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REVIEW

Use of a problem-based learning teaching model for undergraduate medical and nursing education: a systematic review and meta-analysis

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Objectives: The aim of this systematic review and meta-analysis was to evaluate the problem-based learning (PBL) method as an alternative to conventional educational methods in Iranian undergraduate medical courses.

Materials and methods: We systematically searched international datasets banks, including PubMed, Scopus, and Embase, and internal resources of banks, including MagirIran, IranMedex, IranDoc, and Scientific Information Database (SID), using appropriate search terms, such as "PBL", "problem-based learning", "based on problems", "active learning", and" learner centered", to identify PBL studies, and these were combined with other key terms such as "medical", "undergraduate", "Iranian", "Islamic Republic of Iran", "I.R. of Iran", and "Iran". The search included the period from 1980 to 2016 with no language limits.

Results: Overall, a total of 1,057 relevant studies were initially found, of which 21 studies were included in the systematic review and meta-analysis. Of the 21 studies, 12 (57.14%) had a high methodological quality. Considering the pooled effect size data, there was a significant difference in the scores (standardized mean difference [SMD]=0.80, 95% CI [0.52, 1.08], $P<0.000$) in favor of PBL, compared with the lecture-based method. Subgroup analysis revealed that using PBL alone is more favorable compared to using a mixed model with other learning methods such as lecture-based learning (LBL).

Conclusion: The results of this systematic review showed that using PBL may have a positive effect on the academic achievement of undergraduate medical courses. The results suggest that teachers and medical education decision makers give more attention on using this method for effective and proper training.

Keywords: problem-based learning, education, meta-analysis, traditional learning

Introduction

Continuing advances in medical science, technology, and health care delivery have introduced medicine and related fields as a complex, challenging profession.[1] The efficient medical profession requires advanced and reliable skills such as problem solving and the ability of clinical decision making.[2] Today, more than ever, most universities in the world try to find teaching methods that can lead to the expansion of the educational capacity, continuous learning, and self-centered clinical decisions among their students. The use of active-learning strategies significantly improves the correlation between the educational and clinical performances of students.[3] One of the proposed ways to eliminate the gap between academic and clinical performances is changing the traditional educational system to problem-based learning (PBL). PBL was presented as a new teaching method for the first time at McMaster University

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in Canada in the 1960s to enhance the ability of students in independently conducting a study and problem-solving and analytical skills.[4] If the effectiveness of this method can extend, it may lead to enhanced critical thinking skills and attitudes of undergraduate medical students.

In PBL, the training method is based on the principle of using problems as the starting point; students are divided into several groups and do research on the topic of interest, and the questions are then put to discussion.5 PBL is a student-centered approach, which enables individuals to design, implement, and assess solutions for the problems in their own courses.[6] Solving a problem as a mental activity increases the level of knowledge and new skills.[7] Although based on World Health Organization (WHO) data,[8] PBL is growing worldwide, this model is still controversial.[9,10]

There is growing concern among educators that the conventional educational methods may not lead to the appropriate quality to encourage medical students to learn and impart a lifelong respect for learning. However, Iran has not yet developed a suitable approach to replace the conventional teaching methods. In addition, cultural differences influence the effectiveness of PBL methods;[11] consequently, the target population must be limited to Iranian medical students of the education system to observe the possible efficacy of the PBL method in Iran. Therefore, the aim of this systematic review and meta-analysis was to evaluate the PBL method as an alternative to conventional educational methods such as lecture-based learning (LBL) method in Iranian undergraduate medical courses.

Materials and methods

Iranian medical education capacity

Medical education in Iran includes 47 medical universities. These 47 universities contain 14 schools of medical sciences, 36 dental schools, 20 pharmacy schools, and 42 nursing schools. These universities include 157,226 students, of whom 29,975 are medical students, 6,966 are pharmacy students, 8,081 are dentistry students, 60,641 are nursing students, and 51, 563 belong to other fields. There are 27 international branches of universities of medical sciences that include 1,341 students. These meta-analysis covers 21 different universities, including 10 (10/42=23.8%) nursing schools, eight (8/14=57.2%) medical schools, and five (5/36=13.8%) dental schools.

Study design

This is a systematic review and meta-analysis comparing the use of PBL and LBL teaching models in introductory undergraduate medical courses in Iran and providing a scientific basis for evaluating the need and possibility of PBL application in undergraduate medical courses.

Study selection criteria

We considered the definition of PBL according to Fan et al.[12] In short, students schedule to work in small-group activities, make hypotheses about the case of interest and learning subjects, work outside of scheduled hours to meet the learning objectives, and then attempt to solve the problem. The selected studies should fulfill the following criteria, including examination of the PBL application as a teaching method alone or in combination with the traditional LBL teaching model in Iranian medical students, as randomized or non-randomized controlled trials (RCTs). Studies that did not cite the examination data about courses of interest and republished studies were excluded.

Search strategy

We systematically searched international datasets to identify relevant studies, including PubMed, Scopus, and Embase, and internal resources, including Magiran, IranMedex, IranDoc, and Scientific Information Database (SID) using appropriate search terms, such as "problem-based learning", "PBL", "learning based on problems", "learner centered", and "active learning". These search terms were used to identify studies that used PBL and were combined with other key terms such as "Iranian", "Islamic Republic of Iran", "I.R. of Iran", "Iran", "medical", and "undergraduate". The search included the period from 1980 to 2016 with no language limits. We also manually searched through the reference lists of potentially selected studies to find relevant papers.

Data extraction method and quality assessment

Screening was done by two reviewers (FR and MS) independently, considering selection criteria; then, the data were extracted and cross-checked. Any inconsistencies were resolved by consultation with a third reviewer (BL). The information including author name, publication year and location, study sample size, participant characteristics, course name and type, study type, intervention process, and outcome scores was extracted. Quality assessments of the selected studies were individually performed by two researchers using the modified Jadad scale that included eight items[13] and RevMan 5.3 (Cochrane Collaboration, Copenhagen, Denmark).

Statistical methods

The outcome measures of interest were a continuous outcome (i.e., examination scores). For the meta-analysis, RevMan version 5.2 and Stata 10.0 (StataCorp LP, College Station, TX, USA) were used. The analytical statistics of standardized mean difference (SMD) at 95% confidence intervals (CIs) were used to determine the efficacy of the PBL model for outcomes of interest. The method proposed by Zhang et al.[14] was used to assess the heterogeneity of selected studies; consequently, the I^2 statistic and the chi-square test were used to assess the statistical heterogeneity of the selected studies. I^2 value of >50% or P-value of <0.10 was assumed as significant heterogeneity across the included studies. When moderate to high heterogeneity was present, a random-effects model was used to calculate the total SMD score at 95% CI; otherwise, a fixed-effects model was applied. Meta-regression was used to examine the effect of confounding factors. Subgroup analysis was performed considering teaching patterns, the course type, and the intervention type. To assess the degree of publication bias, we used funnel plots and Egger's tests. A sensitivity analysis was performed by exchanging the combined model (fixed-effects model and random-effects model). We performed subgroup analysis considering three different categories, including the comparison method (PBL vs. LBL or PBL plus LBL vs. LBL), disciplines (nursing, medicine, dentistry, medicine plus dentistry, and other), and grade (freshman, sophomore, junior, senior, and other).

Ethical approval

This research was approved by the ethics committee of Welfare Organization, Ahvaz, Iran.

Results

Overall, a total of 1,057 relevant studies were initially found. After the title–abstract screening, 1,034 studies were excluded, and 23 studies were used for the systematic review and meta-analysis.[15–37] The literature screening process and results are illustrated in Figure 1.

The distributions of available literature across the country are illustrated in Figure 2.

The general characteristics of the included studies are shown in Table 1. The 23 studies covered four different medical disciplines, including nursing (10 studies), medicine (six studies), dentistry (four studies), and others (three studies). Of the 11 courses examined, including those in anatomy, pharmacology, and biochemistry, only two were laboratory based.[27,28]

The quality of 23 studies was evaluated using the modified Jadad scale. The assessment revealed that only four (17.4%) studies were assigned scores >5,[18,23,24,34] eight (34.8%) studies were assigned score 5,[15–17,25–28,30] and 11 (47.8%) studies

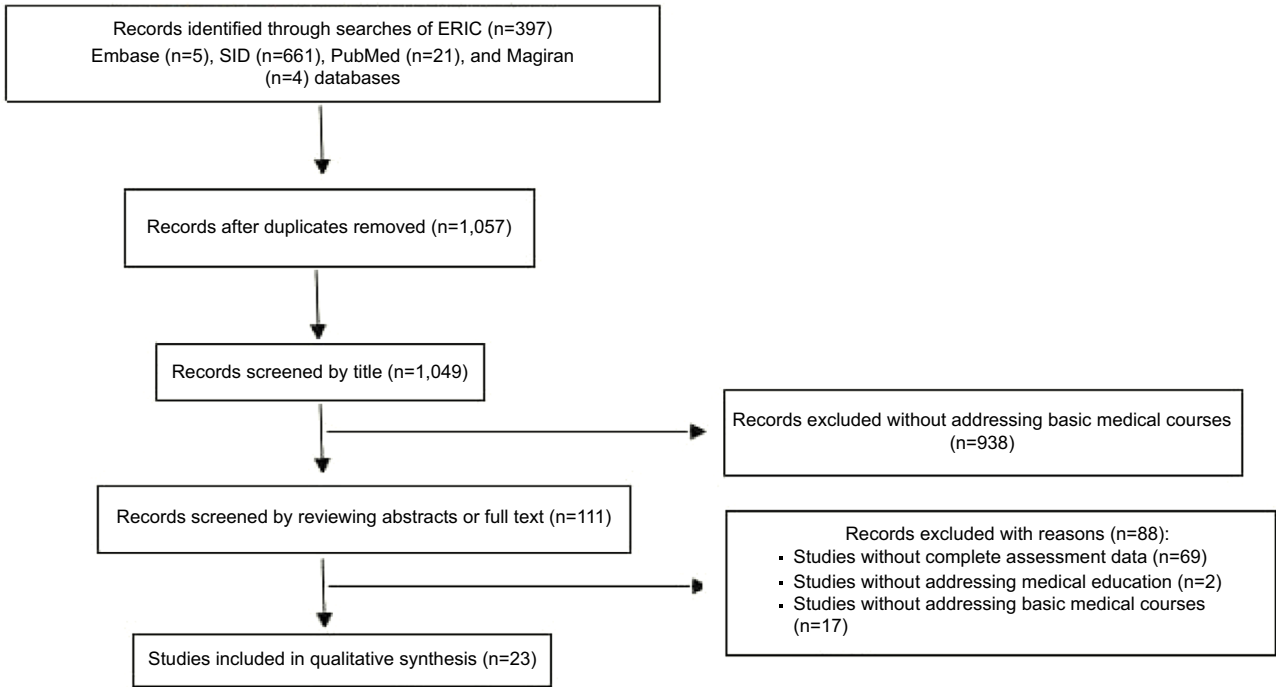

Figure 1 Literature screening process and results.
Abbreviations: ERIC, Education Resources Information Center; SID, Scientific Information Database.

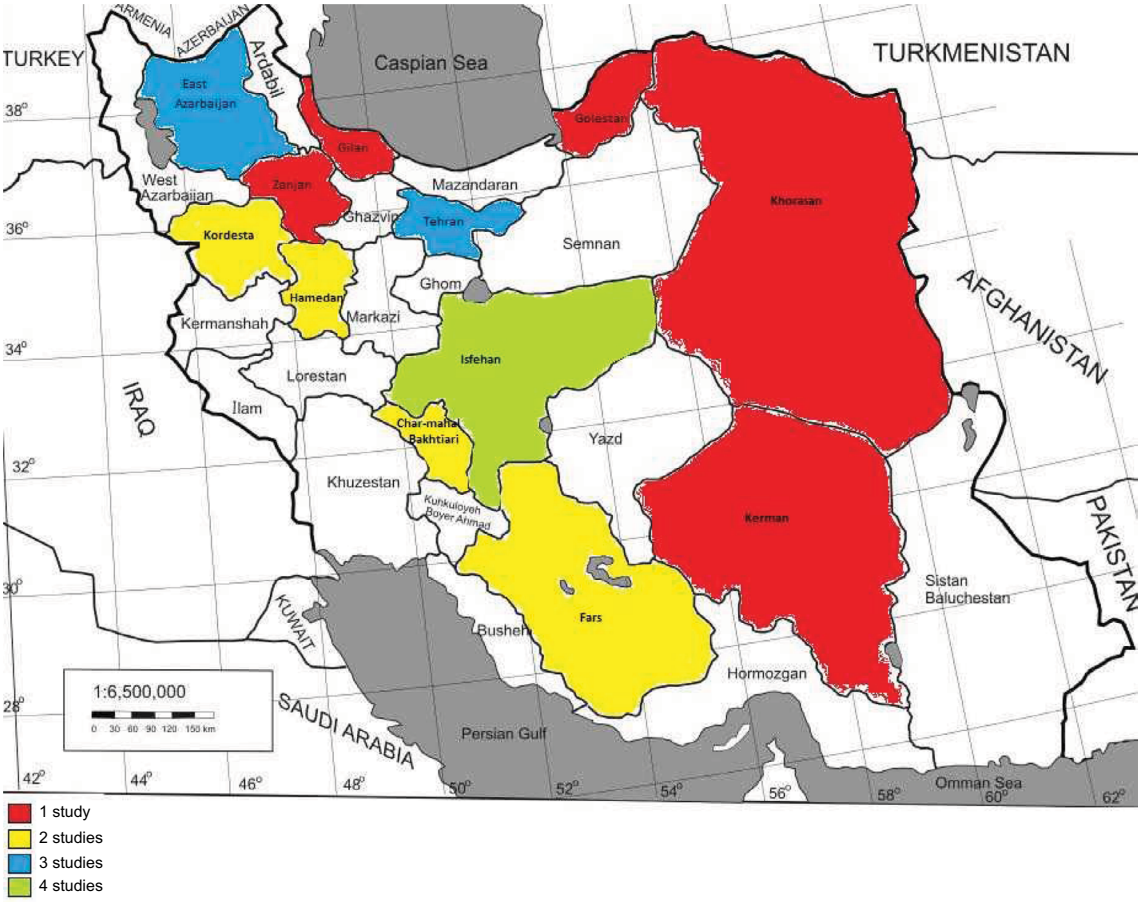

Figure 2 The distribution of the available studies across the country.

were assigned scores 2–4[19–22,29,31–33,35–37] (Figure 3). The mean modified Jadad scale score was 4.3, and the standard deviation was 1.25. The modified Jadad scores collected for each study are shown in the Supplementary materials.

There was high heterogeneity (I^2=81%, P<0.001); hence, the random-effects model was used. Considering the pooled effect size data, there was a significant difference in the scores (SMD=0.80, 95% CI [0.52, 1.08], P<0.000) in favor of PBL, compared with the lecture-based method (Figure 4).

Besides, a sensitivity analysis was done to verify the reliability of the results (Supplementary materials). This was performed using sequential omission of individual studies. After excluding a single,[17] with inadequate generation of a randomized sequence, the effects observed in the primary analysis did not change considering that the pooled effect size favored the PBL group (SMD=0.72, 95% CI [0.46, 0.97], P<0.000). The funnel plot for the 17 studies was symmetrical, indicating no significant publication bias (Figure 5).

Subgroup analysis considering three different comparison learning methods is shown in Table 2. Subgroup analysis revealed that using PBL alone is more favorable compared to using a mixed model with other learning methods such as LBL (Figure S1). In addition, PBL and LBL learning methods were compared within each stratum, which was specified by various disciplines (i.e., nursing, medicine, dentistry, and other discipline). The result showed that PBL is a more appropriate method in another discipline and an acceptable method in medicine compared to nursing and dentistry (Figure S2). We also compared the SMD for evaluating PBL in five subgroups with respect to various grades. Based on our result, implementation of PBL in sophomore students exhibited a better performance (Figure S3). Finally, subgroup analysis in study subjects (i.e., theory and laboratory) exhibited that PBL is a more proper method in laboratory subjects (Figure S4).

Other discipline that was stated covers the health courses such as occupational health courses. Laboratory courses were newborn and hematology–oncology nursing cares.

Discussion

This systematic review and meta-analysis aiming to evaluate the PBL method as an alternative to conventional educational methods in Iranian undergraduate medical courses showed

Table 1 General characteristics of the included studies

Study ID	Study design	Random allocation	Population	Course name	Course type	Number of cases		Study groups		Grade	Outcome, mean±SD	
						Arm 1	Arm 2	Arm 1	Arm 2		Arm 1	Arm 2
Baghaie et al[16]	Quasi-experimental	Yes	Nursing student	Pathology and hematologic	Theory course	14	15	PBL	LBL	Sophomore	14.66±2.46	13.64±3.17
Koleini et al[23]	Quasi-experimental	Yes	Medical student	Biology	Theory course	32	32	PBL	LBL	Freshman	14.3±1.7	12.8±1.8
Sadr Lahijani and Raoof[22]	Descriptive–analytic	No	Dentistry student	Endodontics and musculofascial surgery	Theory course	19	19	PBL	LBL	Senior	16.2±1.6	14.8±1.7
Aein and Nourian[15]	Quasi-experimental	Yes	Nursing student	Pediatric nursing	Theory course	30	30	PBL	LBL	NA	15.5±1.6	12.6±1.7
Hassanpour Dehkordi and Heydarnejad[17]	Quasi-experimental	Yes	Nursing student	Internal surgery	Theory course	20	20	PBL	LBL	Sophomore	6.15±2.10	3.64±1.63
Khaki et al[19]	NA	No	Medical student	Gross anatomy	Theory course	83	76	PBL+LBL	LBL	Freshman	14.32±4.36	12.66±5
Kermaniyan et al[18]	Quasi-experimental	Yes	Medical student	Anatomy	Theory course	20	20	PBL	LBL	Freshman	10.9±2.6	9.9±1.8
Jafari et al[24]	Quasi-experimental	Yes	Dentistry student	Community dentistry	Theory course	32	32	PBL	LBL	NA	12.98±1.22	12.36±1.7
Fesharaki et al[30]	Quasi-experimental	No	Nursing student	Internal surgery 4	Theory course	22	22	PBL	LBL	NA	15.96±2.98	14.72±2.82
Namnabati et al[31]	Quasi-experimental	No	Nursing student	Pediatrics 2	Theory course	52	50	PBL+LBL	LBL	Sophomore	13.63±2.61	10±2.82
Modanloo et al[20]	Quasi-experimental	Yes	Nursing student	Mental health	Theory course	8	24	PBL	LBL	Sophomore	4.074±0.318	3.858±0.208
Zarshenas et al[29]	Interventional	No	Dentistry student	Orthodontia	Theory course	64	64	PBL	LBL	Senior	3.41±0.49	2.9±0.68
Dianati and Adib-Hajbaghery[32]	Interventional	Yes	Nursing student	Critical care	Theory course	13	14	PBL	LBL	Junior	12.76±2.2	12.21±2.77
Jabbari et al[33]	Cross-sectional	No	Medical student/ dentistry student/ pharmacy student	Public health	Theory course	112	54	PBL	LBL	Freshman	16.02±2.03	14.25±1.72
Penjvini and Shahsawari[27]	Quasi-experimental	Yes	Nursing Student	Newborn nursing care	Laboratory course	14	15	PBL	LBL	Sophomore	8.5±0.51	7.93±0.70
Khatiban and Sangestani[26]	Quasi-experimental	Yes	Midwifery student	Pregnancy and childbirth	Theory course	34	36	PBL+LBL	LBL	NA	16.21±0.98	15.71±0.92
Assadi[25]	Cross-sectional	Yes	Occupational health student	Epidemiology	Theory course	22	25	PBL	LBL	NA	18.52±1.03	16.71±1.16
Imanieh et al[34]	NA	Yes	Medical student	Pediatric gastroenterology ward	Theory course	60	60	PBL	LBL	NA	5.504±0.944	4.24±0.814
Sangestani and Khatiban[28]	Quasi-experimental	Yes	Nursing Student	Hematologic and oncologic nursing care	Laboratory course	34	36	PBL	LBL	Junior	12.32±1.73	10.12±1.61
Momeni et al[36]	Quasi-experimental	No	Medical student	Embryology	Theory course	42	40	PBL+LBL	LBL	Freshman	14.83±1.87	14.64±1.56
Farhadi et al[37]	Interventional	No	Dentistry student	Oral and maxillofacial pathology	Theory course	24	24	PBL	LBL	Junior	9.6±3.164	8.55±2.446

Abbreviations: SD, standard deviation; PBL, problem-based learning; LBL, lecture-based learning; NA, not applicable.

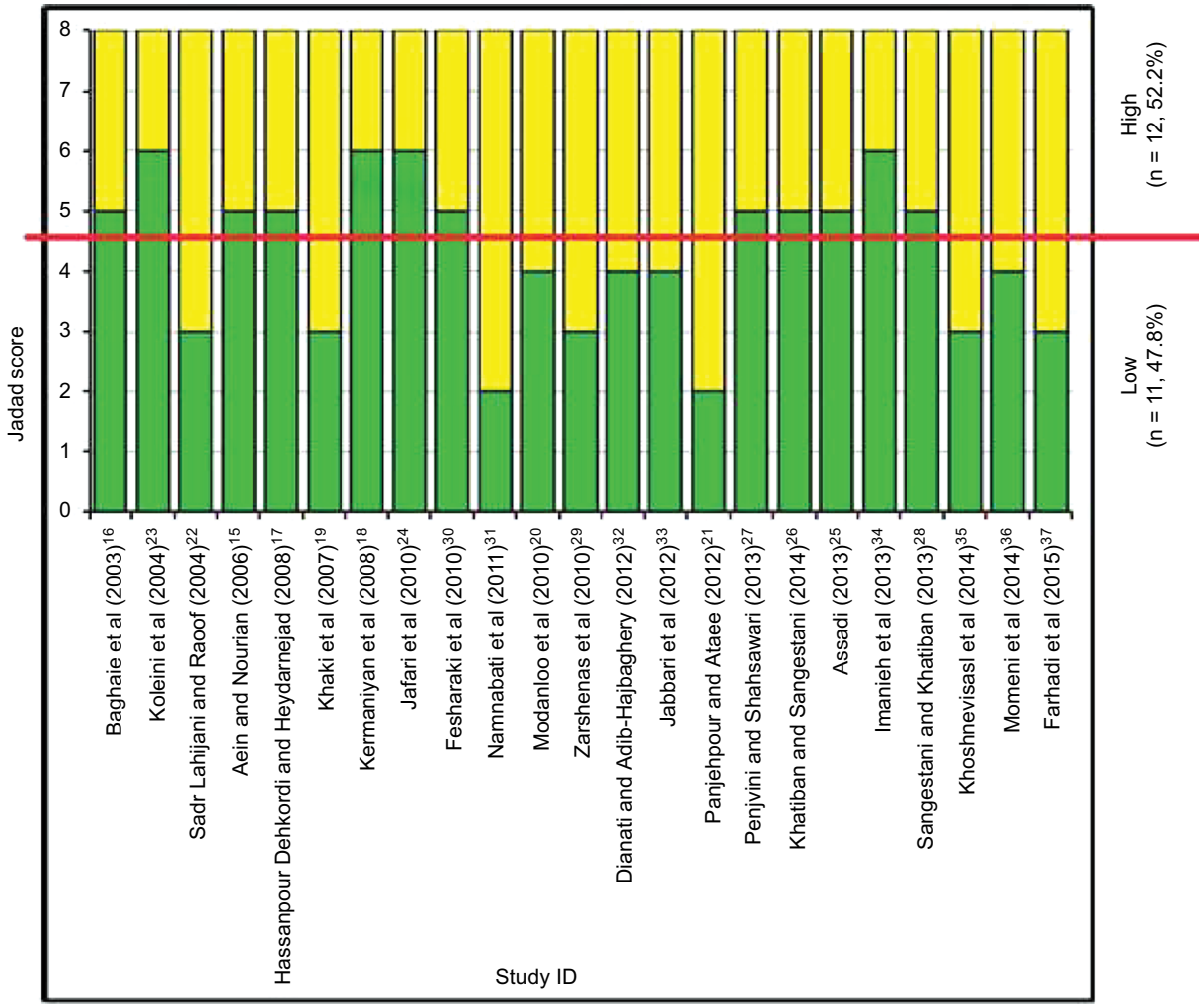

Figure 3 Evaluation of the methodological quality of the included studies.

that academic achievement was relatively higher in PBL method compared to traditional methods such as LBL.

It was shown that the academic achievements of students in the methods such as PBL are significantly higher than those in LBL.[38,39] Furthermore, the results of a systematic review and meta-analysis in China on dental education showed that the PBL method has a positive effect on theoretical and practical test grades and that introducing this learning method is considered superior to the traditional lecture-based method according to the faculty conditions.[40] Another systematic review and meta-analysis in Korea on nursing education found that PBL in nursing education has positive effects on the outcome domains of satisfaction with training, clinical education, and skill course; thus, PBL is more effective than traditional learning methods.[41] Another systematic review and meta-analysis from China on nursing students indicated that PBL might help nursing students to improve their critical thinking.[42] Our analysis was in line with these meta-analyses and showed that PBL has beneficial effects on the nursing education.

Zhang et al conducted a systematic review and meta-analysis on the PBL use in Chinese undergraduate medical education; this teaching method can rise course examination excellence rates and scores, as well as it is more effective when used in laboratory courses than in theory-based courses.[14] Though our meta-analysis showed a nonsignificant effect of PBL on medical education, it showed that PBL has positive effects on the outcome domains of laboratory courses compared to theory ones.

In addition, the results of a systematic review and meta-analysis conducted on medical students to evaluate the effect of PBL on the postgraduate physician's abilities showed that PBL has a positive effect on the physician's abilities, particularly on their cognitive abilities and social skills.[43] Unfortunately, in most medical schools, there is more emphasis on multiple-choice tests as well as the mnemonic and recall

Study or subgroup	PBL Mean	PBL SD	PBL Total	LBL Mean	LBL SD	LBL Total	Weight	SMD difference IV, random, 95% CI
Aein and Nourian (2006)[15]	15.5	1.6	30	12.6	1.7	30	4.5%	1.73 (1.13, 2.33)
Assadi (2013)[25]	18.52	1.03	22	16.71	1.16	25	4.2%	1.62 (0.95, 2.28)
Baghaie et al (2003)[16]	14.66	2.46	14	13.64	3.17	15	3.8%	0.35 (–0.39, 1.08)
Dianati and Adib-Hajbaghery (2012)[32]	12.76	2.2	13	12.71	2.77	14	3.7%	0.02 (–0.74, 0.77)
Farhadi et al (2015)[37]	9.6	3.16	24	8.55	2.45	24	4.7%	0.37 (–0.21, 0.94)
Fesharaki et al (2010)[30]	15.96	2.98	22	14.72	2.82	22	4.5%	0.42 (–0.18, 1.02)
Hassanpour Dehkordi and Heydarnejad (2008)[17]	6.15	2.1	20	3.64	1.83	20	4.0%	1.31 (0.62, 2.00)
Imanieh et al (2013)[34]	5.5	0.94	60	4.24	0.81	60	5.7%	1.43 (1.02, 1.83)
Jabbari et al (2012)[33]	16.02	2.03	112	14.25	1.72	54	6.0%	0.91 (0.57, 1.25)
Jafari et al (2010)[24]	12.98	1.22	32	12.36	1.7	32	5.1%	0.41 (–0.08, 0.91)
Kermaniyan et al (2008)[18]	10.9	2.6	20	9.9	1.8	20	4.4%	0.44 (–0.19, 1.07)
Khaki et al (2007)[19]	14.32	4.36	83	12.66	5	76	6.2%	0.35 (0.04, 0.67)
Khatiban and Sangestani (2014)[26]	16.21	0.98	34	15.71	0.92	36	5.2%	0.52 (0.04, 1.00)
Koleini et al (2004)[23]	14.3	1.7	32	12.8	1.8	32	5.0%	0.85 (0.33, 1.36)
Modanloo et al (2010)[20]	4.07	0.32	8	3.86	0.21	24	3.4%	0.85 (0.02, 1.68)
Momeni et al (2014)[36]	14.83	1.87	42	14.64	1.56	40	5.5%	0.11 (–0.32, 0.54)
Namnabati et al (2011)[31]	13.63	2.61	52	10	2.82	50	5.5%	1.33 (0.90, 1.76)
Penjvini and Shahsawari (2013)[27]	8.5	0.51	14	7.93	0.7	15	3.6%	0.90 (0.13, 1.67)
Sadr Lahijani and Raoof (2004)[22]	16.2	1.6	19	14.8	1.7	19	4.2%	0.83 (0.16, 1.50)
Sangestani and Khatiban (2013)[28]	12.32	1.73	34	10.12	1.61	36	5.0%	1.30 (0.78, 1.82)
Zarshenas et al (2010)[29]	3.41	0.49	64	2.9	0.68	64	5.9%	0.86 (0.49, 1.22)
Total (95% CI)			751			708	100.0%	0.81 (0.60, 1.02)

Heterogeneity: τ^2=0.16: χ^2=68.31, df=20 (P<0.00001): I^2=71%

Test for overall effect: Z=7.53 (P<0.00001)

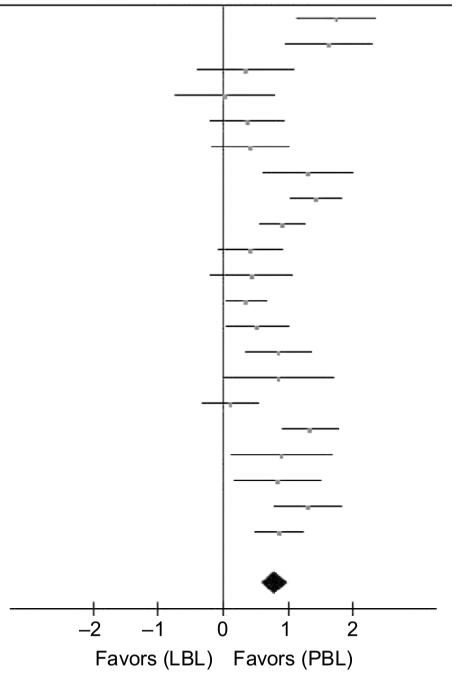

Figure 4 Meta-analysis and forest plot of theoretical scores for PBL compared with the lecture-based method.
Abbreviations: PBL, problem-based learning; LBL, lecture-based learning; SMD, standardized mean difference; SD, standard deviation.

issues learning, although memorization cannot lead to the development of effective problem-solving skills. Besides, the study results were positive in using PBL in all educational levels of students describing the possible effectiveness of this method in undergraduate medical courses.

Recently, Zhou et al[44] evaluated the effectiveness of PBL in Chinese pharmacy education in a meta-analysis and reported that this teaching method is superior to the traditional lecture-based teaching. We did not find even a single study describing the effect of PBL on pharmacy education compared to traditional learning method.

It was reported that clinical education courses had greater impacts and better outcomes than courses on health perspectives and nursing. Similarly, the clinical approach has larger impact than the theoretical approach.[41] This supports our findings and previous reports,[45,46] which found that PBL has a positive effect on medical and nursing students' work-based skills and increases their problem-solving skills. High-level cognitive skills is crucial to develop in clinical practice, which allows students to reach at clinical judgments on the basis of available information when they face unresolved problems, unique cases, ambiguous situations, or cases not present in their textbooks.[47] PBL is among the techniques considered to be effective in increasing the ability of integrating theory and practice in the students by pursuing and acquiring missing knowledge during clinical practice.[48,49] Consequently, our findings along with previous evidences may provide educators with evidence that demonstrates the usefulness of PBL in clinical practice.

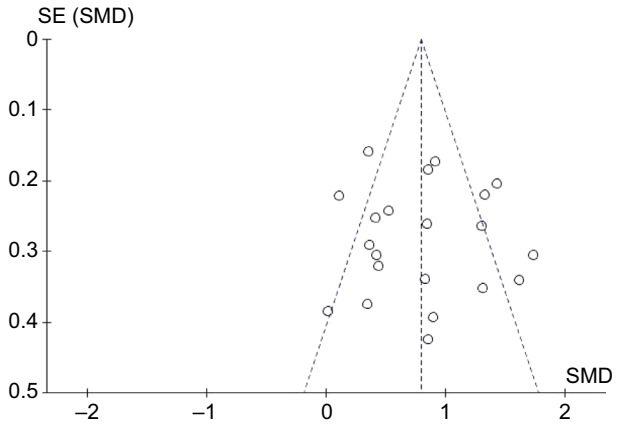

Figure 5 The funnel plot for the studies on PBL, compared with the lecture-based method.
Abbreviations: PBL, problem-based learning; SMD, standardized mean difference; SE, standard error.

It is suggested that further experimental studies with regard to standard methods of evaluating and presenting a full report with a complete description of the test interventions in this area to investigate the effects of using PBL are required.

Conclusion

The results of this systematic review showed that using PBL has a positive effect on the academic achievement of undergraduate medical courses. The results suggest that teachers and medical education decision makers give more attention on using this method for effective and appropriate training. In addition, using suitable methods of evaluation designed for high levels of cognitive tests may encourage students to acquire higher level abilities.

Table 2 Subgroup analysis of selected studies according to various disciplines

Comparison groups	No. of studies	Summary estimates of mean difference (95% CI)	I^2 (%)	Heterogeneity test		Egger's test	
				Q	*P*	*t*	*P*
Comparison groups							
PBL vs LBL	17	0.87 (0.65, 1.08)	59	38.98	0.001	0.22	<0.00001
PBL+LBL vs LBL	4	0.57 (0.07, 1.07)	83	18.01	0.0004	0.11	0.02
Discipline							
Nursing student	10	0.90 (0. 56, 1.24)	67	26.96	0.001	0.19	<0.00001
Medical student	5	0.64 (0.16, 1.13)	84	24.65	<0.0001	0.25	0.01
Dentistry student	4	0.66 (0.25, 1.08)	10	3.34	0.34	0.01	<0.00001
Other	2	1.20 (0.52, 1.88)	71	3.42	0.06	0.18	0.0005
Grade							
Freshman	5	0.53 (0.22, 0.85)	64	11.20	0.02	0.08	0.001
Sophomore	5	1.01 (0.65, 1.38)	33	5.99	0.20	0.06	<0.00001
Junior	3	0.59 (-0.18, 1.36)	79	9.64	0.008	0.36	0.13
Senior	2	0.85 (0.53, 1.17)	0	0.00	0.95	0	<0.00001
Other	6	1.01 (0.52, 1.50)	81	26.23	<0.0001	0.3	<0.00001
Theory vs laboratory							
Theory	19	0.77 (0.55, 1.0)	72	26.23	<0.0001	0.17	<0.00001
Laboratory	2	1.18 (0.75, 1.61)	71	0.73	0.39	0.00	<0.00001

Abbreviations: PBL, problem-based learning; LBL, lecture-based learning.

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Disclosure

The authors report no conflicts of interest in this work.

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