.45	31	69.86	6.11	36	4.9%	6.26 [3.24, 9.28]
Zhang 2020a	83.45	10.02	40	75.63	13.34	38	3.7%	7.82 [2.56, 13.08]
Zhang 2020b	80.12	4.81	130	72.22	5.06	160	5.7%	7.90 [6.76, 9.04]
Zhang 2020c	83.15	9.02	42	78.32	9.17	40	4.4%	4.83 [0.89, 8.77]
Zhong 2020	81.3	8.39	201	77.97	4.79	164	5.7%	3.33 [1.96, 4.70]
Zhou 2019	87.89	7.73	28	74.96	11.65	28	3.7%	12.93 [7.75, 18.11]
Total (95% CI)			**1553**			**1837**	**100.0%**	**6.10 [4.46, 7.75]**

Heterogeneity: Tau² = 11.92; Chi² = 279.01, df = 19 (P < 0.00001); I² = 93%
Test for overall effect: Z = 7.28 (P < 0.00001)

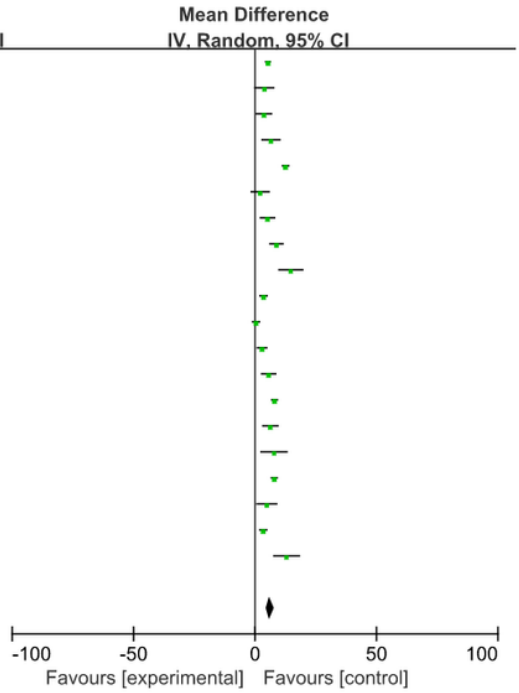

Figure 4

Meta-analysis and forest plot of theoretical scores for BL compared with conventional teaching method

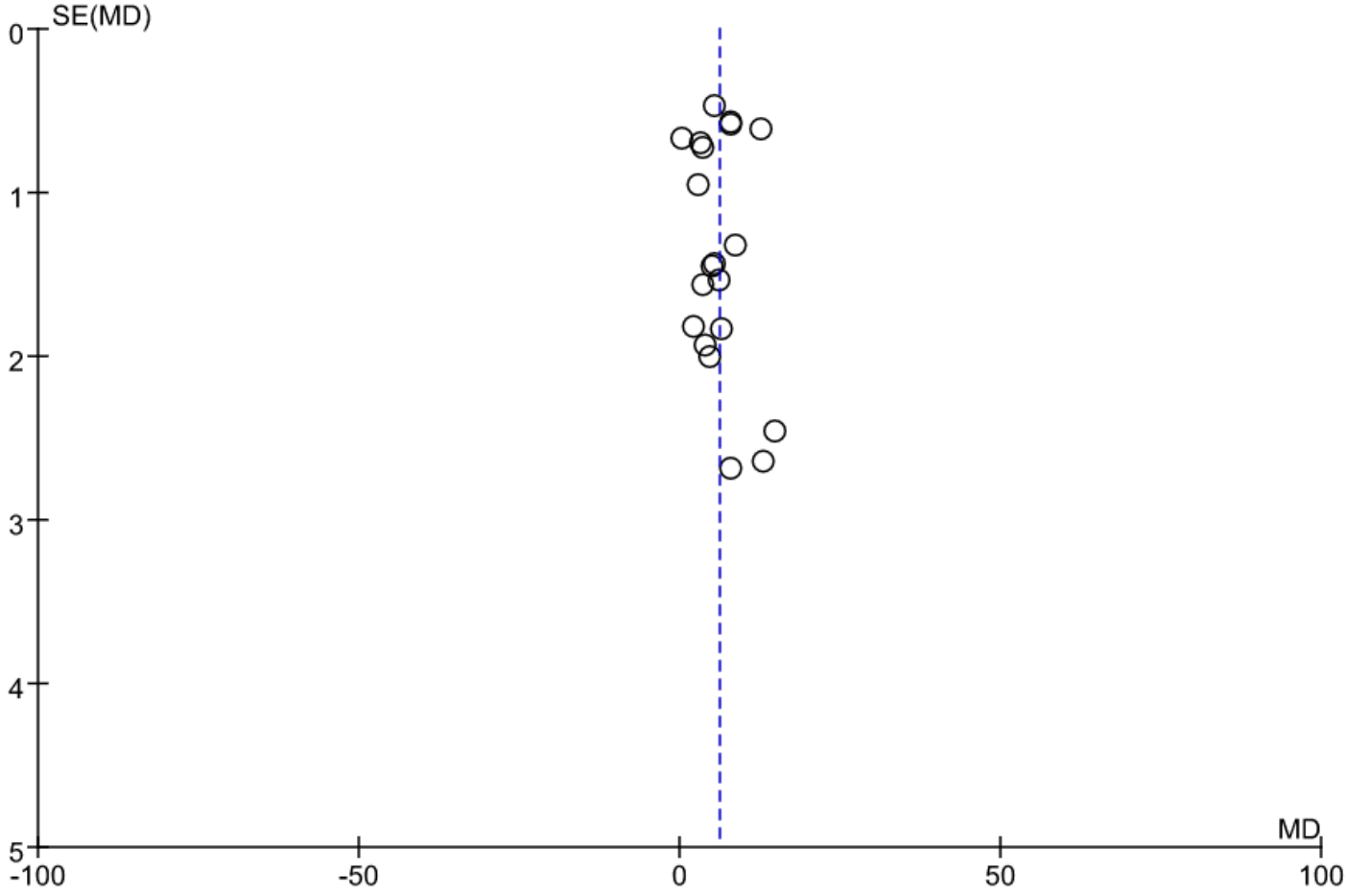

Figure 5

Funnel plot analysis of theoretical scores

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Cai 2016	43.869	0.594	29	41.771	0.731	28	18.3%	2.10 [1.75, 2.44]
Li 2021	97.2	1.1	141	95.5	2.7	203	18.3%	1.70 [1.29, 2.11]
Lin 2018	91.7	7.5	111	83.9	6.8	119	16.2%	7.80 [5.95, 9.65]
Wang 2021	19.36	2.2	188	19.32	2.41	185	18.2%	0.04 [-0.43, 0.51]
Zhang 2020a	85.15	5.84	40	71.48	7.29	38	13.8%	13.67 [10.73, 16.61]
Zheng 2020	94.95	6.23	68	77.53	7.52	69	15.2%	17.42 [15.11, 19.73]
Total (95% CI)			**577**			**642**	**100.0%**	**6.50 [4.33, 8.67]**

Heterogeneity: Tau² = 6.68; Chi² = 335.56, df = 5 (P < 0.00001); I² = 99%

Test for overall effect: Z = 5.86 (P < 0.00001)

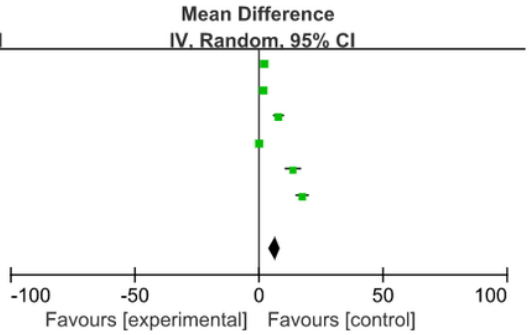

Figure 6

Meta-analysis and forest plot of experimental operation scores for BL compared with traditional teaching method