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Combined administration of problem- and lecture-based learning teaching models in medical education in China

A meta-analysis of randomized controlled trials

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Abstract

Introduction: The aim of this meta-analysis is to assess the effectiveness of the combined administration of problem-based learning (PBL) and lecture-based learning (LBL) teaching models in Chinese medical education.

Materials and methods: We searched the following Chinese electronic databases: China National Knowledge Infrastructure, WanFang Data, China Science Periodical Database, and the Chinese BioMedical Literature Database. We also searched the following English electronic databases: PubMed, Embase, Cochrane Central Register of Controlled Trials, and Google Search Engine. We searched for published studies involving the combined administration of PBL+LBL teaching models in Chinese medical education. All randomized controlled trials were included. The focus of the meta-analysis was on the outcomes of knowledge scores, skill scores, medical writing scores, comprehensive ability scores and teaching satisfaction. A subgroup analysis was also performed.

Results: A total of 23 RCTs were included, with a total sample size of 2589 medical students. The PBL+LBL teaching model significantly increased knowledge scores (95% CI, 2.85–5.78; $P < .00001$), skill scores (95% CI, 0.51–3.71; $P = .01$), medical writing scores (95% CI, 1.04–4.04; $P = .0009$), comprehensive ability scores (95% CI, 2.04–8.71; $P = .002$) and teaching satisfaction (RR, 1.32; 95% CI, 1.10–1.59; $P = .003$) compared with the LBL teaching model alone. Additionally, a subgroup analysis showed significant differences in the effect of PBL+LBL on knowledge scores, medical writing scores, and comprehensive ability scores when comparing practical and theoretical courses. Another subgroup analysis that looked at the level of training showed that the PBL+LBL teaching model also significantly improved the knowledge scores of Freshman, Sophomore, Junior, Senior and Masters students.

Discussion and Conclusions: Based on the current evidence, this meta-analysis showed that the PBL+LBL teaching model is an effective way to increase knowledge scores, skill scores, medical writing scores, and comprehensive ability scores and to improve teaching satisfaction.

Abbreviations: LBL = lecture-based learning, PBL = problem-based learning, RCTs = randomized controlled trials.

Keywords: lecture-based learning, medical education, meta-analysis, problem-based learning

1. Introduction

Problem-based learning (PBL) was originally introduced as a new teaching model at McMaster University in Canada in the 1960s.[1,2] PBL is a student-centered teaching model, advocating students' autonomous learning and aiming to fully mobilize students' enthusiasm for learning.[3–5] In China, PBL teaching reforms have largely been applied to clinical medicine courses, and these reforms have affected teaching effectiveness.[6,7] Compared with traditional lecture-based learning (LBL), many studies have shown that PBL students are better at solving problems and learning autonomously than those in a traditional curriculum.[5,8,9]

Recently, an increasing number of studies have focused on whether the combined application of PBL and LBL teaching models has additional benefits in medical education when compared with only PBL or LBL teaching models.[10–12] Although multiple studies over the last decade have assessed the possible alternatives of PBL+LBL in clinical medicine education in China,[13–16] no study has evaluated all available level I trials defined as prospective randomized controlled trials (RCTs).[17] A meta-analysis regarding the application of PBL +LBL in physical diagnostics education regarding Chinese medical students has been reported;[5] however, this study is lacking in 2 aspects. First, RCTs are considered the gold standard for assessing the efficacy and safety of clinical interventions compared to non-RCTs.[18] We found that a large number of non-RCTs were included in this previous meta-analysis. Therefore, the methodology quality and deficiencies of the non-RCTs should be considered due to the potential bias in the clinical outcome. Second, more high-quality and well-designed RCTs have been published and have shown different results over the past few years. Thus, the current authors performed an updated meta-analysis to assess the highest evidence-based

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(level I) studies to investigate the effectiveness of PBL+LBL in medical education in terms of

(1) knowledge scores,
(2) skill scores,
(3) medical writing scores,
(4) comprehensive ability scores, and
(5) teaching satisfaction.

Subgroup analyses were conducted to evaluate the benefits of the application of different types of courses in terms of knowledge scores, skill scores, medical writing scores, and comprehensive ability scores, as well as teaching satisfaction. Additionally, another subgroup analysis was performed for the level of training regarding the knowledge scores.

2. Materials and methods

The method used for this meta-analysis is based on the recommended PRISMA checklist guidelines.[19] Ethical approval is unnecessary because it is a review of previously published articles and does not involve any processing of individual patient data.

2.1. Search strategy

We searched the following Chinese electronic databases: China National Knowledge Infrastructure, WanFang Data, China Science Periodical Database, and the Chinese BioMedical Literature Database. We also searched the following English electronic databases: PubMed, Embase, and Cochrane Central Register of Controlled Trials. To search for additional eligible studies, we also used Google Search Engine. The end date for all the electronic database searches was November 2017. We used a specific set of keywords to search the above databases: ("problem-based learning" OR "PBL") AND ("lecture-based learning" OR "LBL"). There were no restrictions on language and location.

2.2. Inclusion criteria

We had 5 inclusion criteria:

(1) the target participants for the study were medical students;
(2) the studies were RCTs;
(3) the interventions included the PBL+LBL teaching model in the experimental group and the LBL teaching model in the control group;
(4) a sufficient sample size was included in each RCT; and
(5) the outcomes of each RCT included at least 1 of the following: knowledge scores, skill scores, medical writing scores, comprehensive ability scores, and teaching satisfaction. Studies were excluded if the study was not an RCT, and there were no sufficient outcomes. If any study did not meet the above criteria, it was excluded. All the titles and abstracts were reviewed independently by 2 reviewers (Wen Zeng, Qin Zhang) to identify potential studies. These eligible studies were then obtained for inclusion based on review of the full text. After discussion, the differences were resolved through consensus or a third review (Xue Jia) if necessary.

2.3. Assessment of methodological quality

The methodological qualities of the included trials were assessed independently by the 2 reviewers (Xue Jia, Wen Zeng) using the Cochrane Collaboration for Systematic Reviews.[18] The 7 items of sequence generation, allocation sequence concealment, blinding of participants and personnel, blinding of the outcome assessment, incomplete outcome data, selective reporting, and other biases contained in this specific tool were considered as the meaningful evaluation index. The overall methodological quality of each included study was evaluated as "low risk of bias", "high risk of bias", and "unclear risk of bias".

2.4. Outcome measures

The primary outcomes in this meta-analysis were knowledge scores, skill scores, medical scores, and comprehensive ability scores in the PLB+LBL group and the LBL group. We also considered teaching satisfaction (divided into satisfactory teaching effect, general teaching effect, and poor teaching effect) as a secondary outcome between the 2 groups. Additionally, subgroup analyses were conducted to assess the benefits of applying PBL+LBL and LBL to practical and theoretical courses in the above outcomes.

2.5. Data extraction

Two reviewers (Xue Jia, Qin Zhang) independently extracted the eligibility study results from the predefined data fields. The 2 databases of the 2 reviewers were compared, and any conflict was resolved by discussion. The information and data were extracted from eligibility studies regarding baseline characteristics, such as author, published time, number of participants, course name, course type, intervention method, and eligibility studies of the results. If necessary, we contacted the authors of eligible studies by e-mail to obtain sufficient information for analysis.

2.6. Data synthesis

Statistical analyses of the meta-analysis were performed using RevMan 5 software (Version 5.3, the Cochrane Collaboration, UK). For continuous data, such as knowledge scores, skill scores, medical writing scores, and comprehensive ability scores, the mean difference (MD) and the 95% confidence interval (CI) were calculated. For dichotomous data, such as teaching satisfaction, the risk ratio (RR) and the 95% CI were calculated. The chi-squared test and I^2 statistic were used to assess statistical heterogeneity. If the chi-squared test >0.1 or if the $I^2<50\%$, the fixed effects model was chosen. Otherwise, a random effects model was chosen. Publication bias was tested independently using funnel plots of knowledge scores, skill scores, medical writing scores, comprehensive ability scores, and teaching satisfaction; if the funnel plot was symmetric, then there was a low potential for publication bias, and vice-versa.

3. Results

3.1. Search results

The details on study inclusion and exclusion are summarized in flow diagram (Fig. 1). A total of 1863 studies were screened in the initial search, and 1725 studies were excluded based on their titles and abstracts. We scanned the full text of the remaining 138 studies, and an additional 115 were also excluded since they did not meet the inclusion criteria. Thus, a total of 23 RCTs,[10–16,20–35] involving 2589 medical students, met the inclusion criteria and were selected for this meta-analysis. All of the included studies were published between 2006 and 2017. These studies included 1306 students in the

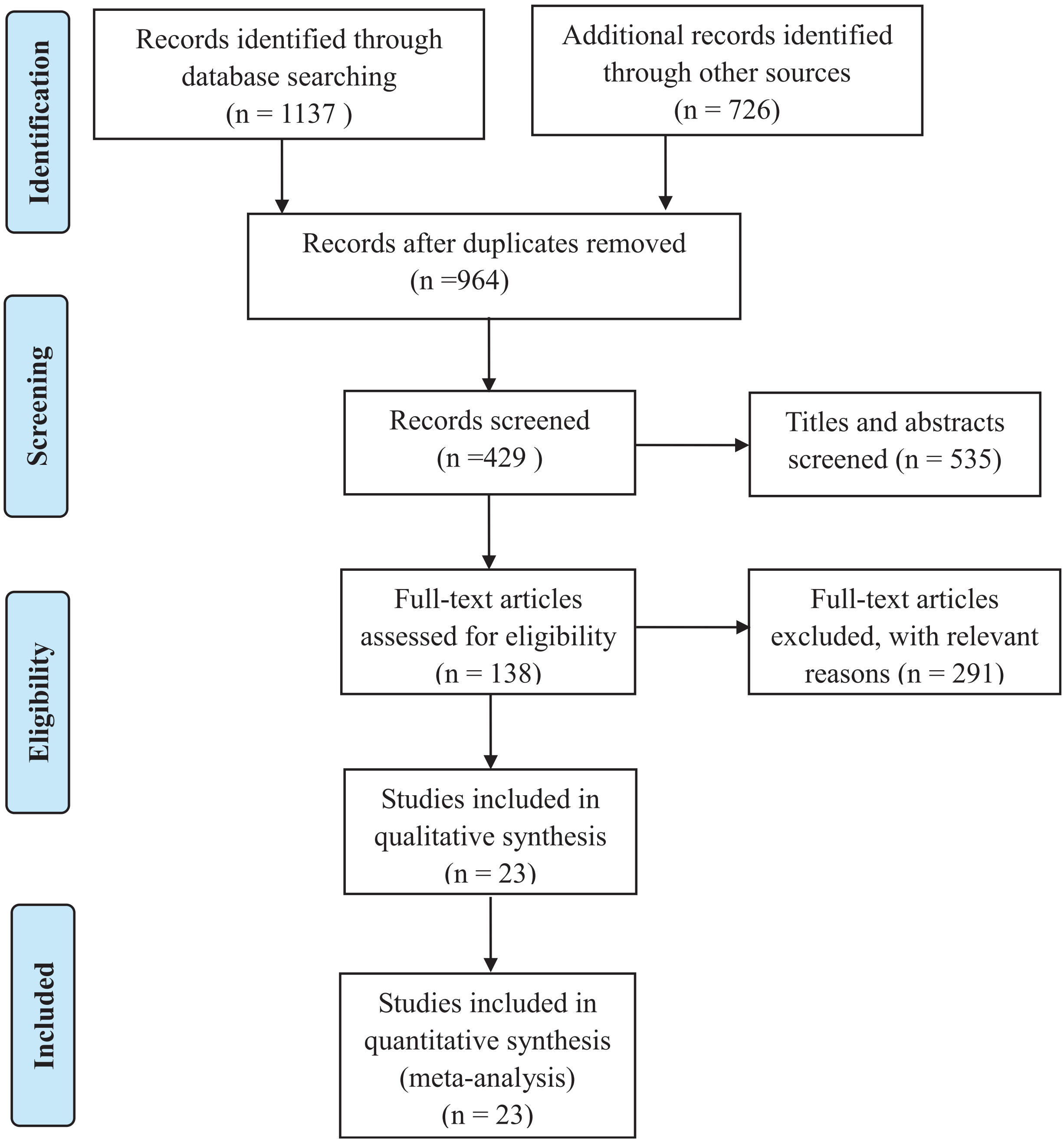

Figure 1. Preferred reporting items for systemic reviews and meta-analyses (PRISMA) flow diagram of literature selection.

combined administration of the PBL+LBL teaching model group and 1283 students in the LBL teaching model group. The sample size in the included trials ranged from 16 to 256. All 23 studies were published in the Chinese language, with English abstracts, and the types of courses included in the studies were epidemiology, anatomy, immunology, infectious diseases, gynecology and obstetrics, pediatrics, and so on. There were 10 RCTs[11,13,14,20,21,25,30–33,35] on practical courses, and 13 RCTs[10,12,15,16,22–24,26–29,31,34] included theoretical courses. Table 1 shows the baseline characteristics of all the included studies.

The quality of the 23 studies was evaluated using the Cochrane Collaboration. Randomization was conducted in all the studies.[10–16,20–35] None of the studies reported randomized or blinded methods. The summary of the methodological quality of each study is shown in Figure 2. The meta-analysis independently uses funnel plots of knowledge scores, skill scores, medical writing scores, comprehensive ability scores and teaching satisfaction to assess publication bias; the plots were generally symmetrical and showed a lower publication bias (Fig. 3 A, B, C, D, E, F, and G).

3.2. Knowledge scores

All the included studies[10–16,20–35] reported relevant data regarding knowledge scores (1306 and 1283 students in the PBL+LBL and LBL groups, respectively). The meta-analysis of

Table 1

The detailed baseline characteristics of all included studies.

Study	Publication time	Study type	No. of PBL+LBL	No. of LBL	Grade	Course name	Coures Type	Outcomes
Yang et al[10]	2012	RCT	256	238	Freshman	Immunology	Theory course	KS
Yu et al[11]	2013	RCT	30	28	The fifth year student	Infectious	Prcatice course	KS
Wang et al[12]	2014	RCT	45	45	No statement	Epidemiology	Theory course	KS, SS
Zhang et al[13]	2010	RCT	20	20	Junior	Hepato biliary surgery	Prcatice course	KS, SS,MWS, CAS, TS
Jin et al[14]	2011	RCT	25	25	No statement	Gynecology and obstetrics	Prcatice course	KS, SS,MWS, CAS, TS
Wang et al[15]	2006	RCT	78	78	Master	Gynecology and obstetrics	Theory course	KS,TS
Wu et al[16]	2015	RCT	62	61	Junior	General Practice Introduction	Theory course	KS, SS,TS
Zhou et al[20]	2012	RCT	40	40	Junior	Breast surgery	Prcatice course	KS, SS,MWS, CAS, TS
Niu et al[21]	2016	RCT	20	20	Senior	Inguinal hernia surgery	Prcatice course	KS,TS
Wang et al[22]	2012	RCT	35	35	Senior	Dermatology and Venerology	Theory course	KS, SS
Wang et al[23]	2011	RCT	147	146	Junior	Gynecology and obstetrics	Theory course	KS, SS, MWS, CAS
Tang et al[24]	2012	RCT	26	27	Freshman	Lboratory immunology	Theory course	KS, SS, CAS
Han et al[25]	2012	RCT	40	40	Junior	Thoracic Surgery	Prcatice course	KS, SS, MWS, CAS, TS
Qu et al[26]	2015	RCT	45	45	Junior	Pediatric	Theory course	KS
Gao et al[27]	2016	RCT	55	54	Sophomore	Gerontology	Theory course	KS
Huang et al[28]	2017	RCT	53	55	No statement	Diagnostics	Theory course	KS, SS
Zhang et al[29]	2017	RCT	99	96	No statement	Biochemistry	Theory course	KS, SS, CAS
Zhu et al[30]	2015	RCT	58	58	No statement	Cardiovascular medicine	Prcatice course	KS, SS, CAS
Fanget al[31]	2015	RCT	40	40	No statement	Anatomy	Theory course	KS, CAS
Wu et al[32]	2014	RCT	30	30	No statement	Vascular Surgery	Prcatice course	KS, SS
Ni et al[33]	2014	RCT	48	48	No statement	Thoracic surgical	Prcatice course	KS, TS
Feng et al[34]	2016	RCT	38	38	No statement	Inetnal medicine	Theory course	KS, TS
Zhang et al[35]	2011	RCT	16	16	Junior	Hepato biliary surgery	Prcatice course	KS, SS, MWS, CAS

CAS = comprehensive ability scores, KS = knowledge scores, LBL = lecture-based learning, MWS = medical writing scores, No. = number, PBL = problem-based learning, RCT = randomized controlled trial, SS = skill scores, TS = teaching satisfaction.

the knowledge scores found that the PBL+LBL teaching model significantly increased knowledge scores by a mean of 4.32 compared with the LBL teaching model (95% CI, 2.85–5.78; $P < .00001$). The random effects model was used for the meta-analysis because of higher heterogeneity ($P < .00001$, $I^2 = 97\%$) (Fig. 4).

3.3. Skill scores

Thirteen studies[13,14,16,20,22–25,28–30,32,35] reported relevant data regarding skill scores (651 and 649 students in the PBL+LBL and LBL groups, respectively). The meta-analysis of the skill scores found that the PBL+LBL teaching model significantly increased skill scores by a mean of 2.11 compared with the LBL teaching model (95% CI, 0.51–3.71; $P = .01$). The random effects model was used for the meta-analysis because of higher heterogeneity ($P < .00001$, $I^2 = 97\%$) (Fig. 5).

3.4. Medical writing scores

Six studies[13,14,20,23,25,35] reported relevant data regarding medical writing scores (288 and 287 students in the PBL+LBL and LBL groups, respectively). The meta-analysis of the medical writing scores found that the PBL+LBL teaching model significantly increased skill scores by a mean of 2.54 compared with the LBL teaching model (95% CI, 1.04–4.04; $P = .0009$). The random effects model was used for the meta-analysis because of higher heterogeneity ($P < .00001$, $I^2 = 84\%$) (Fig. 6).

3.5. Comprehensive ability scores

Eleven studies[13,14,16,20,23–25,29–31,35] reported relevant data regarding comprehensive ability scores (573 and 569 students in the PBL+LBL and LBL groups, respectively). The meta-analysis of the comprehensive ability scores found that the PBL+LBL teaching model significantly increased skill scores by a mean of 5.38 compared with the LBL teaching model (95% CI, 2.04–8.71; $P = .002$). The random effects model was used for the meta-analysis because of higher heterogeneity ($P < .00001$, $I^2 = 97\%$) (Fig. 7).

3.6. Teaching satisfaction

Teaching satisfaction is divided into 3 dimensions: satisfactory teaching effect, general teaching effect and poor teaching effect. First, a total of 9 studies[13–16,20,21,25,33,34] reported relevant data regarding satisfactory teaching effect (371 and 370 students in the PBL+LBL and LBL groups, respectively). The meta-analysis of satisfactory teaching effect in the PBL+LBL teaching model found higher rates compared with the LBL teaching model (RR, 1.32; 95% CI, 1.10–1.59; $P = .003$). The random effects model was used for the meta-analysis because of higher heterogeneity ($P = .0001$, $I^2 = 75\%$) (Fig. 8). Second, a total of 6 studies[13–15,20,25,33] reported relevant data regarding general teaching effect and poor teaching effect (251 and 251 students in the PBL+LBL and LBL groups, respectively). There was not a statistically significant difference in general teaching effect and poor teaching effect between the 2 groups (RR, 0.77; 95% CI, 0.55–1.08; $P = .14$; RR, 0.52; 95% CI, 0.23–1.51; $P = .11$; respectively). A fixed effects model was used for the meta-analysis because of lower heterogeneity ($P = .15$, $I^2 = 38\%$; $P = .34$, $I^2 = 12\%$; respectively) (Figs. 9 and 10)

3.7. Subgroup analysis

Subgroup analyses were performed to examine the differences between practical and theoretical courses when PBL+LBL was used compared to LBL alone. The outcome revealed that the

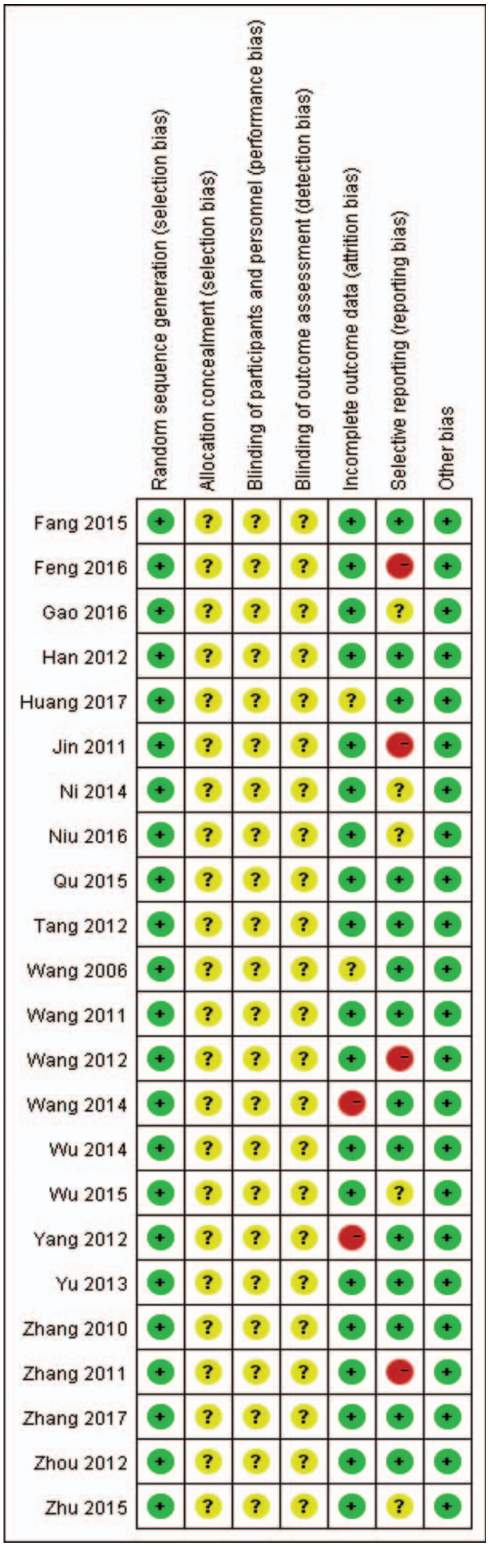

Figure 2. Risk of publication bias summary.

differences in knowledge scores, medical writing scores, and comprehensive ability scores between practical and theoretical courses were significant, and satisfactory teaching effects in practical courses were significant. However, no significant differences were found in skill scores, general teaching effect, or poor teaching effect between practical and theoretical courses, and no difference was observed in the satisfactory teaching effect in the theoretical courses. Table 2 shows the results of the subgroup analysis. Additionally, a subgroup analysis of the level of training showed that the PBL+LBL teaching model also significantly improved the knowledge scores of Freshman, Sophomore, Junior, Senior, and Master students (Table 3).

4. Discussion

PBL is a student-centered teaching model and has been widely used in medical education across the globe.[36,37] However, this teaching method is controversial in China. To the best of our knowledge, few studies have assessed whether the combined application of PBL and LBL teaching models has additional benefits in medical education. Thus, we performed a meta-analysis to assess the efficacy of the PBL+LBL teaching model in medical education in China.

The main finding of this meta-analysis was that the PBL+LBL teaching model can significantly increase knowledge scores, skill scores, medical writing scores, comprehensive ability scores and teaching satisfaction compared to the application of the LBL teaching model alone. Subgroup analyses also showed that the knowledge scores, medical writing scores, and comprehensive ability scores between practical and theoretical courses were significant, and satisfactory teaching effects in practical courses were significant. Additionally, a subgroup analysis of the level of training showed that the PBL+LBL teaching model also significantly improved the knowledge scores of Freshman, Sophomore, Junior, Senior, and Master students.

The core idea of PBL teaching is based on questions, with students at the center and with teachers serving as guides.[12,20] Consequently, the more passive, accepting style of education is transformed into active learning to stimulate student interest.[13,21,22] Recently, PBL has garnered more and more attention by medical education practitioners in China, and a large number of related studies have been conducted.[10–13,22–25] Studies have shown that PBL has more advantages compared with traditional teaching models in improving grades and in stimulating interest in learning.[10–13,22] However, PBL is not perfect, and LBL has its strengths. In the early stages of the PBL teaching model, for example, students lack systematic and in-depth levels of theoretical knowledge, and they focus on solving problems.[23,27,38] Thus, students are not yet able to organize and grasp the internal logical structure of knowledge, which may increase learning difficulties. Unlike Western countries, Chinese students have long accepted the traditional teaching model as adequate for the accumulation of theoretical knowledge. The PBL teaching model is new for Chinese students and has greatly stimulated their interest in learning.[39] In this study, PBL+LBL and traditional LBL students use the same textbooks and syllabi. However, PBL students seem to learn more actively, leading to higher knowledge scores.

The administration of the PBL+LBL teaching method in medical education has been well established in the literature. A randomized controlled trial[33] comparing 96 students who received the combined PBL+LBL teaching model or the LBL teaching model alone in vascular surgical clinical education found that PBL+LBL resulted in significantly higher knowledge scores and skill scores. Wang et al[15] reported similar results comparing the PBL+LBL and LBL teaching models in gynecology and obstetrics teaching and observed increased knowledge scores and improved teaching satisfaction. Furthermore, our meta-analysis indicates that the comprehensive ability scores found in the combined group

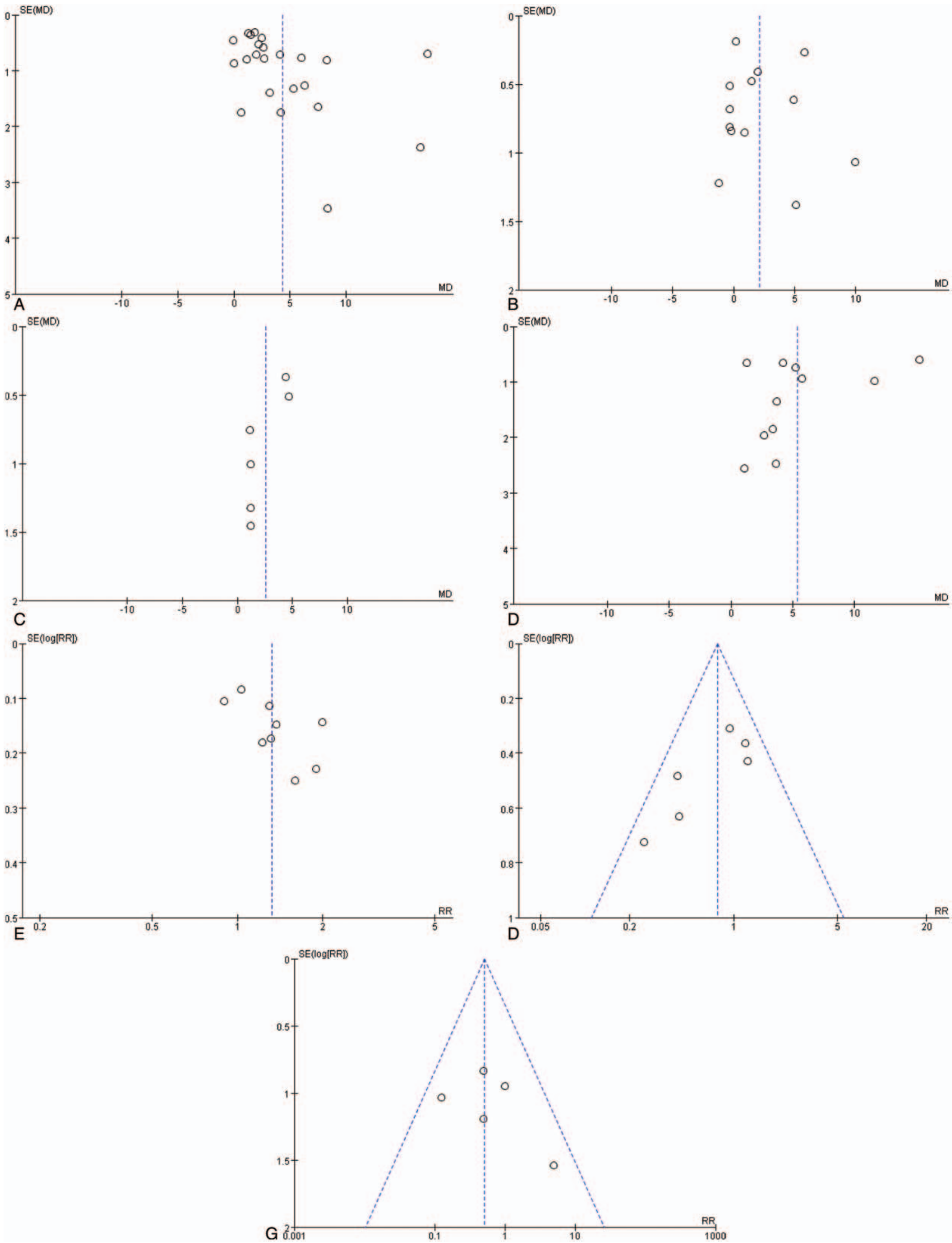

Figure 3. A publication bias of knowledge scores. B publication bias of skill scores. C publication bias of medical writing scores. D Publication bias of comprehensive ability scores. E publication bias of satisfactory teaching effect. F publication bias of general teaching effect. G publication bias of poor teaching effect.

significantly increased scores by a mean of 5.38 compared with the LBL group alone. Therefore, the combined application of the PBL +LBL teaching model may be a reasonable alternative to improve learning and skills in medical education.

In our current meta-analysis, teaching satisfaction surveys were divided into 3 aspects: satisfaction teaching effect, general teaching effect, and poor teaching effect. We found that the satisfaction teaching effect of students in the PBL+LBL teaching

Study or Subgroup	PBL+LBL Mean	PBL+LBL SD	PBL+LBL Total	LBL Mean	LBL SD	LBL Total	Weight	Mean Difference IV, Random, 95% CI	Year
Wang 2006	59.28	10.51	78	58.63	11.37	78	3.8%	0.65 [-2.79, 4.09]	2006
Zhang 2010	33.3	5.34	20	30.1	3.28	20	4.1%	3.20 [0.45, 5.95]	2010
Jin 2011	35.3	2.34	25	32.6	3.18	25	4.6%	2.70 [1.15, 4.25]	2011
Zhang 2011	31.3	6.28	16	27.1	3.14	16	3.8%	4.20 [0.76, 7.64]	2011
Wang 2011	35.4	3.2	147	33.9	3	146	4.8%	1.50 [0.79, 2.21]	2011
Han 2012	36.4	3.7	40	35.3	3.5	40	4.6%	1.10 [-0.48, 2.68]	2012
Zhou 2012	33.5	2.22	40	30.9	3.02	40	4.7%	2.60 [1.44, 3.76]	2012
Yang 2012	74.93	11.76	256	68.62	15.9	238	4.3%	6.31 [3.83, 8.79]	2012
Wang 2012	81.97	15.11	35	73.63	13.85	35	2.4%	8.34 [1.55, 15.13]	2012
Tang 2012	52.6	2.7	26	46.6	2.9	27	4.6%	6.00 [4.49, 7.51]	2012
Yu 2013	94.13	4.36	30	88.79	5.56	28	4.2%	5.34 [2.76, 7.92]	2013
Wu 2014	88.8	8.7	30	81.3	2.5	30	3.9%	7.50 [4.26, 10.74]	2014
Wang 2014	18.11	1.54	45	16.83	1.61	45	4.8%	1.28 [0.63, 1.93]	2014
Ni 2014	58.3	4.16	48	58.29	4.34	48	4.5%	0.01 [-1.69, 1.71]	2014
Fang 2015	34.6	1.56	40	32.78	1.32	40	4.8%	1.82 [1.19, 2.45]	2015
Zhu 2015	24.53	2.24	58	24.62	2.67	58	4.8%	-0.09 [-0.99, 0.81]	2015
Wu 2015	86	4.7	62	81.9	3	61	4.6%	4.10 [2.71, 5.49]	2015
Qu 2015	88.7	2.41	45	86.2	1.49	45	4.8%	2.50 [1.67, 3.33]	2015
Gao 2016	91.5	4.36	55	83.24	4.12	54	4.6%	8.26 [6.67, 9.85]	2016
Feng 2016	89.36	3.03	38	72.11	3.12	38	4.6%	17.25 [15.87, 18.63]	2016
Niu 2016	86.9	8.8	20	70.3	5.9	20	3.3%	16.60 [11.96, 21.24]	2016
Huang 2017	90.7	3.73	53	88.73	3.68	55	4.6%	1.97 [0.57, 3.37]	2017
Zhang 2017	26.11	3.33	99	23.93	4.08	96	4.7%	2.18 [1.13, 3.23]	2017
Total (95% CI)			**1306**			**1283**	**100.0%**	**4.32 [2.85, 5.78]**	

Heterogeneity: Tau² = 11.51; Chi² = 643.95, df = 22 (P < 0.00001); I² = 97%
Test for overall effect: Z = 5.78 (P < 0.00001)

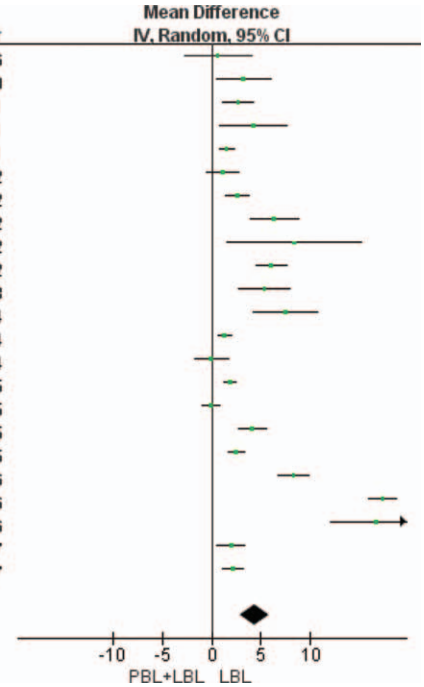

Figure 4. Funnel plots of knowledge scores.

Study or Subgroup	PBL+LBL Mean	PBL+LBL SD	PBL+LBL Total	LBL Mean	LBL SD	LBL Total	Weight	Mean Difference IV, Random, 95% CI	Year
Zhang 2010	24.4	2.61	20	24.6	2.72	20	7.6%	-0.20 [-1.85, 1.45]	2010
Zhang 2011	22.4	3.41	16	23.6	3.51	16	7.0%	-1.20 [-3.60, 1.20]	2011
Jin 2011	15.8	2.58	25	16.1	2.25	25	7.8%	-0.30 [-1.64, 1.04]	2011
Wang 2011	26.5	2.1	147	20.7	2.5	146	8.2%	5.80 [5.27, 6.33]	2011
Tang 2012	31.9	3.1	26	32.2	2.8	27	7.6%	-0.30 [-1.89, 1.29]	2012
Zhou 2012	15.1	2.45	40	15.4	2.14	40	8.0%	-0.30 [-1.31, 0.71]	2012
Wang 2012	12.18	6.01	35	7.06	5.53	35	6.7%	5.12 [2.41, 7.83]	2012
Han 2012	27.1	2.8	40	22.2	2.7	40	7.9%	4.90 [3.69, 6.11]	2012
Wu 2014	45.6	4.9	30	35.7	3.2	30	7.2%	9.90 [7.81, 11.99]	2014
Zhu 2015	21.59	2.43	58	19.62	1.95	58	8.1%	1.97 [1.17, 2.77]	2015
Wu 2015	13.3	1.1	62	13.1	1	61	8.2%	0.20 [-0.17, 0.57]	2015
Huang 2017	90.75	2.01	53	89.31	2.89	55	8.0%	1.44 [0.50, 2.38]	2017
Zhang 2017	33.64	6.09	99	32.76	5.81	96	7.6%	0.88 [-0.79, 2.55]	2017
Total (95% CI)			**651**			**649**	**100.0%**	**2.11 [0.51, 3.71]**	

Heterogeneity: Tau² = 8.09; Chi² = 425.61, df = 12 (P < 0.00001); I² = 97%
Test for overall effect: Z = 2.58 (P = 0.010)

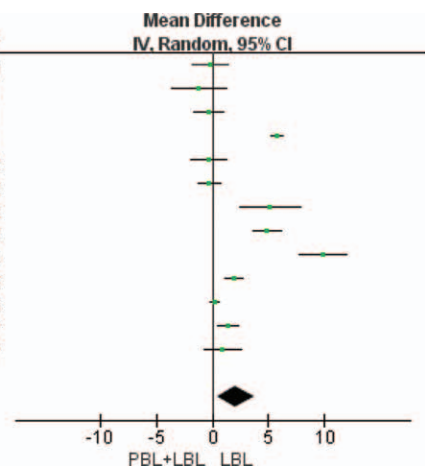

Figure 5. Funnel plots of skill scores.

Study or Subgroup	PBL+LBL Mean	PBL+LBL SD	PBL+LBL Total	LBL Mean	LBL SD	LBL Total	Weight	Mean Difference IV, Random, 95% CI	Year
Zhang 2010	27.5	4.87	20	26.3	4.29	20	12.2%	1.20 [-1.64, 4.04]	2010
Zhang 2011	25.5	4.21	16	24.3	3.19	16	13.2%	1.20 [-1.39, 3.79]	2011
Jin 2011	37.5	3.62	25	36.3	3.49	25	15.9%	1.20 [-0.77, 3.17]	2011
Wang 2011	26.3	2.5	147	21.9	3.7	146	20.8%	4.40 [3.68, 5.12]	2011
Zhou 2012	35.6	3.44	40	34.5	3.32	40	18.0%	1.10 [-0.38, 2.58]	2012
Han 2012	26.5	2.2	40	21.8	2.4	40	19.9%	4.70 [3.69, 5.71]	2012
Total (95% CI)			**288**			**287**	**100.0%**	**2.54 [1.04, 4.04]**	

Heterogeneity: Tau² = 2.68; Chi² = 31.90, df = 5 (P < 0.00001); I² = 84%
Test for overall effect: Z = 3.32 (P = 0.0009)

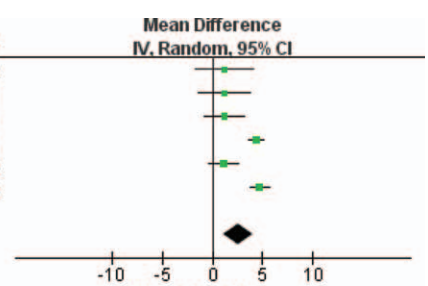

Figure 6. Funnel plots of medical writing scores.

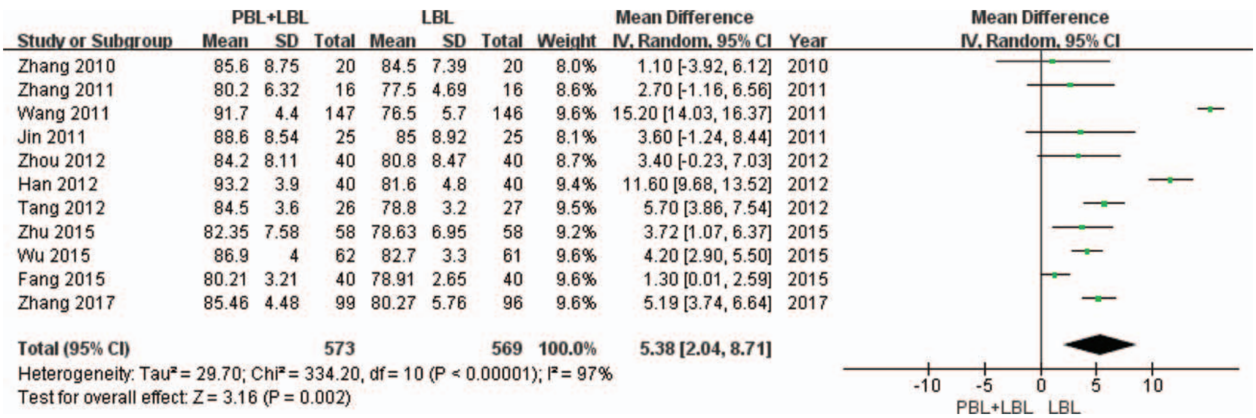

Figure 7. Funnel plots of comprehensive ability scores.

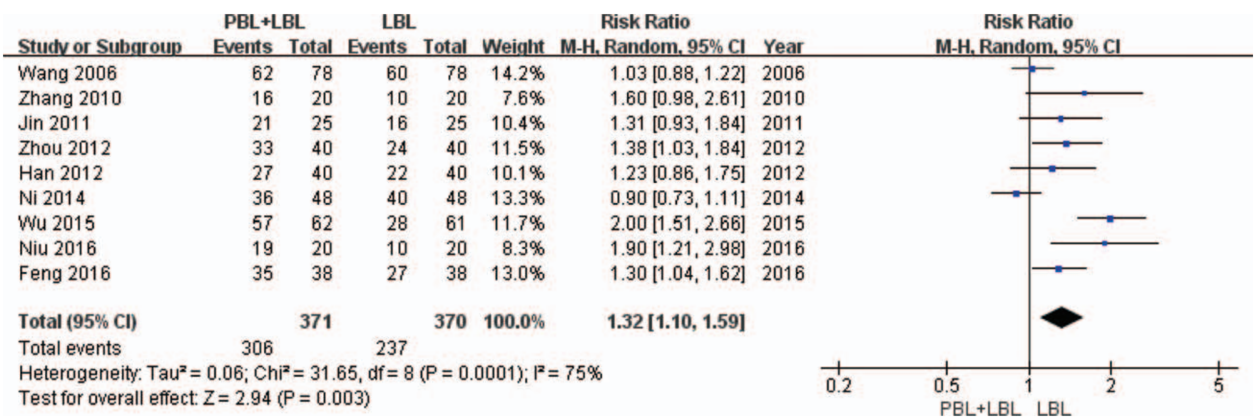

Figure 8. Funnel plots of satisfactory teaching effect.

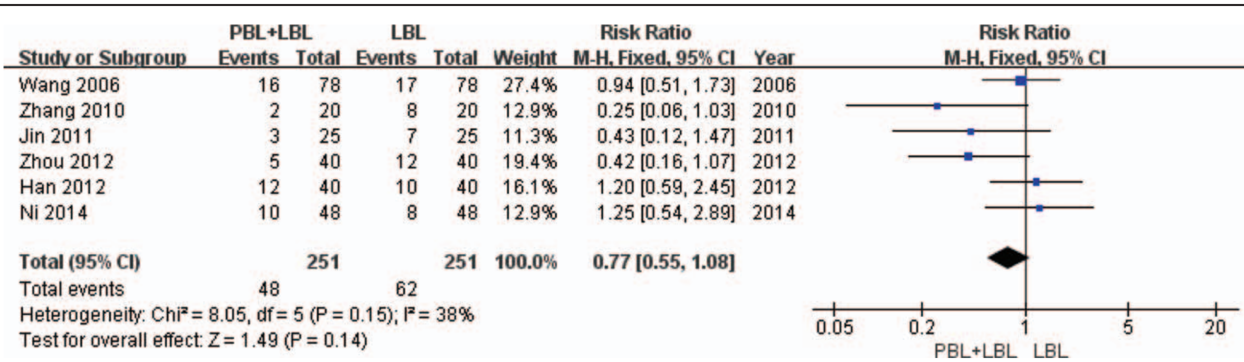

Figure 9. Funnel plots of general teaching effect.

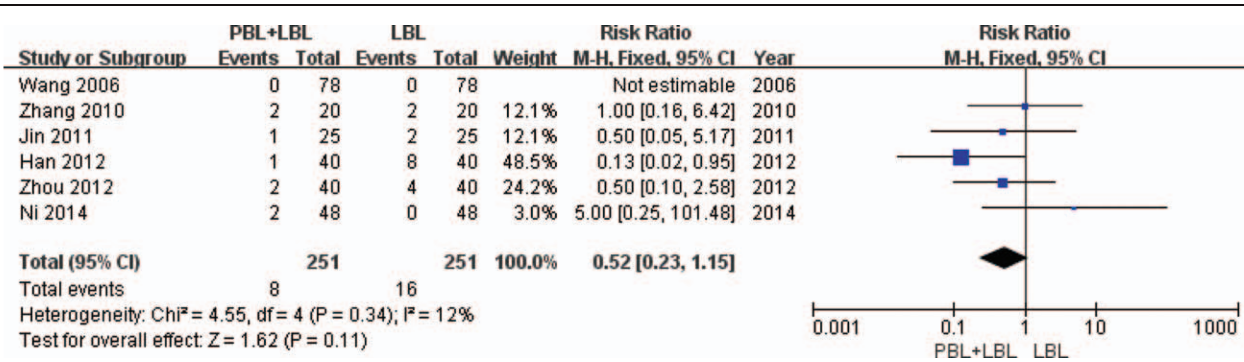

Figure 10. Funnel plots ofgeneral teaching effect.

Table 2

Clinical results of subgroup analyses in the current meta-analysis.

		No. of participants			Incidence			
Clinical outcomes	Studies	PBL+LBL	LBL	P	MD/RR	95% CI	Heterogeneity (I2)	Model
Knowledge scores*								
Practical courses	10	327	325	<.0001	3.67	1.88–5.46	<0.00001 (97%)	Random
Theoretical courses	13	979	985	<.0001	4.71	2.62–6.81	<0.00001 (98%)	Random
Skill scores*								
Practical courses	7	229	229	.07	2.08	−0.13–4.30	<0.00001 (95%)	Random
Theoretical courses	6	422	420	.11	2.15	−0.47–4.78	<0.00001 (98%)	Random
Medical writing scores*								
Practical courses	5	141	141	.04	2.01	0.06–3.96	<0.0001 (83%)	Random
Theoretical courses	1	147	146	<.00001	4.40	3.68–5.12	n.s.	Fixed
Comprehensive ability scores*								
Practical courses	6	199	199	.03	4.56	0.56–8.56	<0.00001 (89%)	Random
Theoretical courses	5	374	370	.02	6.32	1.09–11.56	<0.00001 (99%)	Random
Satisfactory teaching effect†								
Practical courses	6	193	193	.03	1.30	1.03–1.64	0.01 (65%)	Random
Theoretical courses	3	371	370	.10	1.37	0.95–1.99	0.0002 (88%)	Random
General teaching effect†								
Practical courses	5	173	173	.10	0.71	0.47–1.07	0.10 (48%)	Fixed
Theoretical courses	1	78	78	.84	0.94	0.51–1.73	n.s.	Fixed
Poor teaching effect†								
Practical courses	5	173	173	.13	0.52	0.22–1.22	0.21 (34%)	Fixed
Theoretical courses	1	78	78	n.s.	n.s.	n.s.	n.s.	Fixed

CI=confidence interval, LBL=lecture-based learning, MD=mean difference, n.s=non-significant, No.=number, PBL=problem-based learning, RR=risk ratio.
* Values presented as mean difference and 95% confidence interval.
† Values presented as risk ratio and 95% confidence interval.

group was significantly higher than in the LBL teaching group. Furthermore, the subgroup analysis indicated that differences in the satisfaction teaching effect were found in practical courses; however, there was no difference for theoretical courses regarding the satisfactory teaching effect between the PBL +LBL group and the LBL group. In traditional LBL teaching in China, teachers are mainly active, while students play a more passive role in accepting knowledge.[15,28] Thus, the students are less likely to take initiative and may show a lack of analytical reasoning ability; they often have lower levels of communication and cooperation. The PBL+LBL teaching model is student-centered and question-oriented, combining the advantages of both. The model inspires students to learn both autonomously and under the guidance of teachers. In the PBL+LBL dual-track teaching model, students can effectively learn more comprehensive knowledge and can gain the flexibility to use that knowledge to solve problems. Consequently, these students naturally achieve higher degrees of satisfaction.

Compared with the meta-analyses previously published by Zhang et al[5] and Dong et al,[38] the present study had several strengths. First, all the included studies were well-designed, and they satisfied the defined eligibility criteria of comparing the efficacy of the combined PBL+LBL teaching model versus the LBL teaching model alone in medical education. Second, the meta-analysis included 23 RCTs. Third, a subgroup analysis was performed comparing the course type between the theoretical courses and the practical courses. The results showed that the combined administration of PBL+LBL in medical education can effectively increase knowledge scores, medical writing scores, comprehensive ability scores, and satisfactory teaching effects compared with the LBL alone. Finally, this study independently used funnel plots to assess publication bias; the plots were generally symmetrical and showed a lower publication bias.

There were also several limitations in the present study. First, although most of the included studies in this meta-analysis were RCTs, none of the included studies reported allocation

Table 3

Subgroup analyses of the level of training in the current meta-analysis.

		No. of participants			Incidence			
Clinical outcomes	Studies	PBL+LBL	LBL	P	MD/RR	95% CI	Heterogeneity (I2)	Model
Knowledge scores*								
Freshman	2	282	265	<.00001	6.08	4.80–7.37	0.83 (0%)	Fixed
Sophomore	1	55	54	<.00001	8.26	6.67–9.85	n.s.	Fixed
Junior	7	370	368	<.00001	2.28	1.85–2.71	0.009 (65%)	Random
Senior	2	55	55	.002	12.86	4.80–20.92	0.05 (74%)	Random
The fifth year student	1	78	78	.71	0.65	−2.79–4.09	n.s.	Fixed
Master	1	30	28	<.0001	5.34	2.76–7.92	n.s.	Fixed

CI=confidence interval, LBL=lecture-based learning, MD=mean difference, n.s=non-significant, No.=number, PBL=problem-based learning, RR=risk ratio.
* Values presented as mean difference and 95% confidence interval.

concealment and blinding. Consequently, the quality of methodologies included in the meta-analysis is not generally high. Second, considering that there are only Chinese medical students in this study, this conclusion may be more suitable for medical education in China and Asia, not Western medical education. Third, the heterogeneity of the reported results, including knowledge scores and skill scores, was very high. Therefore, the authors used random effects models to analyze these data, taking into account the bias in clinical outcomes. Finally, although the subgroup analysis was performed according to different training levels, this analysis was limited by the incomplete nature of the information and data. Some results, such as the skill scores, medical writing scores, comprehensive ability scores and satisfactory teaching effects, could not be concluded. Therefore, more scientifically designed RCTs are needed in the future.

5. Conclusions

Based on the current evidence, this meta-analysis showed that the PBL+LBL teaching model is an effective method for increasing knowledge scores, skill scores, medical writing scores, and comprehensive ability scores and for improving teaching satisfaction. Thus, the use of the PBL+LBL teaching model may be optimal for improving medical education in China.

Author contributions

Conceptualization: Wen Zeng.
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Investigation: Xue Jia, Qin Zhang.
Methodology: Xue Jia, Wen Zeng, Qin Zhang.
Software: Xue Jia, Wen Zeng, Qin Zhang.
Writing – original draft: Xue Jia.
Writing – review & editing: Xue Jia, Wen Zeng.

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