The Effectiveness of Problem-Based Learning in Improving Critical Thinking and Problem-Solving Skills in Medical Students: A Systematic Review of Fifteen Years' Experience (2005-2019)

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Abstract

Background: An ongoing challenge for medical education in the twenty-first century is determining the best method to foster problem-solving and critical thinking in learners. These higher-order aptitudes help to prepare medical doctors for practice in a rapidly evolving health system. In medical education, Problem-Based Learning (PBL) is an instructional pedagogy in which pupils are challenged to seek answers to authentic patient scenarios in small groups. PBL techniques are proposed as one method to enhance pupils' learning abilities including critical thinking and problem-solving.

Aim: This systematic review was conducted to search for evidence from the past fifteen years of literature, demonstrating the capability of PBL to improve critical thinking and problem-solving skills for medical students.

Review Question: Is there evidence to support the capability of PBL to improve problem solving and critical thinking skills in medical students?

Methods: The search process was conducted through electronic databases on publications related to the impact of PBL, particularly, on two fundamental skills; critical thinking and problem-solving for medical students. The search process was restricted to publications between January 1, 2005 and December 31, 2019. Four electronic databases were searched, namely; Medline, PubMed, EMBASE and Scopus. The Best Evidence Medical Education (BEME) guidelines were utilised to guide the way this systematic review was conducted. Quality assessment was performed through rating the evaluation methods of the included studies. This rating was through employing a five-point Likert scale (1= strongly disagree to 5= strongly agree) for each study in relation to three items; the appropriateness of study design, the implementation of the study as well as the appropriateness of data analysis. The rating for each study was then mapped to a grade from grade 1 (low) to grade 5 (high), which aligns with the BEME strength of the study findings.

Results: Searching the four aforementioned databases produced 657 publications, including 249 duplicates. Therefore, 408 publications were screened based on their titles against inclusion and exclusion criteria, leaving 86 articles to screen their abstracts. A further 9 articles were manually obtained such that a total of 95 articles were obtained for a review of their abstracts. Forty-one met the criteria for full text review. Following the full text review, twenty-nine articles were excluded. Therefore, twelve studies were included in this systematic review. The BEME strength of study findings were as follows; only two of the reviewed studies were graded as grade 5, four were graded as grade 4, and six were graded as grade 3. Of the twelve studies reviewed, only five studies provided evidence in support of the capability of PBL to improve critical

thinking and problem-solving skills among medical students. Two of these five studies were graded as grade 5 and two were graded as grade 4, while one was graded as grade 3.

Discussion: The available evidence in this systematic review provided limited support of the claim that PBL improves medical students' critical thinking and problem-solving aptitudes. Only five studies provided evidence in support of this claim, while the remaining seven studies did not. Two of these seven studies assessed only the knowledge, comprehension, and application domains, as their evaluation of problem-solving and critical thinking abilities was based on student perspectives. A further two of these seven studies, where the description provided either for case-analysis tests or modified essay questions, did not give an actual indication for measuring critical thinking and problem-solving skills. Another two of these seven studies did not describe their written tests i.e. case-analysis tests and proxy questions that are purported to measure higher-order skills, including critical thinking and problem-solving. This prevented the use of the findings from these two studies as evidence to support the specified review question. The remaining study reported that PBL students' scores in the final assessment did not improve significantly ($p>0.05$) compared to the initial assessment.

Conclusion: There is very little published evidence over the last fifteen years supporting the claim that PBL improves critical thinking and problem-solving skills in medical students. Therefore, recent practice is not based on evidence. As such, investigations are required to legitimise the claims that PBL improves critical thinking and problem-solving skills for medical students.

Key words: Problem-Based Learning, Critical Thinking and Problem-Solving Skills, Medical Students

Background

In the past six decades, there have been significant numbers of health education institutions around the world which have adopted Problem-Based Learning (PBL) curricula as an alternative to traditional lecturing or Lecture-Based Learning (LBL) (1). Lectures still occupy an important place in the educational process through their ability to impart knowledge. One of the merits of the lectures is the ability to explain difficult concepts and introduce new topics (2). They also have an economic advantage as they can be presented to a large group of learners (2). Nevertheless, in LBL, the medical students' role is limited to receiving information from their instructors without making a mental effort in analysis, thinking and rethinking, inference, synthesis and evaluation. This process focuses on the knowledge itself without interrogation on how this knowledge can be applied in practice (3). This led to the emergence of practice-oriented and inquiry-based learning strategies that are believed to be more pertinent to medical education. These strategies were adopted by learning through a variety of innovative approaches such as PBL. PBL gives students the opportunity to place knowledge itself out of their centre of attention by emphasising the importance of learning through higher levels of thinking such as problem-solving, critical thinking and clinical reasoning, while knowledge is presumed to be acquired automatically as a secondary product (4).

Since its inception in the late 1960s at McMaster University in Canada, PBL has brought a tremendous and comprehensive change in teaching and learning strategies in medical education (2, 5, 6). PBL is a learner-centred strategy where pupils are encouraged to recognize their learning needs in a particular topic to solve a problem (6, 7). In addition, PBL can be defined as an active learning strategy which challenges pupils with genuine problems which function as a trigger for learning in which problems are the focus for synthesising what has been acquired for implementation in coming problems and situations (4, 8, 9). The ultimate purpose of using genuine problems is to encourage pupils to consider alternatives, to furnish a substantiated rationale to uphold the explanation they create and, afterward, to implement this to new situations (4, 10).

This noticeable shift from passive approaches to learning towards more active approaches encountered many different reactions across medical, educational institutions around the globe (11). Some preferred to continue with traditional instructions while implementing some principles of PBL pedagogies, while others have adopted PBL and its philosophy as a fundamental component of their curricula and as a guide for the entire educational process. PBL pedagogy, as an active learning strategy, plays a critical role in enhancing health professionals' skills such as self-directed learning, clinical reasoning, problem-solving, and critical thinking skills, as well as in preparing pupils to be lifelong learners (12, 13). The fundamental theory in implementing the principles of PBL philosophy in medical curricula is its ability to enhance the quality of education, which enhances the perception and performance of graduating doctors and thus enhances the level of healthcare provided (14-16). The fundamental presumption is that PBL pedagogies have the capability to improve pupils' knowledge, skills, and behaviour by engaging pupils through problem-solving and self-directed learning strategies (14, 17). Therefore, PBL is a small group learning strategy which utilises patient problems as a context for pupils to obtain knowledge regarding the fundamental and practical sciences.

Purpose of the Review

The aim of this systematic review is to provide a focused insight of the literature from the beginning of 2005 to the end of 2019 regarding the efficacy of Problem-Based Learning (PBL) on two fundamental competencies which are critical thinking and problem-solving among medical students. It can be described as a focused systematic review as it targets the effectiveness of PBL in specifically enhancing these two fundamental skills, which would allay concerns related to any health education organisation that considers PBL a substantial part of its curricular renovation in graduating highly qualified doctors. Fifteen years was chosen as the time period for this review as the researcher recognised the limited available research in the area over the last five years, hence a longer period was chosen.

Systematic Review Question

Is there evidence to support the capability of PBL to improve problem solving and critical thinking skills in medical students?

Review Methodology

In order to answer the review question, a systematic review of the literature was executed of research published during the past fifteen years (2005-2019). The Best Evidence Medical Education (BEME) guidelines were utilised to guide the way this systematic review was conducted (18). The BEME supports the work of systematic reviews, disseminates best evidence to medical educationists and policymakers, and generates an enlightenment of best evidence among medical educators and researchers (19, 20). It was found useful for medical educators in providing theoretical guidance to guide the process of their systematic reviews (19, 20).

Search Methods for Studies Identification

In the months of March and April of the year 2020, the search process was conducted through electronic databases on publications related to the impact of PBL, particularly, on two fundamental skills; critical thinking and problem-solving for medical students. The search process was restricted to publications between January 1, 2005 and December 31, 2019. The publications were searched for through four electronic databases, namely; Medline, PubMed, EMBASE and Scopus. Searching the four aforementioned databases produced 657 publications. Duplication of retrieved articles was noted across the aforementioned databases leaving 408 publications after identifying and eliminating unnecessarily repetitive citations. The two reviewers independently screened all of the titles, in order to exclude articles not pertinent to the systematic review. Both reviewers reached agreement on eighty-six articles that required abstract review. A further nine articles were manually [1] obtained through searching the aforementioned databases such that a total of ninety-five articles were included for a review of their abstracts. The dissertation author screened the abstracts resulting in a total of forty-one articles to be coded, which was approved by the dissertation supervisor. Following the full text review and coding process by the two researchers, twenty-nine articles were excluded. Therefore, twelve studies were included for analysis which was approved by the dissertation supervisor.

Quality Assessment of the Reviewed Studies

After obtaining the full texts of the twelve articles, their methodological qualities were systematically evaluated by both reviewers. The BEME coding sheet was used to rate the evaluation methods of the included studies. This rating was through employing a five-point Likert scale (1= strongly disagree, 2= disagree, 3= uncertain, 4= agree, 5= strongly agree) for each study in relation to three items. These items are; the appropriateness of study design, the implementation of the study as well as the appropriateness of data analysis.

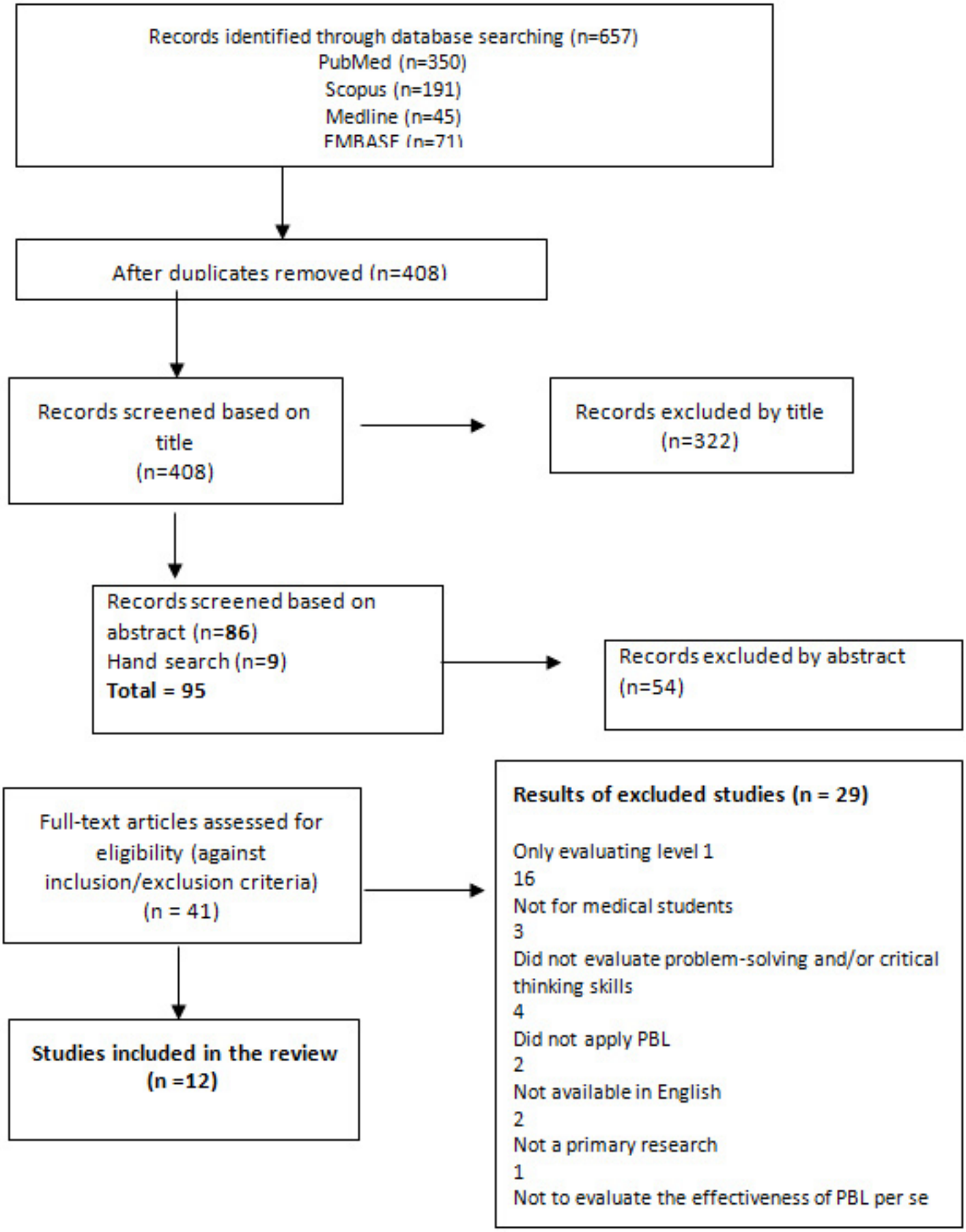
These judgments on the rating of evaluation methods for each study were then mapped to a grade from grade 1 to grade 5. This is called grading of strength of study findings which is an element in the BEME coding sheet related to quality assessment on the basis of data exhibited in the reviewed studies. As shown in (Table 1), the strength of study findings has five grades (from low to high grade findings) where grade 5 indicates that results are conclusive or unequivocal. Both the dissertation author and the supervisor of the review autonomously rated the methodological quality of the reviewed studies and after several discussions they reached an agreed quality assessment between them for the included studies.

Table 1. The BEME Strength of the findings of the included studies (19)

GRADE	DETAIL
Grade 1	No clear conclusions can be drawn. Not significant
Grade 2	Results ambiguous, but there appears to be a trend
Grade 3	Conclusions can probably be based on the results
Grade 4	Results are clear and very likely to be true
Grade 5	Results are unequivocal

Footnote 1: Since some of electronic databases such as PubMed provide similar articles to each article appears in the search results, this feature was used to not miss any article that fulfills the inclusion criteria

Figure 1. The search strategy and selection procedure



Results

Overview of the studies included in the review

After searching through electronic databases and applying inclusion and exclusion criteria, twelve studies were eventually included in the review. Table 2 shows the titles of the reviewed studies and their authors.

Table 2. The Titles of the Reviewed Studies and their Authors

Reference	The Title of the Study
Lian & He, 2013(21)	Improved performance of students instructed in a hybrid PBL format
More et al., 2019(22)	Introducing Hybrid Problem-Based Learning Modules in Ayurveda Education: Results of an Exploratory Study
Li et al., 2013(23)	Comparison of three problem-based learning conditions (real patients, digital and paper) with lecture-based learning in a dermatology course
Murat et al., 2006(24)	Short-term effects of problem-based learning curriculum on students' self-directed skills development
Kong et al., 2009(25)	Effect of Digital Problem-Based Learning Cases on Student Learning Outcomes in Ophthalmology Courses
Al-Faris et al., 2008(26)	Evaluation of three instructional methods of teaching for undergraduate medical students, at King Saud University, Saudi Arabia
Saalu et al., 2010(27)	Quantitative evaluation of third year medical students' perception and satisfaction from problem based learning in anatomy: A pilot study of the introduction of problem based learning into the traditional didactic medical curriculum in Nigeria
Al-Damegh & Baig, 2005(28)	Comparison of an integrated problem-based learning curriculum with the traditional discipline-based curriculum in KSA
Meo, 2013(29)	Evaluating learning among undergraduate medical students in schools with traditional and problem-based curricula
Steadman et al., 2006(30)	Simulation-based training is superior to problem-based learning for the acquisition of critical assessment and management skills
Tayyeb, 2013(31)	Effectiveness of problem based learning as an instructional tool for acquisition of content knowledge and promotion of critical thinking among medical students.
He et al., 2018(32)	A comparison between the effectiveness of PBL and LBL on improving problem-solving abilities of medical students using questioning.

Study Design

As shown in Table 3, there were four (21, 23, 25, 32) prospective randomised studies and three (27-29) cross-sectional studies. Only one (30) of the reviewed studies utilised the higher methodological quality study of a randomised controlled trials. The remaining studies were two (24, 31) quasi experimental studies, one (22) case-control study and one (26) non-randomised trial.

Table 3. Evaluation Methods of Included Studies

METHODS		NUMBER	PERCENTAGE
1	Prospective randomised studies	4	33.33
2	Cross-sectional studies	3	25
3	Randomised controlled studies	1	8.33
4	Quasi experimental studies	2	16.7
5	Case-control study	1	8.33
6	Non-randomised trials	1	8.33
Total		12	100%

Methodological quality of the included studies

As discussed in the methodology section, the methodological quality of all twelve studies were systematically evaluated through applying the BEME coding sheet (19). Rating the evaluation methods of studies included in the review was through employing a five-point Likert scale (1= strongly disagree, 2= disagree, 3= uncertain, 4= agree, 5= strongly agree) for each study in relation to three items i.e. the appropriateness of study design, the implementation of the study as well as the appropriateness of data analysis (Table 4).

Table 4. The BEME Rating of Evaluation Methods of the Included Studies

No	Reviewed studies	Appropriateness of study design	Implementation of study design	Appropriateness of data analysis
1	Tayyeb, 2013(31)	5	5	4
2	Saalu et al., 2010(27)	4	3	3
3	Lian & He, 2013(21)	5	4	4
4	More et al., 2019(22)	4	4	4
5	Al-Damegh & Baig, 2005(28)	3	2	3
6	Kong et al., 2009(25)	3	3	4
7	He et al., 2018(32)	4	3	4
8	Murat et al., 2006(24)	5	5	4
9	Al-Faris et al., 2008(26)	3	3	2
10	Meo, 2013(29)	3	3	3
11	Li et al., 2013(23)	4	5	4
12	Steadman et al., 2006(30)	3	4	4

The rating for each study was then mapped to a grade from grade 1 to grade 5, which represents the strength of the study findings. As shown in (Table 5), only two (24, 31) studies were graded as grade 5. Four (21-23, 32) of the reviewed studies were graded as grade 4, and six (25-30) studies were graded as grade 3.

Table 5. The BEME Strength of the Findings of the Reviewed Studies

No	Reviewed studies	Strength of the Findings (grade 1 to grade 5)
1	Tayyeb, 2013(31)	Grade 5 (Results are unequivocal)
2	Saalu et al., 2010(27)	Grade 3 (Conclusions can probably be based on the results)
3	Lian & He, 2013(21)	Grade 4 (Results are clear and very likely to be true)
4	More et al., 2019(22)	Grade 4 (Results are clear and very likely to be true)
5	Al-Damegh & Baig, 2005(28)	Grade 3 (Conclusions can probably be based on the results)
6	Kong et al., 2009(25)	Grade 3 (Conclusions can probably be based on the results)
7	He et al., 2018(32)	Grade 4 (Results are clear and very likely to be true)
8	Murat et al., 2006(24)	Grade 5 (Results are unequivocal)
9	Al-Faris et al., 2008(26)	Grade 3 (Conclusions can probably be based on the results)
10	Meo, 2013(29)	Grade 3 (Conclusions can probably be based on the results)
11	Li et al., 2013(23)	Grade 4 (Results are clear and very likely to be true)
12	Steadman et al., 2006(30)	Grade 3 (Conclusions can probably be based on the results)

As a summary of the findings from the twelve studies reviewed in relation to the capability of PBL in improving critical thinking and problem-solving skills among medical students, only five (23, 24, 29, 31, 32) studies provided evidence. Two (24, 31) of these five studies were graded as grade 5 and two (23, 32) were graded as grade 4, while one (29) was graded as grade 3. The remaining seven studies did not provide sufficient quality evidence in support of the specified review question. In fact, one (30) of these seven studies provided evidence that PBL was not better in improving critical thinking and problem-solving skills compared to simulation-based learning. Two (21, 26) of these seven studies where the description was provided, whether for case-analysis tests or modified essay questions, did not give an actual indication for measuring higher-thinking skills. One (21) of these two studies was graded as grade 4, while the other (26) was graded as grade 3. In the study conducted by Kong et al. (25), there was no description of case-analysis tests, which prevented the findings of this study from being used as evidence for the review question. The proxy questions used in the study conducted by Al-Damegh and Baig (28) were not sufficiently clarified, which prevented their findings from being used as evidence, and the study was graded as grade 3. Written tests used in two (22, 27) studies only measured the knowledge, comprehension, and application domains, as their evaluation of problem-solving and critical thinking abilities was based on student perspectives. Findings from Steadman et al.(30) indicated that PBL students' scores in the final assessment did not improve significantly compared to the initial assessment in a type of performance test that required the student to critically assess and manage a life-threatening situation. This type of performance test requires higher-order abilities, including problem-solving and critical thinking, yet PBL failed to significantly improve the students' scores in the final assessment in this study. That is, this study (30) provided evidence that PBL was not better compared to simulation-based learning in this regard.

Discussion

Theoretically, applying PBL techniques is purported to improve pupils' learning abilities including critical thinking and problem-solving (4), however the available evidence in this systematic review provided limited support of this theoretical basis. Only five (23, 24, 29, 31, 32) studies provided evidence in support of the capability of PBL to improve critical thinking and problem-solving skills among medical students. Two (24, 31) of these five studies were graded as grade 5 and two (23, 32) were graded as grade 4, while one (29) was graded as grade 3. The findings from the current systematic review are consistent with the findings from a systematic review in nursing education (33). In that systematic review, ten studies were reviewed to investigate the capability of PBL to develop critical thinking skills in nursing pupils. Findings of that review could not provide sufficient evidence for the evolvement of critical thinking aptitudes for nursing pupils through PBL.

The remaining seven studies did not provide evidence in support of the capability of PBL to improve critical thinking and problem-solving skills among medical students. In fact, one (30) of these seven studies provided evidence that PBL was not better in this regard compared to simulation-based learning. Two (22, 27) of these seven studies assessed only the knowledge, comprehension, and application domains, as their evaluation of problem-solving and critical thinking abilities was based on student perspectives. Two (21, 26) of these seven studies where the description provided either for case-analysis tests or modified essay questions, did not give an actual indication for measuring higher-thinking skills. Two (25, 28) of these seven studies did not describe their written tests i.e. case-analysis tests and proxy questions that are purported to measure higher-order skills. This prevented the use of the findings from these two studies as evidence to support the specified review question. The remaining study (30) of these seven studies provided evidence that PBL was not better in this regard compared to simulation-based learning. It reported that PBL students' scores in the final assessment did not improve significantly ($p>0.05$) compared to the initial assessment. This insignificant improvement was in a type of performance test on mannequins that required the student to critically assess and manage a life-threatening situation which could implicitly measure critical thinking and problem-solving skills. However, PBL failed to significantly improve the students' scores in the final assessment in this study.

Of the included studies, two studies (24, 31) compared pre and post-test scores to investigate the impact of PBL on medical students' higher-order thinking skills. In the first study, Tayyeb (31) found a statistically significant improvement ($p<0.001$) in post-test scores for PBL students in MCQs testing higher order skills, while the improvement in this aspect was insignificant ($p<0.093$) for LBL students. In the other study, Murat (24) used the PSI, STSQ, and CRS inventories to explore short-term impacts of PBL on learners' problem-solving, scientific thinking as well as conflict resolution abilities. The study consisted of three cohorts; the study group was under PBL instructions, whereas the other two control groups were under traditional lecturing. The study reported that post-test scores in the PSI, STSQ, and CRS were statistically significantly better for students in the PBL group compared to the LBL groups ($P<0.001$ in all inventories).

In addition, Li et al. (23) used written exams, OSCE stations and pupil performance throughout the course of practice to contrast the influence of three forms of PBL instructions i.e. real patients, digital as well as paper, and traditional lecturing on medical students' learning outcomes. In regard to the OSCE part, students were required to assess the patient's condition on the basis of the findings in the dermatological cases offered to them and to provide a thorough management plan. This type of clinical exam is exceedingly related to problem-solving and requires critical thinking aptitudes, and since PBL participants significantly obtained higher scores in this exam, this observation suggests a trend towards the capability of PBL to promote both skills. Moreover, findings from pupil performance throughout the course of practice as assessed by tutors demonstrates that all PBL groups statistically significantly outperformed the traditional group ($P<0.001$) in the majority of items including an item measuring problem-solving skills. Findings from this study are consistent with what Albanese and Mitchell (34) reached in their review, as they found that PBL pupils obtained higher scores than LBL pupils in clinical examinations as well as tutors' evaluations.

The three studies (23, 24, 31) discussed above, can be considered as utilizing a longitudinal, comparative methodological method. Findings from these three studies demonstrated the capability of PBL in improving medical students' problem-solving and critical thinking skills. Nevertheless, the evidence obtained from these three quality studies [(2)] (23, 24, 31) was insufficient to support the capability of PBL in improving critical thinking and problem-solving abilities among medical students. Therefore, further controlled, longitudinal studies are required as evidence to demonstrate the capability of PBL to improve these two skills. These findings from these three studies are consistent with a number of studies from different educational fields suggesting PBL as an efficient approach to foster pupils' problem-solving and critical thinking abilities (35-39).

Physicians in their daily practice ask their patients questions regarding symptoms and complaints in order to reach the accurate diagnosis. In light of this, the more effective the questioning skills, the more physicians get to a precise and timely diagnosis. Substantially, coaching medical students to become effective problem solvers through utilising aimed questions while taking patient-history, is a

Footnote 2: As assessed by the BEME strength of study findings; two of them were graded as (grade 5), while one was graded as (grade 4).

significant mission. This is what the study conducted by He et al.(32) relied on to explore the effectiveness of PBL compared to traditional learning in enhancing problem-solving skills for medical students through the strategic utilisation of questions. The study authors used what they called a modified 20-questions task. They found that 63% of PBL pupils solved the task using 8 questions, whereas 48% of LBL pupils solved the task using same number of questions, and that difference was significant ($p<0.05$). Therefore, this study also provided evidence in support of the review question and was graded as grade 4.

Moreover, the findings from the study conducted by Meo (29) were also in support of the specified review question. Meo (29) found that PBL students obtained statistically significantly higher scores ($P=0.001$) than LBL students in MCQs testing level 3,4,5, and 6 of Bloom's taxonomy which definitely includes critical thinking and problem-solving skills. The study also found statistically significantly higher scores ($P=0.0001$) in the OSPE part for PBL students. In the OSPE part, students were required to interpret the respiratory findings, diagnose, and make a differential diagnosis. Such type of practical exam requires higher-order skills including problem-solving and critical thinking, and since PBL students significantly outperformed LBL students in this aspect, this superiority demonstrates the beneficial influence of PBL in improving these two skills.

Conclusion

There is very little published evidence over the last fifteen years supporting the claim that PBL improves critical thinking and problem-solving skills in medical students. Therefore, recent practice is not based on evidence. As such, investigations are required to legitimise the claims that PBL improves critical thinking and problem-solving skills for medical students. Moreover, further studies of larger samples and higher methodological quality are required to adequately illustrate the impact of PBL pedagogies on critical thinking and problem-solving progression within medical educational context, those that are indeed measuring problem-solving and critical thinking skills of medical students at the beginning and end of a PBL curriculum. Although the evidence from the current systematic review for developing critical thinking and problem-solving skills through a PBL pedagogical approach is insufficient, it does not mean it will not contribute to the development of these two skills.

Author's contribution

The authors contributed to the data analysis and interpretation. They also contributed to the final draft's critical review and approval. They are also accountable for the manuscript's content and similarity score.

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Conflict of interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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